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MULTICRITERIA METHODOLOGY FOR ESTIMATING CONSUMER ACCEPTANCE OF ALTERNATIVE POWERTRAIN TECHNOLOGIES: AN EXPANDED OVERVIEW

Dissertation under the Master's in Energy for Sustainability oriented by Professors Nuno Miguel Marques de Sousa & Arminda Maria Marques Almeida, and presented to the Faculty of Science and Technology of the University of Coimbra – Department of Mechanical Engineering.

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ABSTRACT

The Environmental Sustainability most discussed topic in the sustainability environment is the Climate Change and its irreversible effects across the world that began many years ago, and within it, the field of fuel consumption and urban mobility, more specifically, cars. By the end of this century, most fossil fuels like petrol, natural gas and coal will be gone, and an alternative must be found in order to keep the world spinning in an eco-friendly way. That is where the electric and hybrid cars come in, as the only way to achieve independence of petrol in the automotive segment. While humanity runs to accelerate the fuel transition, maybe it should be asked if the consumers are ready for this, and the best way is to conduct a consumer's preference research. Based on a related article elaborated by (Sousa et al., 2020) which presents a multicriteria methodology for estimating consumer acceptance of vehicles with alternative powertrain technologies, this dissertation continues such research, by expanding it to a global vision of the preferences among different fuel-powered vehicles. The approach is based on the non-compensatory ELECTRE TRI method that, running together with the MATRIX program, compares hybrid, plug-in hybrid and electric vehicles to conventional models, considering as criteria the ownership costs and vehicle use restrictions that apply mainly to electric vehicles. In total, 365 vehicles from four countries, namely, Portugal, Brazil, USA and Germany and four segments (Small, Medium, Medium SUV and Large) will be included, considering internal combustion (ICEV), hybrid electric (HEV), plug-in hybrid electric (PHEV) and battery electric vehicles (BEV); two driver profiles and a baseline scenario for all cases. For statistical significance, a sensitivity analysis on the base scenario and three other alternative scenarios are made. It is expected that all powertrain types are competitive between each other. However, whatever the results are, the ultimate goal of this work is to offer a tool that enables Governments and Industries to address technical and public policy changes that are required for disseminating electric mobility in the near future, paving the transition way to a new and greener era.

Keywords: alternative powertrain technologies; consumer acceptance; multicriteria decision-making; ELECTRE-TRI;

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF TABLES – APPENDIX A

LIST OF TABLES – APPENDIX C

ABBREVIATIONS AND ACRONYMS

ACEA	European Automobiles Manufacturers Association (Translated)
AFV	Alternative Fuel Vehicles
BEV	Battery Electric Vehicle
DC	Direct Current
EU	European Union
EV	Electric Vehicle
GHG	Greenhouse Gas
HEV	Hybrid Electric Vehicle
ICEV	Internal Combustion Engine Vehicle
IEA	International Energy Agency
LPG	Liquefied Petroleum Gas
MCDA	Multi-criteria Decision Analysis
NEDC	New European Driving Cycle
NGV	Natural Gas Vehicles
PHEV	Plug-in Hybrid Electric Vehicle
RCCI	Reactivity Controlled Compression Ignition
SUV	Sport Utility Vehicle
TCO	Total Cost of Ownership
WLTP	World Harmonized Light Vehicle Test Procedure

1. INTRODUCTION

1.1 AUTOMOTIVE MARKET SCENARIO

Since 1997, when the Kyoto Protocol was created, a global effort to reduce GHG (Greenhouse Gases) emissions took place, covering all sectors, especially the industry, and, the focus of this work: transportation. Currently, transportation is responsible for more than 20% of the world's GHG emissions according to a dynamic chart of the International Energy Agency (IEA, 2020d), with road traffic being the largest emitter (passenger and freight vehicles combined), accounting for approximately 65% in the global scenario in 2018 (IEA, 2020c), as shown on the respective dynamic chart. In terms of consumption, the transport sector is responsible for almost 55% of the global consumption, and so, deserving priority to implement fuel-reduction policies and actions. According to the British green energy company (Ecotricity, 2020), oil reserves are expected to end around 2050 if the actual consumption rate is maintained, demanding its independence as soon as possible. Throughout the years from the 1990s until the present, many strategies took place to expand the so called "alternative fuel vehicles" (AFV) diffusion across the globe. Another dynamic chart (IEA, 2020a) shows how alternative powertrain vehicle deployment has evolved so far till 2018, the last data release year, while Figure 1 below presents the stock of electric cars by global region evolving from 2013 to 2019.

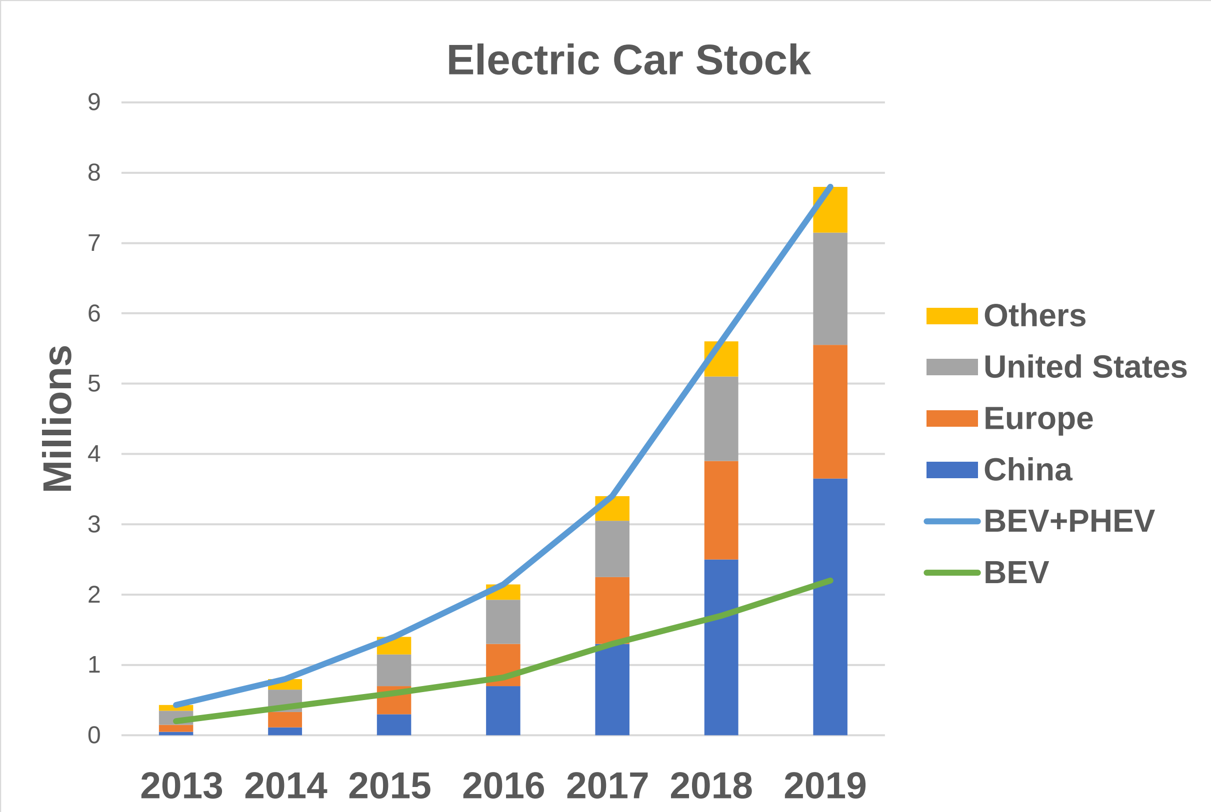

Figure 1 – Electric car stock by region and technology, 2013-2019. Source: (IEA, 2020b) (Adapted by the author)

Looking out only to the European Union (EU) this time, statistical data from the European Automobile Manufacturers Association (ACEA, 2020b) show that in 2019, 58,9% of all the new cars registered in the EU (compared to 56,6% in 2018) are petrol-powered, while the preference for diesel cars was 30,5% (in the predecessor year this value is 35,9%), while electric cars increased from 2% in 2018 to 3% in 2019, as shown on Figure 2, below.

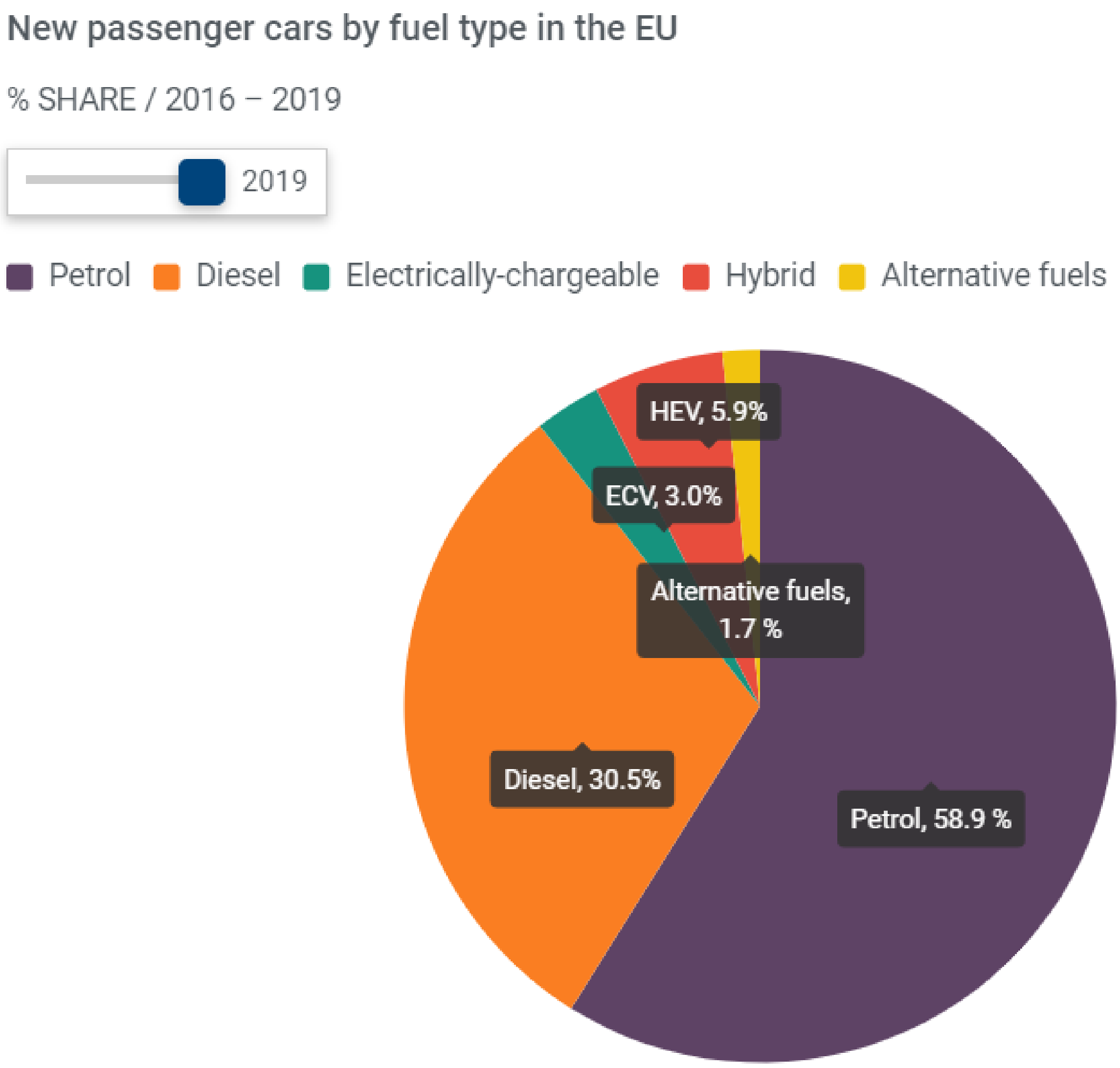

Figure 2 – New passenger cars by fuel type in the EU in 2019. Source:ACEA (2020b)

Even if the number of them increases year-by-year, due to availability of multiple models to choose, the overall market penetration rate is still too low. Maybe the fear to embrace unseasoned expensive technology could partially explain their slow adoption, but other factors also must be considered. These vehicles have higher prices than the conventional ICEV (Internal Combustion Engine Vehicles) due to their advanced powertrain and production technologies, and in the case of BEV (Battery Electric Vehicles), the sales can be possibly influenced by use restrictions, depending on the market they are commercialized (Lévay et al., 2017). This brings the context to this work's main question, which is: "In what degree quantifiable factors, such as costs and use restrictions, can influence consumer choice for these vehicle types?". Sousa et al. (2020) wrote an article proposing a new way to answer it, using MCDA (Multicriteria Decision-making Analysis) methods, complementing other approaches found throughout the literature. They tested it on a case study applied to the Portuguese market with vehicle availability data as of 2017, and the country's fiscal and financial context. Now, in this dissertation, their study will be replicated in other markets worldwide, giving global behavior of consumer's preference for different types of powertrains.

When considering a vehicle for purchase, multiple aspects are considered (such as fuel consumption, maintenance costs, taxes to keep it legalized…), so it is natural to attempt explaining consumer acceptance of alternative powertrain vehicles using tools that consider multiple dimensions of reality, especially quantifiable ones, such as costs and use restrictions. Several studies showed that ownership costs, driving range, charging availability, and charging time are the biggest influencing factors in the adoption of electrically charging vehicles (Liao et al., 2017). This research adopts the previously mentioned criteria, giving a more complete analysis.

In this research three main powertrain technologies are considered, namely internal combustion engine vehicles (ICEV) (including HEV – Hybrid Electric Vehicles – because they do not have vehicle use restrictions as well as do not travel a meaningful distance in electric power); plug-in hybrid electric vehicles (PHEV) and battery electric vehicles (BEV). In the last quarter (Q4) of 2019, together they represented 98.3% of the EU sales, being 86.8% (ICEV with HEV) and 11.5% (PHEV + BEV). Other Alternative Fuel Vehicles (AFV) like LPG (Liquefied Petroleum Gas), NGV (Natural Gas Vehicles) and Ethanol had a participation of 1.7% (ACEA, 2020a). LPG, NGV and Ethanol powered vehicles were not included in the research due to their low share as seen previously, and also because they are not truly alternative powertrains, but merely ICEV running on different fuels. ICEVs were included to serve as comparison term, since it is against them that alternatives are compared to. In addition, the analysis was segregated into four vehicle sizes (small, medium, medium SUV and large vehicles) and two driver profiles (city and all-purpose) for a total of eight different sets of analysis and four countries, and as an example, Sharma et al. (2012) applied this type of analysis in the Australian market.

In order to estimate consumer acceptance of the various vehicles on offer for each set, Sousa et al. (2020) used the ELECTRE TRI decision analysis method. It classifies vehicles (i.e. organizes them into bins or classes, ordered from "Avoid" to "Buy"), and compares them one-by-one against pre-defined reference classes, in a non-compensatory way. To facilitate the calculations, the MATRIX software (an online-based software developed by the University of Coimbra to solve problems of ELECTRE TRI and other multicriteria methods) was used. The proposed methodology considers a baseline scenario, consisting of current real-world market and financial conditions, followed by a sensitivity analysis with alternative scenarios approaching criteria importance and financial changes. The results are deeply examined in order to obtain important conclusions about the current and future acceptance by consumers.

1.2 MOTIVATION

As mentioned before, with the increasing amount of pollution caused by fossil fuels and their daily decreasing reserves, it is necessary to take actions and move to a new reality, which is the hybrid and fully electric automotive fleet. From a technical point of view, the main reasons that motivated this study are:

- BEV have zero-emissions of GHGs when in use, moving the world one step closer to the carbon reduction emission goals of the Kyoto Protocol and Paris Agreement;
- BEV do not generate noise when they are used, indirectly contributing to a better life quality in general;
- They use only electricity as power source, providing a safer and more economic use.

However, not only the advantages compose this motivation. Some challenges also got the attention of the author, that are:

- The need to expand the charging stations network, in order to provide an easier and accessible reload of the batteries;
- More efficient batteries to achieve the same range of ICEVs or even better ones;
- Political and economic changes to disseminate the BEV technology.

The research used as basis for this work brings a different perspective to the alternative powertrain technologies, showing that, beyond their advantages, it is important to consider how consumers accept them together with other alternative powertrain technologies, finding ways to make them more popular.

1.3 OBJECTIVES

The objective of this work is to study consumer acceptance for different alternative powertrain technologies using a multicriteria method applied to multiple automotive markets worldwide. Continuing the study done by Sousa et al. (2020), which uses the ELECTRE TRI multicriteria method applied to specific scenarios under certain conditions of vehicle usage, the original data-set was focused on the automotive market of Portugal, but this time, a global vision will be provided. To accomplish it, the data-set will be composed by the following structure:

- Four countries: Portugal, Brazil, United States and Germany
- Three technologies: ICEV including HEV, PHEV and BEV
- Four segments of vehicles: small, medium, medium SUV and large
- Two driver profiles: city and all-purpose
- Baseline scenario for all datasets plus three alternative scenarios (TCO-only, CO_2 emissions with final weight of 33% and Economic)
    - TCO-only: a scenario where BEVs are free of the known use restrictions, where availability of charging points and the charging time would be like the other powertrains;
    - CO_2 emissions with final weight of 33%: scenario focused on analyzing the behavior of consumers with a noticeable environmental concern;
    - Economic: allows an evaluation of a situation where BEVs become more attractive in function of economic changes, like increase of fuel price, reduction of its purchase prices in consequence of application of incentives and a longer holding period, where running costs of ICEVs and BEVs have a considerable difference.

The convergence of these goals aims to provide a novel contribution to the scientific community, developing different approaches and improving existent ones to the transition of traditional automotive powertrains to alternative ones.

1.4 STRUCTURE OF THE REPORT

Chapter 2 shows the literature review. Some relevant works were analyzed by the author, and the findings of those articles were summarized. Moreover, a cross-reference has been made to connect the articles with the present research. Next, in Chapter 3**,** the details of the methodology and methods that are going to be used in the dissertation are presented. Furthermore, section 3.1 details the main assumptions of this work, while section 3.2 explains the criteria used for the analysis. For section 3.3, the information related to the vehicle set is presented and at section 3.4 the method itself is detailed.

Chapter 4 explains the results of the study and is divided in two parts. First, in section 4.1 the baseline scenario for each country is analyzed, and at section 4.2 the sensitivity analysis presents the possible consumer behavior for 10 different scenarios for each market. The following section 4.3 brings a global discussion of all these results and their relations with policy actions. Finally, Chapter 5 show the conclusions of this research and suggests future work.

2. LITERATURE REVIEW

Since the beginning of this century, the automotive market saw several evolutions in many aspects, being fuel efficiency, alternative fuel and powertrain the most important ones. Today we are facing the challenges of a transition era, from where humanity will start to abandon fossil fuels, and move to electricity, in order to reduce Greenhouse Gas (GHG) emissions and improve life quality and environment for all of us. With this in mind, the literature review on this research comprises three main topics: "alternative fuel vehicles" (AFV), "electric/urban mobility" and "Political and economic factors for alternative fuel vehicles". These topics together are of major importance for this work, and also give the reader a general overview of the importance, evolution and challenges on the road to the automotive future.

AFV already are a reality, and in a few years, are expected to have a larger market share for new cars and small cargo vehicles. Since the launch of the Toyota Prius in the beginning of the 2000s, each day we see more greener cars in the streets, evolving not only in performance of GHG emissions reduction, but especially in range, a key factor for Battery Electric Vehicles (BEV), as seen in Bonges & Lusk (2016), which try to increase the sales of BEVs by addressing charging-related policies, like affordable charging fees, re-designing the charging stations and relocating them. Other related studies are presented by Jyotheeswara Reddy & Natarajan (2018) proposing the use of a multi-input DC-DC (Direct Current) converter to optimize the efficiency of BEVs, while Farfan-Cabrera (2019) try the same approach reviewing their most critical components and solutions to improve them.

Another perspective is the usage phase impacts, where the real efficiency of the Hybrid electric Vehicles (HEV) and Plug-in Hybrid Electric Vehicles (PHEVs) are put to test, and recent studies like the one performed by Benajes et al. (2020) show that, when they compare the RCCI (Reactivity Controlled Compression Ignition) dual-fuel combustion mode in different types of HEVs and no-hybrid vehicles under the WLTP (World Harmonized Light Vehicle Test Procedure) normative, the results show that this technology can decrease fuel consumption strongly. Craglia & Cullen (2019) studied the gains of technical improvements in different powertrains for British vehicles between 2001 and 2018 with driver-reported data on real-world fuel consumption, discovering that emissions have increased between 2017 and 2018 even with adoption of fuel economy standards in the EU, and suggest three ways to avoid this continuing, that are increase the rates of technical efficiency improvements in powertrains, vehicle size and power reduction by increasing taxes for larger vehicles, and increase technology switching by adoption of hybrid and electric vehicles.

When talking about alternative powertrains, the concept of urban/electric mobility also plays a role in the context, as we are preparing to change from petroleum era to the electricity era. It is important to research the advances already achieved in this sector, as well as the challenges still waiting for a solution. Sovacool et al. (2018) study the influence of demographic factors for the preferences of electric mobility in the Nordic region, showing that the BEVs are preferred between men that have occupations in non-profit organizations and aged between 25 and 44 years, and also that other segments can be exploited for BEVs owners, like higher income females and retirees/pensioners. Some studies even conclude that electric mobility can be applied out of the passenger/light-duty segment, like the one performed by Iwan et al. (2019), where he demonstrates the status and attempts to improve electric powertrain usage in urban freight and logistics, and Scorrano et al. (2020) that study the mandating adoption of electric taxis in Florence, analyzing their advantages and challenges. However, it is not only benefits that comprises the studies for electric mobility; the challenges for dissemination has the largest role played in this context, as seen in Kalghatgi (2018) where he discusses the transition to the electric mobility era, especially in terms of infrastructure and electricity sources, and also in de Rubens et al. (2020), where they conduct interviews with transportation and electricity experts in the Nordic countries, finding that EVs are in an unfavourable business case and recommending policies to change this situation.

Now talking about the financial aspects, many studies were made over the past years, such as e.g. estimating total cost of ownership (TCO) for different powertrain options. Two good examples are Bubeck et al. (2016) and Letmathe & Suares (2017), presenting a perspective of TCO for electric vehicles in the German market and similarly concluding that PHEV and BEV demand a significant amount of premium from potential buyers, causing difficulties to acquire these vehicles without governmental subsidies. For the Australian market, Sharma et al. (2012) used sensitivity analysis to identify the necessary TCO changes to favor BEV. Rudolph (2016) uses logit models to analyze how financial incentives can impact the possible purchase of BEV, having found that increasing fuel prices together with a high purchase grant would be the biggest factors increasing BEV sales. Tamor et al. (2013) use statistical trip data in a US city and a payback model to estimate acceptance of BEV and PHEV on a financial level. More recently, Lévay et al. (2017) carried out TCO calculations in eight European countries to find out how costs and sales of BEV relate to each other and to examine the role of fiscal incentives in reducing TCO and increasing BEV sales.

This research attempts to continue the work of Sousa et al. (2020) by estimating consumer acceptance of alternative powertrains in different markets around the world in a perspective other than survey-based or regression studies, being closely related to multicriteria decision-making research. Instead of conducting surveys focused on the consumer's reaction to certain prototype vehicles or their abstract characteristics, subsequently deducing purchase choice log-odds from the replies, or searching highlights by analyzing real sales data, the methodology used here presents a new vision for this type of study, based on a real market line-up of vehicles, whose consumer acceptance it tries to predict by applying an adequately calibrated multicriteria decision-making model. If the task was asking a large number of consumers about their personal opinion on various vehicles, it would be very exhaustive and complex due to data compilation challenges, and especially, participation of subjective factors. Thanks to the wide variability of available models with alternative powertrains, it became possible to get a deeper look into consumer preferences in a different perspective than stated preference methods, in this case, statistical perspective, taking the research one such step in that direction.

The methodology applied by Sousa et al. (2020) presents a new contribution to the state-of-the-art on consumer acceptance of alternative powertrain vehicles due to the above-mentioned approach, and also by using a non-compensatory multicriteria method, which simulates more truly the human decision-making process than other methods while filling the literature gap on the subject. This is the first time ELECTRE TRI is used to approach the problem, revealing significant tendencies towards a certain powertrain technology, anticipating such tendencies and allowing the automotive industry and governments to increase attractiveness to AFV by adopting specific policies.

3. METHODOLOGY AND METHODS

This chapter describes the methodology and methods used to accomplish the proposed objectives, using a Multicriteria Analysis tool to estimate the consumer acceptance about alternative powertrain technologies in four different countries across the globe. In order to accomplish it, some assumptions were made and will be presented on section 3.1, followed by a description of the selected criteria in section 3.2. In section 3.3, the vehicle set will be presented and in section 3.4 the subject will be the Multicriteria Analysis method, explaining the main concepts and how it will be applied for this study. The selected countries were Portugal, Brazil, United States and Germany.

3.1 MAIN ASSUMPTIONS

The scenario at hand for this study is a consumer who wants to purchase a brand-new car but he is undecided about acquiring a model using alternative powertrains, or an Internal Combustion Engine Vehicle (ICEV). It will be the main car in the household, meaning that its usage level (frequency and distance travelled) will be greater than any other car in the house; and it is also possible that this will be the only vehicle available in the household. Some examples of researches considering two or more cars in a house are Tamor et al. (2013), Jakobsson et al. (2016), Karlsson (2017) and Björnsson & Karlsson (2017). Also, access to a reliable source of electric power for Plug-in Hybrid Electric Vehicles (PHEV) and Battery Electric Vehicles (BEV) (either being at home or in a nearby street) is assumed, as acquiring such type of vehicle makes no sense without having a charging station or a domestic power output. Speaking about purchasing cars, consumers have four main factors in mind, which are the type of engine (mostly petrol, diesel, electric or hybrid), the vehicle size, the usage profile and the holding time (with overall costs depending on this criterion). The main assumptions are the same from the original study, and are shown below:

- Three powertrain technologies: ICEV (including HEV), PHEV and BEV.
- Four vehicles sizes: small, medium, medium SUV and large.
- Two driver profiles: city and all-purpose.

These assumptions, plus the country, will act as disaggregation factors in the statistical analysis results. Regarding the driver profiles, they were maintained the same as the original research, because they are the most commonly used types, and are defined as follows: city driving profile is directed for users who drive inside the city or use their vehicle for short-distance travels, while the all-purpose profile is adopted by drivers that use their cars for work (reasonably far from home) or frequent long-distance road trips. The short-distance travels and in-city travels also can be referred to as “urban use”, while the long-distance ones can also be termed “road use”. As from the original research, the following standards for the respective driver profiles will be used:

- City driver profile: annual travelled distance of 15.000 km, where 80% is urban use, and the remaining 20% are road use.
- All-purpose driver profile: annual travelled distance of 30.000 km, where 80% is road use, and the other 20% are urban use.

As Sousa et al. (2020) did not find any referred data for the clustering of drivers in Portugal and other countries, the annual travelled distance and the urban road percentage are assumed, based on a study of Pasaoglu et al. (2014) for six EU countries, finding that the daily driven distance for ICEVs varies between 40 and 80 km, depending on the country. The last two assumptions before moving to the criteria themselves are the vehicle holding period, which according to BEUC (2012) is 5 years, typical for European standards, and the exclusion of the costs related to battery replacement, due to its long time to degrade, that can be more than ten years Pelletier et al. (2017).

3.2 ANALYSIS CRITERIA

Paying attention to the selected criteria, four items will be considered in the analysis, namely: the TCO [Total Cost of Ownership (cost-related)], Range, Charging points and Charging time, where the range and charging items are related to possible restrictions during the use of the vehicles, and only apply to BEVs, as this type of technology is the only true alternative powertrain different from ICEVs in the foreseeable future, and are in practice as well. Also, performance, comfort and practicality (e.g. trunk space) as well as brand image/aesthetics where excluded, respectively, due to their similarity and subjectivity.

Before detailing each criterion, some additional considerations must be addressed. When talking about the ownership costs, vehicles with alternative powertrains will have a higher price than those with comparable ICEV technology. This difference is explained by the costs of the batteries in the case of BEVs, and for HEV and PHEV models, added to the battery costs, the powertrains are more complex, and so, to achieve a better fuel-efficiency, it is more expensive to produce the specific components. Even with an increased manufacturing scale for vehicles with hybrid, plug-in hybrid and electric technologies in the future, a reduction in purchasing prices will take some time until it reaches the end-users, but in the other hand, if the vehicle is more energy-efficient, that means lower running costs (for this study, denominated "energy cost"). Another point to consider is about the purchasing price, being an important factor considered by consumers in general, as shown by Rezvani et al. (2015) and Dumortier et al. (2015), where TCO has greater importance than other factors, and hence, this is the criterion with the biggest importance within the financial context. Concerning about use restrictions, Sousa et al. (2020) identified in the original study that range, charging points availability and charging time can possibly be dependent criteria, because one can counterargue that is always possible to happen situations where one of them may be individually responsible for restrictions in vehicle use, and thus, they decided to treat each of these criteria as independent factors for the decision-making process, an approach that Yavuz et al. (2015) also used on their study for acquiring alternative powertrain vehicles for a corporate fleet, where the electric car was the best option in the end.

3.2.1 TOTAL COST OF OWNERSHIP

The Total Cost of Ownership (TCO) covers the main expenses that consumers have when purchasing a new vehicle and along its usage year-round, that are: purchase price, energy cost, insurance premium, maintenance and circulation taxes and resale value. For BEV, it is possible that a purchase rebate exists depending on the country under study, like in the United States, where according to one of the best automotive market research websites, Edmunds.com (2020), federal incentives and tax rebates on BEVs and PHEVs can reach a value up to 7.000 dollars (approximately 5900 euros per today's Exchange rate quotation) depending on the model, and even further, state incentives also make part of this role. The US Government through their "Fuel Economy" website (Fuel Economy, 2020) provides a full list of the current eligible vehicles for the respective incentives. In Europe, each country has different incentive rules (if existent), and the conditions for Portugal and Germany can be found on a table elaborated by ACEA (2020c). For this study, the insurance premium and maintenance costs were removed from the TCO, and this was decided because it could be difficult and take too much time to acquire the information, and so, only the main factors were considered. Also, the TCO was made for both driver profiles (city driver and all-purpose driver) because the energy cost in each profile is different, and so, both values must be considered. Below, the way that each of these main factors was obtained will be presented.

Purchase price

The prices were obtained throughout the websites of the manufactures, and these include legal costs, taxes and shipment. For the American and Brazilian markets, the prices were converted to euros, with an Exchange rate quotation of 1,13 dollars per euro in the beginning of July, and a 5,68 Brazilian Real (BRL) per euro at the same time, to simplify the analysis and give an idea of how much the price is different for a specific model or an equivalent vehicle in different markets. One difficulty found at the Brazilian market is that some vehicles did not show the price on the manufacture's website, being necessary to find their prices on articles from automotive magazines or the national price table, and this gap of prices can be explained by the possibility that these models do not sell too much, and may be treated as custom-order models.

Energy costs

The energy cost (or "running cost") is the cost of the necessary energy to keep an object or system in operation, and in this context, it is the necessary energy to keep the car running. For the present study, the energy cost is based on the powertrain type, the distance driven, and the price of the energy used. Table 1 below shows the medium price of energy and fuel in the four countries considered, based on the website Global Petrol Prices (2020), also for the beginning of July.

Table 1 – Energy cost for the selected countries. Source: Global Petrol Prices (2020)

Energy Cost (EUR)			
	Petrol (EUR/l)	Diesel (EUR/l)	Electricity (EUR/kWh)
Portugal	1.40	1.24	0.26
Brazil	0.67	0.57	0.13
USA	0.59	0.52	0.12
Germany	1.30	1.10	0.32

After obtaining the fuel prices and the consumption of each vehicle, the calculations were made for each driving profile, combining the distance travelled annually, fuel/charge price, and the most important factor, the vehicle's consumption. To simplify the calculations, the unit of measurement was adopted as liters/100 kilometers (l/100 km) (the most commonly used in Europe), the combined consumption was used whenever available, and the standard of consumption is the new World Harmonized Light Vehicle Test Procedure (WLTP), which is a more accurate and realistic method, reflecting truly the real-world driving conditions and behaviors adopted by drivers worldwide, and already is the standard procedure for the EU since January 2018. In relation to the older method (NEDC – New European Drive Cycle), consumptions in WLTP have a higher value than in NEDC (Pavlovic et al., 2016), and are already being applied to any new car registration since September 2018.

The difficulty this time was to acquire fuel consumptions values, because some vehicles in the Brazilian market did not present the consumption values on their websites, being necessary to find these values on other sources (firstly achieve an assumed combined consumption, then convert from kilometers/liter to l/100 km), in both Brazilian and US markets, CO_2 values were not available in most vehicles, being necessary to convert the fuel consumption into CO_2 equivalent data. In Germany, some vehicles presented emissions and consumption values already in WLTP standard, while others shown these references in NEDC-equivalent values. This is explained by a FAQ (Frequently Asked Question) of a WLTP-specialized website (WLTP Facts, 2020), which says that the NEDC-equivalent presentation is to monitor the compliance with the 2021 CO_2 targets, which are still based on the old NEDC test. For the US market, the values were converted from Miles per Gallon (MPG) to l/100 km, and for the German market, the values presented in the websites were maintained. For all markets, the energy consumption (kWh/100 km) (separate from fuel consumption) of each PHEV was maintained the same, as these cars are sold in the four markets considered, and the only mechanical difference from country to country is the power of the combustion engine.

Circulation tax

The circulation taxes are different in each country. In Portugal and Germany, the tax is based on engine capacity and car CO_2 emission; tax charges were obtained applying the legal formula for each vehicle. In Brazil, the tax varies from 1 to 4% of total car price depending on the state of residence; in this study, 4% was assumed. For the USA, the tax varies in each state, and in some states, the county and city may impose their own taxes independently, as it is in California, Florida, Illinois and others, while some states tax the vehicle based on its price, or even on its weight. For this study, the state of California was chosen, and the state tax (without considering city taxes for simplicity) is 7,25% of final retailing price. It is worth noting that for the Portuguese and German markets, BEVs do not pay this tax, although this will end this year in Germany.

Resale value

Car depreciation depends on several factors, such as conservation, comfort items, and many others, but a factor that is common in all countries is the five-year holding period, as already mentioned before, typical for European standards. As depreciation for each country is different (especially overseas countries like Brazil and USA) and the goal is to harmonize data as much as possible, a rate of 42% depreciation for all markets was used for a five-year period, based on a recent insurance company pre-contractual information from Portugal (N Seguros, 2020), which shows a 84% depreciation rate for a 10-year holding period.

3.2.2 RANGE

In the range criteria, the official-reported range was used for BEVs, while for the other technologies, a 700 km range was used as standard for calculating the range performance (the minimum range for ICEVs), with all ranges normalized (divided by 700), with the final score varying from [0,1] (for a 700 km range or more), which also is one of the breakpoints of Figures 4 and 5 presented ahead, according to the result of the division. No other restrictions of range or charging were applied to PHEVs.

3.2.3 CHARGING POINTS

The charging point criteria considers two different availability values for BEVs. The first is a 100% availability for urban use, assuming users can access charging points at their homes or nearby (drivers living in apartment buildings were not considered because it's very unlikely that they will buy an PHEV or BEV without having a power source in the garage). However, it must be considered that new public and private charging stations are installed almost all the time, increasing current density, and at the same time, increasing the number of drivers that consider these types of vehicles as an option. The second value, directed for road use, is of 25% availability, according to Sousa et al. (2020) (applied for all countries to simplify the calculations). Combining these values with the driver profile yields previously mentioned, a charging availability for BEVs of 85% for city profile and 40% for all-purpose profile was reached. In the case of ICEVs (including HEVs) and PHEVs, an availability of 100% was considered, thanks to the abundancy of fuel stations.

3.2.4 CHARGING TIME

The fourth criteria to be discussed is the charging time. According to Hackbarth & Madlener (2013) and Ito et al. (2013), non-BEV vehicles usually refuel in 5 minutes, and thus this was used. The charging time of BEVs is an issue and depends mostly on the power of the charging station, regardless whether the charging happens at home or at public points. For urban use, it was necessary to divide the battery capacity of each vehicle by the power of a 3.7 kW charger (230 V, 16 A) (assumed for all countries), the maximum power output available in Portugal for charging at home or in slow public points. Now for road use, a 40 kW power output is taken into account (also assumed for all countries), as this is the standard offered in highway service stations in Portugal.

3.3 VEHICLE SET

The vehicle set originally used comprehends a total of 94 models including the technologies and sizes described before. Figure 3 below shows the dataset originally used – for this study, a maximum of 10 models for each tech (ICEV including HEV, PHEV and BEV), for each segment (Small, Medium, Medium SUV and Large) for each country was the adequate to be considered; this would provide a total of 480 vehicles for the analysis. However, due to lack of options in some cases, the real number of vehicles considered is 365. The full set of vehicles for each country on this study with the respective data can be found in Appendix A.

	ICEV	HEV	PHEV	BEV
Small	*Citroën C1* *Fiat Panda* *Peugeot 108* *Smart for two* *Toyota Yaris (D+P)* *Toyota Aigo* *VW Up*	*Toyota Yaris*	*BMW i3 Rex*	*BMW i3* *Citroën C Zero* *Mitsubishi i MIEV* *Peugeot i-on* *Renault ZOE* *Smart fortwo ED* *VW e-UP*
Medium	*Audi A3 Sportback (D+P)* *BMW 2 Series (D+P)* *BMW 3 Series (D+P)* *Citroën DS5 (D+P)* *Kia Soul* *Mercedes B Class (D+P)* *Mercedes C Class (D+P)* *Nissan Qashqai (D+P)* *Toyota Auris (D+P)* *Toyota Auris TS (D+P)* *VW Golf (D+P)* *Volvo V60 (D+P)*	*Citroën DS5* *Hunday IOINC* *Lexus GT* *Lexus ES* *Lexus NX* *Mercedes C Class* *Toyota Auris* *Toyota Auris TS* *Toyota Prius* *Toyota Prius Plus* *Toyota RAV 4*	*Audi A3 Sportback* *BMW 2 Series* *BMW 3 Series* *Mercedes C Class* *Toyota Prius* *VW Golf* *Volvo V60*	*Kia Soul* *Mercedes B Class* *Nissan Leaf 24* *Nissan Leaf 30* *VW Golf*
Large	*BMW X5 (D+P)* *Ford Mondeo (D+P)* *Mercedes D Class (D+P)* *Mercedes S Class (D+P)* *Mitsubishi Outlander* *Peugeot 500 (D+P)* *VW Passat* *Volvo XC90 (D+P)*	*Ford Mondeo* *Lexus RX* *Lexus GS* *Mercedes S Class* *Peugeot 508*	*BMW X5* *Mercedes S Class* *Mitsubishi Outlander* *VW Passat* *Volvo XC90*	*Tesla S75D* *Tesla X75D*

Legend: D-Diesel ICEV; P-Petrol ICEV

Figure 3 – Original vehicle dataset. Source: Sousa et al. (2020)

However, the real number was smaller than the supposed, and is shown below on Tables 2 through 5, for each market:

Table 2 – Vehicle set numbers for Portugal.

Portugal				
Tech / Size	ICEV + HEV	PHEV	BEV	Total
Small	8	0	11	19
Medium	28	9	7	44
Medium SUV	20	7	9	36
Large	12	7	3	22
Total	68	23	30	121

Table 3 – Vehicle set numbers for Brazil.

Brazil				
Tech / Size	ICEV + HEV	PHEV	BEV	Total
Small	16	0	4	20
Medium	12	3	1	16
Medium SUV	12	1	0	13
Large	13	3	0	16
Total	53	7	5	65

Table 4 – Vehicle set numbers for USA.

USA				
Tech / Size	ICEV + HEV	PHEV	BEV	Total
Small	10	0	4	14
Medium	8	5	4	17
Medium SUV	8	5	6	19
Large	10	7	3	20
Total	36	17	17	70

Table 5 – Vehicle set numbers for Germany.

Germany				
Tech / Size	ICEV + HEV	PHEV	BEV	Total
Small	10	0	10	20
Medium	19	7	7	33
Medium SUV	21	7	9	37
Large	10	6	3	19
Total	60	20	29	109

It was attempted to list as much as possible the largest number of common models among all countries, in order to take a standardized selection, but this was not always possible, and to overturn the situation, similar/equivalent vehicles were selected where a specific model was not available. One challenging issue was the difficulty to acquire the CO_2 emissions, fuel consumption and energy consumption (in the case of BEVs and PHEVs) from the manufactures. To solve this, some steps were taken. For the CO_2 emissions, the fuel consumption (l/100 km) was converted to emissions values, using the rates of 23,4 g/l (for gasoline cars) and 26,9 g/l (for diesel-powered vehicles). The fuel consumption had to be converted from "km/l" (in the Brazilian market) and "MPG" (the USA case) to "l/100 km", and especially with USA models, there was no combined values sometimes, needing to calculate an average value and assuming it for the designated purposes, or like in the Brazilian market, no consumption data was available in the manufactures, being necessary to assume the same consumption obtained in other markets. The same happens for BEVs and PHEVs energy consumption.

3.4 MULTICRITERIA DECISION ANALYSIS METHOD

Now, the attention is concentrated on the method used for this research, the ELECTRE TRI multicriteria method, as mentioned in the introduction. When using ELECTRE TRI, the alternatives (in this study, vehicles) are compared using pre-defined and ordered performance (or reference) classes, being assigned to one of these classes at the end of the analysis. For this case study, four classes were defined a priori, being seen qualitatively as consumer decisions of "1 – Avoid", "2 – Consider", "3 – Shortlist" and "4 – Buy" for each considered vehicle. In class number 4 ("Buy"), it is possible to have multiple vehicles, where only one of them will be chosen by the consumer in the end, according to his subjective preferences, and hence, each vehicle is assigned to one specific class, reflecting consumer's desire.

The comparison itself is made by using the criteria characterizing the vehicle and criteria that characterize the borders, or breakpoints of each reference class (see Figures 4 and 5 on item 3.4.2). This happens in a non-compensatory way, that is, when some criterion has a significant low performance, it cannot be compensated by very high performances in other criteria (differently from the compensatory methods, where this is possible). According to Mousseau et al. (2001), each criterion can individually have a major influence in the aggregated performance of an alternative. Then, a relationship between the alternative and the reference class is built by using the outranking concept, where one alternative (A) can almost surely be better than other (B) if there is a majority of criteria supporting it (concordance) and no individual criterion is strong enough to oppose it (non-discordance) (for more details, see Mousseau et al. (2001)).

This is applied especially when an alternative has all criteria situated between two consecutive reference class breakpoints, assigning it to the class delimited by the referred breakpoints. To get a realistic outranking relation, the imprecision and uncertainty inherent to human decision are accommodated by the thresholds of indifference, preference and veto, entering in the concordance and discordance calculations, and locating themselves at the center of the non-compensatory nature. In reality, to apply the ELECTRE TRI method, the decision-maker (DM) needs to define a series of technical parameters, namely weights, reference class breakpoints, thresholds, cut level and class assignment rule, and each of these parameters is explained below.

3.4.1 WEIGHTS

In the ELECTRE TRI method, weights are parameters that indicate how important a specific criterion is and are used to calculate the so-called index of concordance (Mousseau et al., n.d.). Saaty (1987) presents the Analytic Hierarchy Process (AHP), a pairwise comparison method which was used to define weights. In AHP, there is a transformation from a matrix of pairwise comparisons among criteria into a vector (matrix eigenvector), and after normalizing these values, the weights are obtained. To compare criteria between them, the Decision Maker (DM) must subjectively judge the importance of the criteria by assigning a value from an integer scale of 9 levels (1 = equally important, 9 = absolutely more important). This work uses the same weights used in the original study. Table 6 represents the original weights.

Table 6 – Baseline criteria weights. Source: Sousa et al. (2020)

	TCO	Range	Charging Points	Charging Time
City driver profile	68.1%	12.3%	8.4%	11.2%
All-purpose driver profile	52.4%	21.1%	13.2%	13.2%

3.4.2 REFERENCE CLASSES

After defining the previously mentioned classes (Avoid, Consider, Shortlist & Buy), now it is necessary to define the breakpoints, that is, the borders where one class ends and the next one begins. For this study, the breakpoints are set on a per-criteria basis for each driver profile.

TCO: For this first criteria, the breakpoints were defined as quartiles of the total TCO amount for each of the 32 cases (4 segments x 2 driver profiles per country x 4 countries).

Range: Considering the evaluated daily distance travelled for both profiles (41 km for city profile and 82 km for all-purpose profile) adopted in the original study, and standardizing their procedures, the lowest breakpoint was set at 50% of the daily value, allowing for eventual fluctuations and alleviating of range anxiety; for classes 3 and 4, the breakpoints were defined at 50% over ranges, requiring 2 and 1 weekly charges, respectively. After a normalization to a [0,1] scale and ranges of 700+ km corresponding to 1, the final breakpoints are 0.088, 0.308 and 0.615 for city driver profile and 0.176, 0.615 and 1 for all-purpose driver profile.

Charging Points: For this criterion, the breaking points for both driver profiles are 0.33, 0.5 and 1. The reason for choosing 0.33 for the lowest break is in accordance with recommendations from the Portuguese Road Safety Prevention Service (PRP, 2020), which states that drivers must do a 15-minute break every 2 hours of driving, equivalent to 150 to 200 km at average road speeds. Considering a distance of 50 km between service stations in Portugal, and taking it as standard to facilitate calculations, this results in a 33% minimal coverage for BEVs so they can complete a road trip, and hence, 0.33 is the lowest breakpoint.

Charging Time: The breakpoints are different for each driver profile, due to the assumption of slow/fast charging for urban/road use; so, the times established were 8, 4 and 0.167 hours for city and 0.5, 0.33 and 0.167 hours for all-purpose driver profiles, respectively. The lowest number means that any vehicle that can refuel/recharge in less than 10 minutes will be allocated to Class 4 "Buy" in this criterion, which is the maximum time a car will spend at a station to fuel the tank/battery. The values 8 and 4, respectively, represent a whole/half nighttime for recharging, making the vehicle fit in Class 1 "Avoid" in case this happens. As already mentioned earlier, only BEVs are issued on charging time.

CO_2 emissions: CO_2 emissions can play a role in two different ways, which are TCO level and environmental impact level. In the first case, CO_2 influences the final price of the car (applied import and local taxes) and the running cost, as the selected countries (except Brazil) consider it to calculate the circulation tax, and so, more emissions mean higher annual cost. For the second case, it will be considered a separate criterion, as the environmental concern level varies a lot depending on consumer conscience. For this study, the CO_2 emissions were considered according to the WLTP standards in combined cycle, for ICEVs, HEVs and PHEVs, while the BEVs, instead of having emissions based on the energy mix of each country, had zero emissions during the use-phase. This criterion has breakpoints of 30, 120 and 180, and originally no weight, as weight settings will be done as an alternative scenario (shown on subsection 4.2). The two last values coincide with circulation tax breaks, while the 30 value was used to create distinction between electric and combustion powertrains. As mentioned above, Figures 4 and 5 show the breakpoints represented in a graphical format.

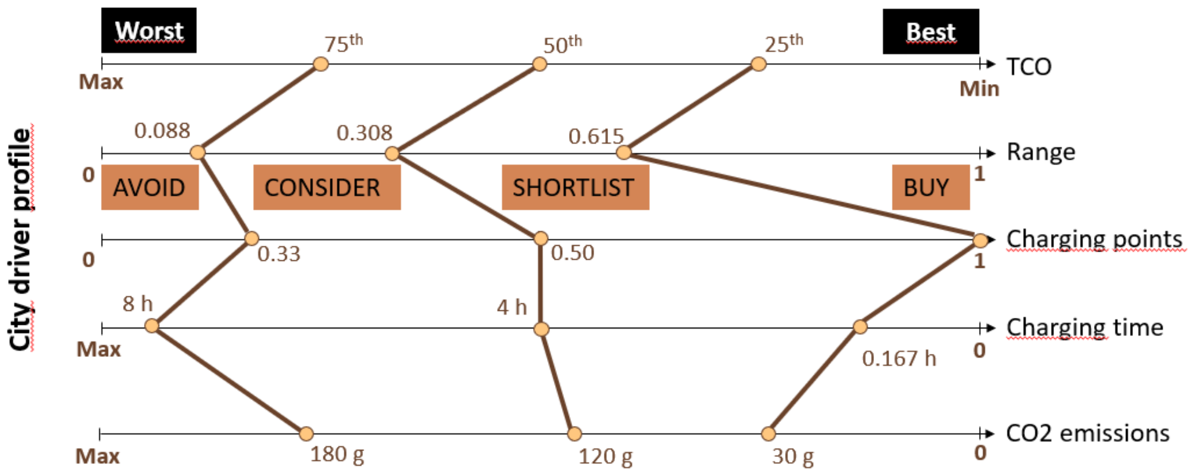

Figure 4 – Breakpoints and Reference Classes for City Driver Profile. Source: Sousa et al. (2020) (Adapted by the author)

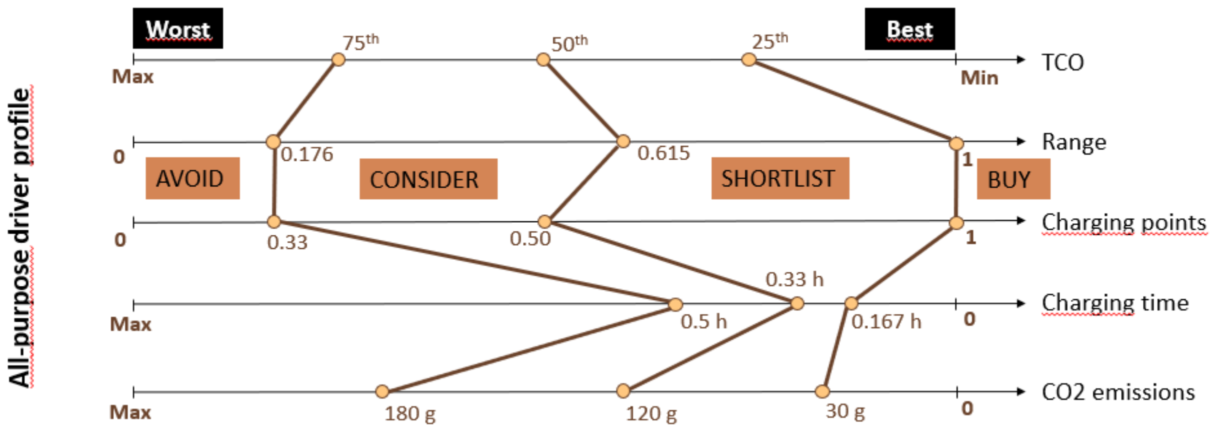

Figure 5 – Breakpoints and Reference Classes for All-Purpose Driver Profile. Source: Sousa et al. (2020) (Adapted by the author)

A vehicle will fit into a class if all its criteria values lie within that class lower/upper breakpoints. But typically, this is not the case: vehicles usually have criteria values spanning several classes. What ELECTRE TRI does is to decide which is the most appropriate class using outranking relations that compare vehicles against breakpoints, ultimately to a well-defined class assignment for that vehicle.

3.4.3 THRESHOLDS

The ELECTRE TRI method, as well as other methods of the same family, have 3 main thresholds that must be taken into account, which are Indifference, Preference and Veto. These thresholds are used to account for imprecision and uncertainty aspects of human decisions, especially when a consumer faces two options with small differences in criterion values. To illustrate this, let us consider a comparison between two TV models, where Model A costs 1,500 € and Model B has a price of 1,600 €. So far, there is no sensitiveness for one or other, but if Model B costs 1,900 €, the customer will prefer A, when considering only the price. Supposing that the price of B is now 3,000 €, it could not be considered as better than A, regardless of the remaining criteria (for example image quality, inputs/outputs, etc.), because it would be too expensive. Summarizing, the price criterion puts a veto on the statement “TV Model B is at least as good as Model A”. Threshold values define the limits where indifference, preference and veto lie.

Following the example of Almeida-Dias et al. (2010), the thresholds for all the criteria were chosen as percentages in indirect preference (i.e. percentage of best value vs worst value). In the first criterion, TCO, the values are 4, 7 ad 10%, as TCO values are tightly packed and a higher percentage could cause the indifference and preference to span multiple classes. For the remaining criteria (Range, Charging Points, Charging Time and CO_2 emissions), the percentages adopted were 10, 20 and 30%, since criteria values have a higher diffusion.

3.4.4 CUT LEVEL AND ASSIGNMENT RULE

The ELECTRE TRI method has various internal parameters governing the outranking relations, and one of the main ones is the cut level, which according to Mousseau et al. (2001), should be located between 0,5 and 1. The value of 76% was used, meaning that TCO alone cannot determine the result of a concordance relation, and thus, other criteria matter on the final score. Assignment rules decide how the outranking relations are used to assign a class to a vehicle. Two rules are possible (optimistic and pessimistic) (Mousseau et al., n.d.). In this thesis the pessimistic rule was used, as it provided a better span over all classes.

4. RESULTS AND DISCUSSION

After defining the vehicle data set and setting the thresholds accordingly, the method can now be ran over the datasets. In section 4.1, the results for the baseline scenario are presented, while in section 4.2 a sensitive analysis is performed, and a discussion based on the overall case follows. The baseline scenario represents the current driving and infrastructure conditions as they are, and the sensitivity analysis has the objective of predicting future acceptance as the conditions are lifted/or improved and technology evolves.

4.1 BASELINE SCENARIO

The results of the baseline scenario are presented in Figures 6 to 13 followed by the respective market comments, for the 8 combinations of size and driver profile in each country. Here is shown each car percentage distribution for each powertrain according to the ELECTRE TRI performance classes defined earlier, and are organized in the size/profile format. Also, for each of the mentioned figures, a table with the statistical significance between powertrains (p-value) is shown in sequence (Tables 8 to 15). In this analysis, Kruskal-Wallis variance tests were applied for each of the 32 cases, and later applied for the 96 remaining configurations corresponding to the alternative scenarios. This testing method is based on the rankings of an independent variable and a chosen factor, becoming ideal for analyzing discrete and ordered outputs, as is the case here. So, for this research, the selected dependent variable is the ELECTRE TRI class (expressed in a 1-to-4 Likert scale) and the factor of choice is the powertrain technology. Also, the Kruskal-Wallis test has the objective of checking whether, as a whole, powertrain technology has an influence on the outcome class. If so (i.e. where p-values are inferior to 10%), post-hoc Dunn tests with Benjamini-Hochberg (BH) false discovery rate correction are done to identify which are the technologies that cause the deviation (significant if two-way p-values are less than 5%). To illustrate, Table 7 below presents one of the cases as an example.

Table 7 – Example of statistical analysis case.

Baseline – US – All-Purpose – Medium		
Kruskal-Wallis chi-squared = 6.728		
Column mean – Row mean	BEV	ICEV
ICEV	-2.569111	
	0.0153*	
PHEV	-1.996032	0.493959
	0.0344*	0.3107
Conclusion: BEV < PHEV = ICEV		

The table shows three post-hoc comparisons, whose significance is determined by the two numbers in the corresponding row/column intersection. The top one is the Dunn test statistic value (with BH correction) and the bottom is its associated p-value. The negative/positive sign of the test statistic indicates whether the technology of the column leads to respectively lower/higher class scores than the technology on the line. The closer the Dunn test statistic is to zero (negatively or positively), the more the technologies are equally attractive. The p-value then indicates whether test statistic deviations from zero are statistically significant. The Dunn test is, by construction, a two-way test, so there is significance at 10% if the p-value is lower than 5% (indicated by the asterisk). In other words, table p-values lower than 5% indicate that there is as statistical difference between the two technologies under scrutiny.

As can be seen, BEV have lower scores than ICEV and PHEV (negative Dunn test statistic values; column minus row), and these lower scores are statistically significant (p-values lower than 0,05 [5%]). ICEV score slightly higher than PHEV (positive Dunn test statistic value), but this difference is not statistically significant (p-value 0,31 [31%]), so the two technologies are equivalent. This outcome can be summarized by 'BEV < PHEV = ICEV', if one accepts the slight notation abuse of '<' meaning (statistically) inferior to and '=' equivalent to.

The first country to be analyzed is Portugal, because the generated results can be directly compared to those obtained by Sousa et al. (2020) and at the same time give a perspective whether the general performance has improved or not. It must be remembered that Portugal offers a 3,000 EUR standard incentive for electric cars (as commented in section 3.2), and this value can play a role in the results. Looking in first place to the small segment (see Figure 6 below), for both driver profiles, the results show that ICEVs dominate the preference and BEVs are clearly less preferred. This first result is explained by the performance that combustion models have in the overall picture (with most models positioned in the higher classes for both driving profiles), and is strongly supported by the lower TCO these models have, due to the accessible purchase price (extremely high for electrics), which is an important factor in this vehicle size, as well as the freedom of use restrictions, while electric cars have limited range, charging availability and capacity, criteria that penalize them in most situations.

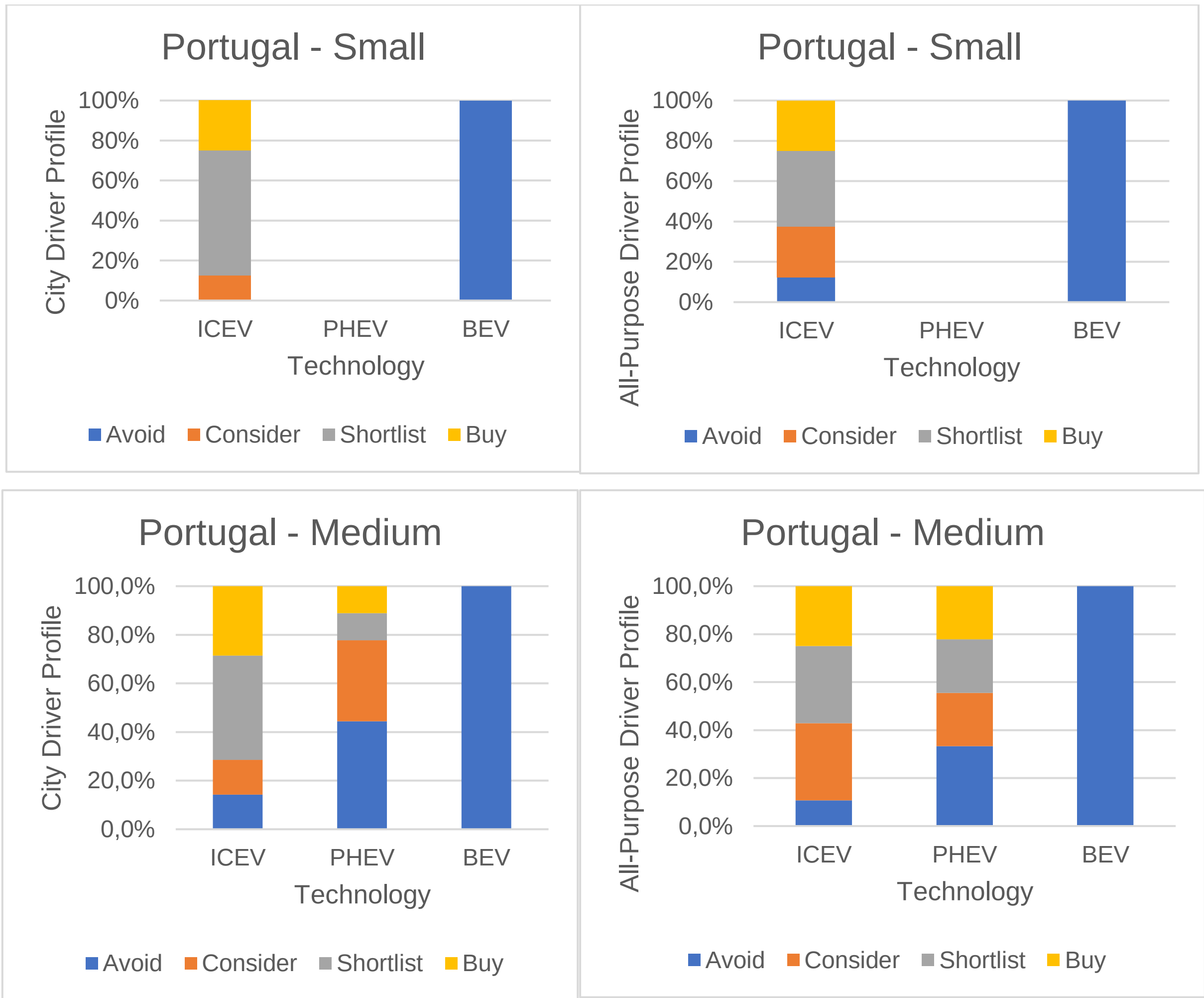

Figure 6 – ELECTRE TRI Baseline results for Portugal: Small and Medium segments.

Table 8 – Statistical significance (p-value) for Portugal: Small and Medium segments.

Size	Driver Profile	Tech	ICEV	PHEV	BEV	Conclusion
Small	City	ICEV	-	-	0.0000	BEV < ICEV
		BEV	0.0000	-	-	
	All-Purpose	ICEV	-	-	0.0000	
		BEV	0.0000	-	-	
Medium	City	ICEV	-	0.0237*	0.0002*	BEV = PHEV < ICEV
		PHEV	0.0237*	-	0.0622	
		BEV	0.0002*	0.0622	-	
	All-Purpose	ICEV	-	0.1782	0.0003*	BEV < PHEV = ICEV
		PHEV	0.1782	-	0.0118*	
		BEV	0.0003*	0.0118*	-	

In the medium segment (see Figure 6 above), outcomes start to get interesting because for city driver profile, both BEVs and PHEVs start to gain some notice, even acquiring a same appeal between each other as appointed in the statistical results, but still are not desirable enough as ICEVs for this situation. At the all-purpose driver profile, however, electric models stay behind in desirability, while the combustion and plug-in hybrid cars are equally preferred. The results for this segment can be explained in two ways. The first, technical view, shows that the higher desirability for ICEVs in city driver profile is a result of better range and TCO these cars have against PHEVs, and against BEVs, use restrictions are decisive as seen before. The second perspective (analytical vision) presents a change of classes of some cars. Looking closely at Figure 6, is possible to see that some PHEVs are "promoted" towards upper classes, while some ICEVs are downgraded, and this change in ranks can influence the statistical results, as is the case here. Together with this observation, the number of representatives from each technology for a specific class makes a difference as well, and for city driver profile, the number of representatives for electrics and plug-in hybrids in class 1 "avoid" is nearly the same, explaining the statistical conclusion between these two powertrains, and the increased presence of the latter against combustion samples in classes 3 "shortlist" and 4 "buy" explains the same preference for both technologies in all-purpose profile. Also, it is important to have in mind that, in case of users travelling a lower annual distance, a BEV can be an option in this segment (Hackbarth & Madlener, 2013; Hoen & Koetse, 2014).

For the Medium SUV segment, Figure 7 below reveals interesting findings because PHEVs are equally desirable as ICEVs in both driver profiles in the statistical perspective, even with plug-in hybrids being minority in class 3 "shortlist" in both cases mentioned previously. For BEVs, use restrictions are the main factor that keep them in the worst class. Just as seen in the previous segment, some class changes happen here, as well as changes in the number of representatives from the technologies for each class in both driving profiles. The statistical same appeal between ICEVs and PHEVs is explained by the similar number of samples for these two powertrains in class 2 "consider", regardless of the driving profile, with the decreased number of combustion models in class 4 "buy" for all-purpose driving profile, reinforcing the results.

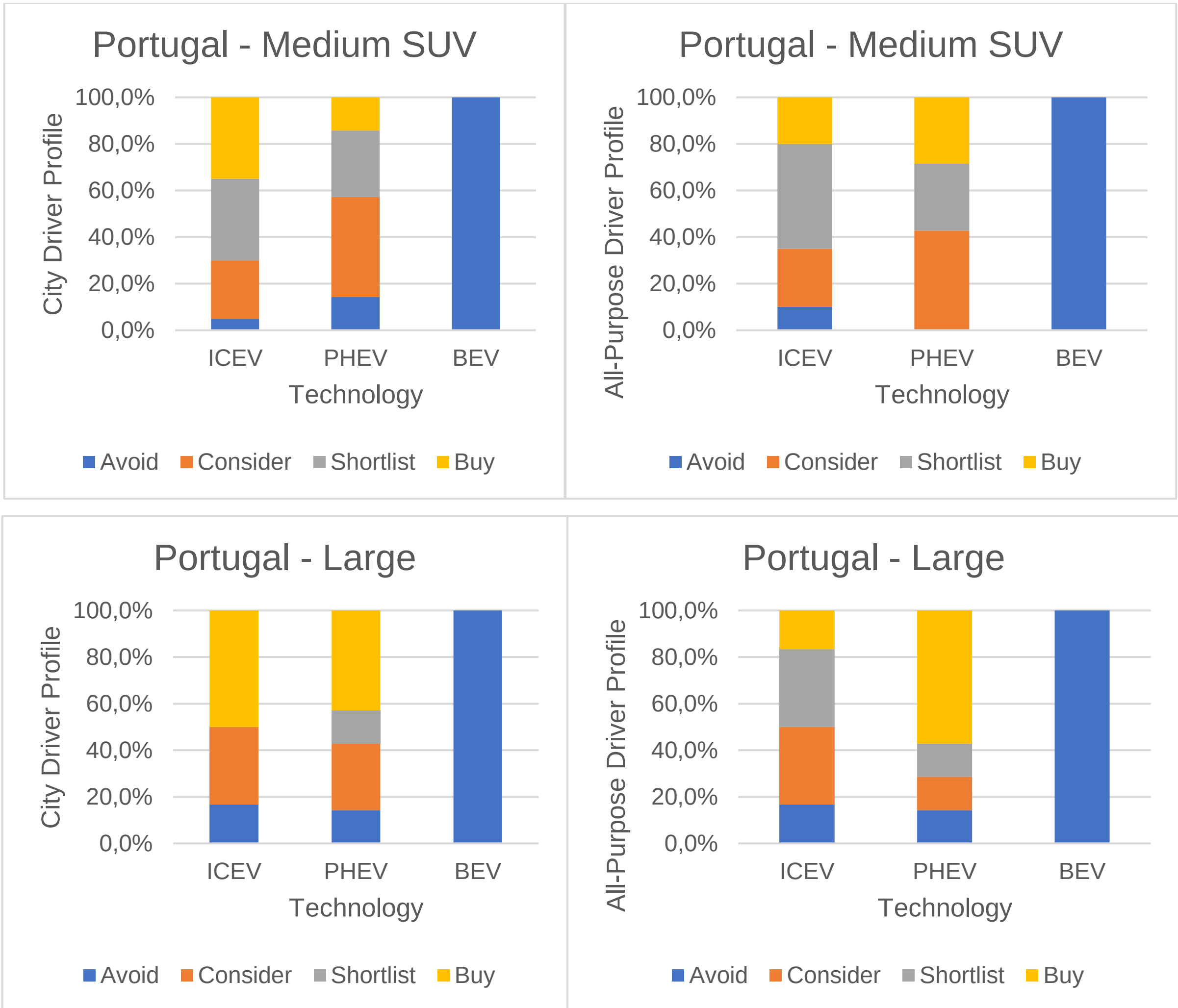

Figure 7 – ELECTRE TRI Baseline results for Portugal: Medium SUV and Large segments.

Table 9 – Statistical significance for Portugal: Medium SUV and Large segments.

Size	Driver Profile	Tech	ICEV	PHEV	BEV	Conclusion
Medium SUV	City	ICEV	-	0.1342	0.0000*	BEV < PHEV = ICEV
		PHEV	0.1342	-	0.0085*	
		BEV	0.0000*	0.0085*	-	
	All-Purpose	ICEV	-	0.4172	0.0001*	
		PHEV	0.4172	-	0.0005*	
		BEV	0.0001*	0.0005*	-	
Large	City	ICEV	-	0.4951	0.0293*	BEV < PHEV = ICEV
		PHEV	0.4951	-	0.0212*	
		BEV	0.0293*	0.0212*	-	
	All-Purpose	ICEV	-	0.1258	0.0366*	
		PHEV	0.1258	-	0.0127*	
		BEV	0.0366*	0.0127*	-	

Finally, the large segment (see Figure 7 above) brings a very similar situation of what is seen with Medium SUVs: PHEVs and ICEVs compete equally in both driving profiles (confirmed in the statistical results), with plug-in hybrids having a better representation in the all-purpose profile, while BEVs "are stuck" as less desirable, due to use restrictions, as usual. The reason for identical conclusions is the change of rankings of some vehicles from one profile to the other, and so, the final results are the same. As a final view, combustion models lose space for plug-in hybrids as the size of the vehicle grows, and differently from the original study where electric cars have some competitive capability, here they can't compete at all. Now, the reality can be completely different from Europe, because the next country is Brazil, the most unfavorable of the four countries for alternative powered vehicles. The largest contributors for this trait are the extremely high prices and taxes that are levied on imported cars (independent of powertrain technology), and the lack of infrastructure for BEVS and PHEVs, causing an alternative powertrain model to be very rare in this market. In the small segment (see Figure 8 below), Portugal results are the same, with ICEVs dominating the preference and BEVs with no chance of improving their performance, regardless of the driving profile, for the same reasons appointed before. For the medium segment (see Figure 8 below), a remarkably interesting surprise shows up: all technologies are statistically similar in appeal, in both driving profiles.

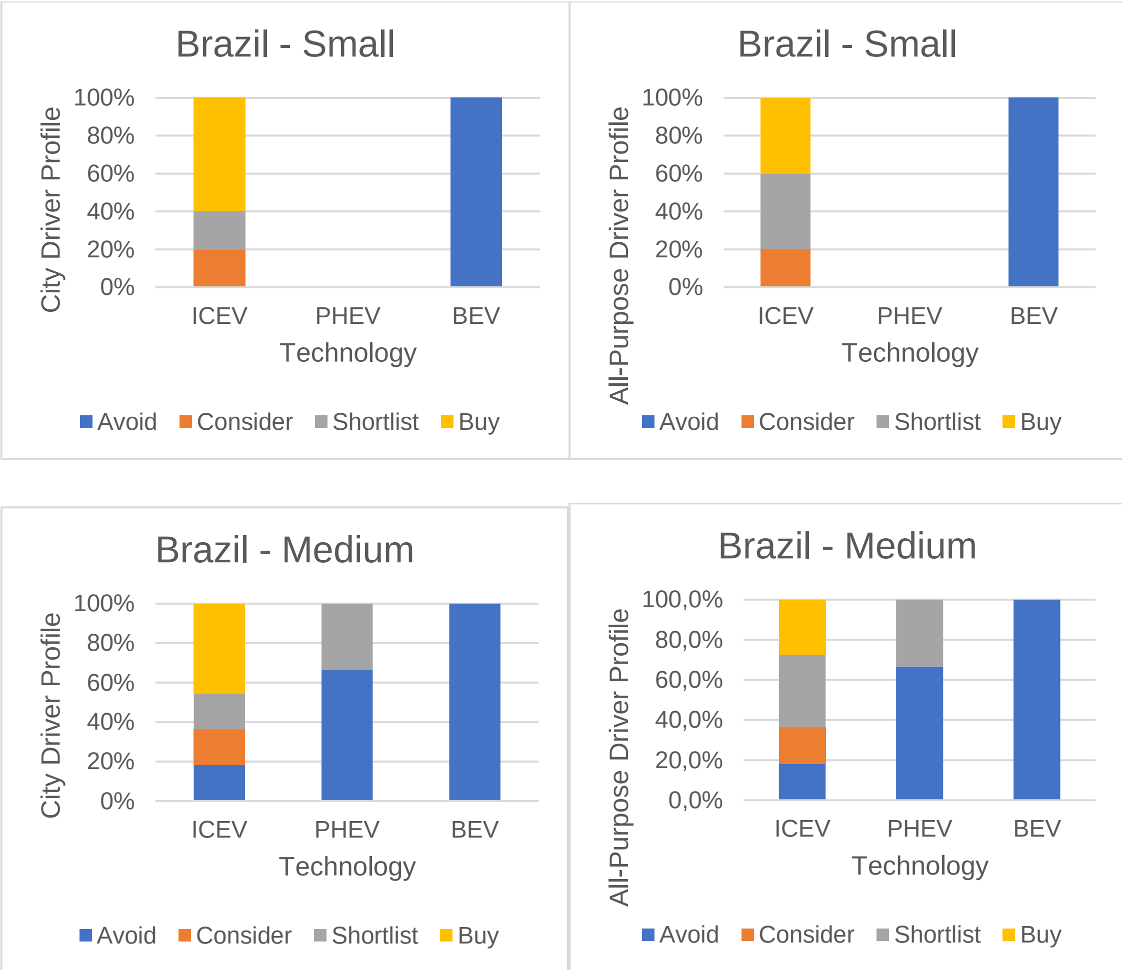

Figure 8 – ELECTRE TRI Baseline results for Brazil: Small and Medium segments.

Table 10 – Statistical significance (p-value) for Brazil: Small and Medium segments.

Size	Driver Profile	Tech	ICEV	PHEV	BEV	Conclusion
Small	City	ICEV	-	-	0.0100	BEV < ICEV
		BEV	0.0100	-	-	
	All-Purpose	ICEV	-	-	0.0100	
		BEV	0.0100	-	-	
Medium	City	ICEV	-	0.1892	0.1211	BEV = PHEV = ICEV
		PHEV	0.1892	-	0.3432	
		BEV	0.1211	0.3432	-	
	All-Purpose	ICEV	-	0.1262	0.2514	
		PHEV	0.1262	-	0.3188	
		BEV	0.2514	0.3188	-	

The explanation is the limited cluster of models in offer, more specifically the number of representatives of each powertrain, where only three cars have BEV or PHEV technology, and the others are ICEVs, and in situations like this, the statistical analysis points that there is a lack of data, becoming difficult to access a difference between classes, resulting in equal desirability by all powertrains. This observation can also be done for the medium SUVs and large models (Figure 9 below) in both driver profiles as well. The only differences are: there are no BEVs in these segments and the model list for medium SUVs is smaller than the medium lineup, with only one representative for PHEV, and as happened above, all classes are equally good for both sizes.

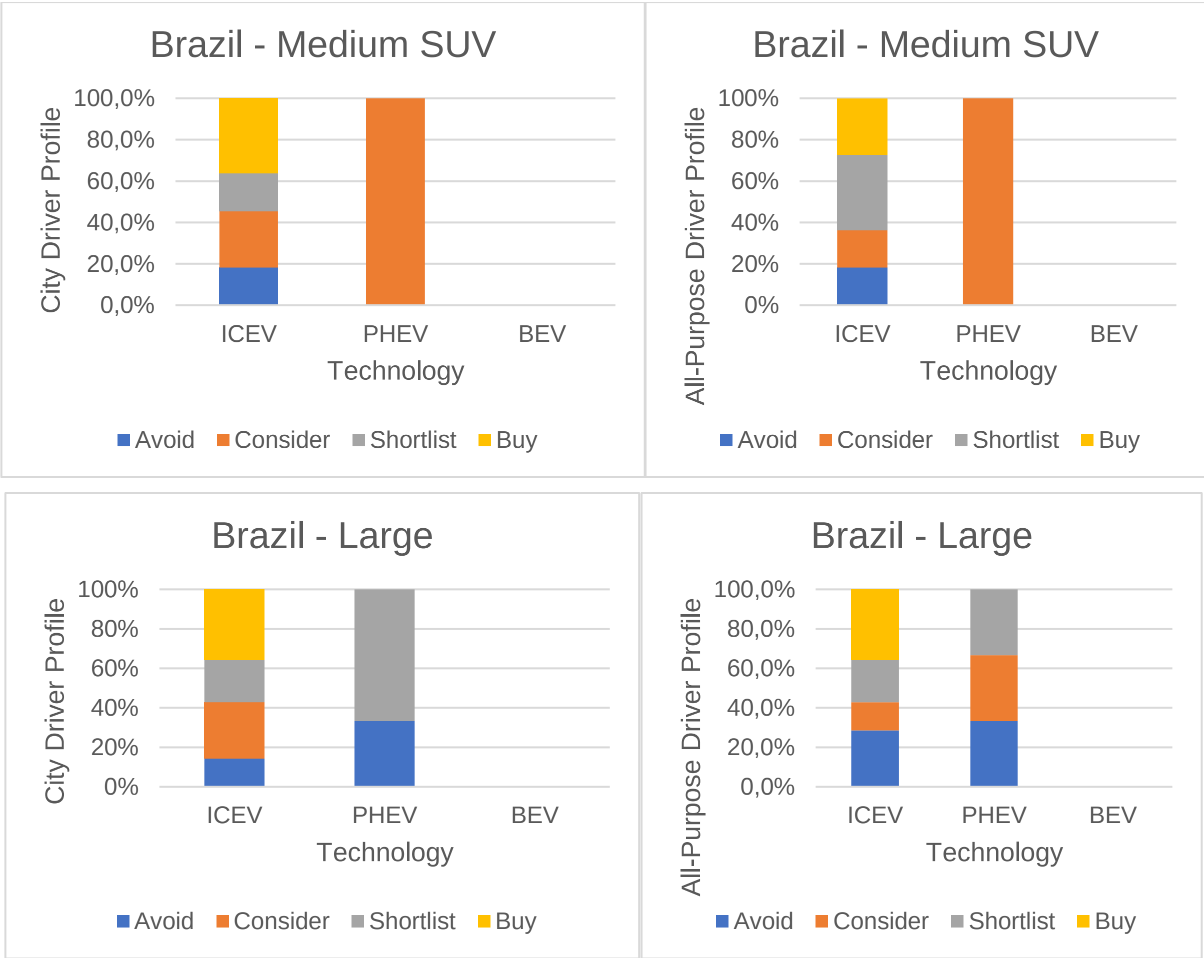

Figure 9 – ELECTRE TRI Baseline results for Brazil: Medium SUV and Large segments.

Table 11 – Statistical significance (p-value) for Brazil: Medium SUV and Large segments.

Size	Driver Profile	Tech	ICEV	PHEV	Conclusion
Medium SUV	City	ICEV	-	0.5500	PHEV = ICEV
		PHEV	0.5500	-	
	All-Purpose	ICEV	-	0.4500	
		PHEV	0.4500	-	
Large	City	ICEV	-	0.5100	PHEV = ICEV
		PHEV	0.5100	-	
	All-Purpose	ICEV	-	0.4000	
		PHEV	0.4000	-	

This time, the upper portion of the Americas will be explored, analyzing the USA automotive market, that presents a smaller general lineup of vehicles as Brazil, but this country has more plug-in hybrid and electric options in all segments except for small cars, and in consequence, interesting results can appear. The small vehicle size (Figure 10 below) “shares” the results of Brazil and Portugal: clear preference of ICEVs over BEVs in both driving profiles, by the same reasons pointed before: high TCO, use restrictions, and high production costs. For the medium cars (Figure 10 below), BEVs are less desired in both driving profiles. The statistical analysis becomes partially inconclusive for the city driver profile, as it can only be clearly ascertained that BEV are inferior to ICEV (as shown in Table 12 below). The reduced total number of models available (comparing USA to Portugal and Germany) makes it difficult for the statistical methods to reach clear conclusions, and this, combined with close class scores, is the reason why are partially inconclusive, not only in this scenario, but for other scenarios as well.

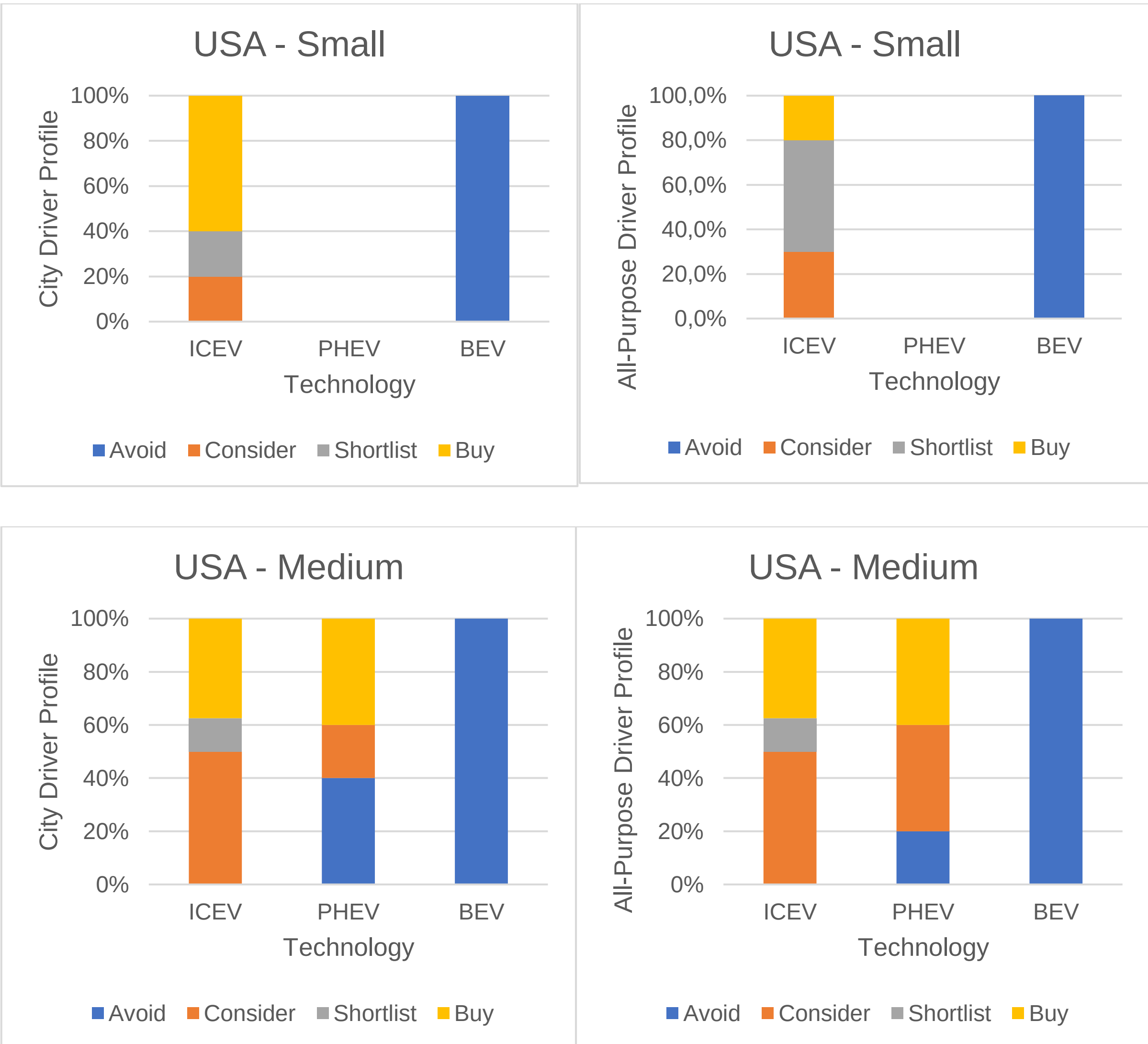

Figure 10 – ELECTRE TRI Baseline results for USA: Small and Medium segments.

Table 12 – Statistical significance (p-value) for USA: Small and Medium segments.

Size	Driver Profile	Tech	ICEV	PHEV	BEV	Conclusion
Small	City	ICEV	-	-	0.0000	BEV < ICEV
		BEV	0.0000	-	-	
	All-Purpose	ICEV	-	-	0.0000	
		BEV	0.0000	-	-	
Medium	City	ICEV	-	0.1953	0.0198*	BEV < PHEV = ICEV
		PHEV	0.1953	-	0.0779	
		BEV	0.0198*	0.0779	-	
	All-Purpose	ICEV	-	0.3107	0.0153*	
		PHEV	0.3107	-	0.0344*	
		BEV	0.0153*	0.0344*	-	

Just as seen in Portugal, PHEVs have the same desirability against ICEVS for Medium SUVs (Figure 11 below), because of their similar TCO, and the ranks of all vehicles that, with exception of one ICEV that changes ranks, keeps the same regardless of the driver profile, with unchanged results, and again, BEVs are penalized by use restrictions. Finally, large cars (Figure 11 below) present the same results of the medium segment, even with the statistical result partially inconclusive. In the end, PHEVs and ICEVs equally match the consumer's preference, and BEVs maintain the usual inferior results for the same reasons seen before. The rank downgrade for three vehicles from city to all-purpose driver profile (two combustion cars and one plug-in hybrid) is the cause of such conclusions, resulting in similar preference in classes 2 "consider" and 3 "shortlist" between ICEVs and PHEVs independently of the driver profile. with a regular advantage in class 4 "buy" of the city driver profile, but smaller for the same class in all-purpose profile, and so, achieving a complete statistical conclusion is not possible for this last case.

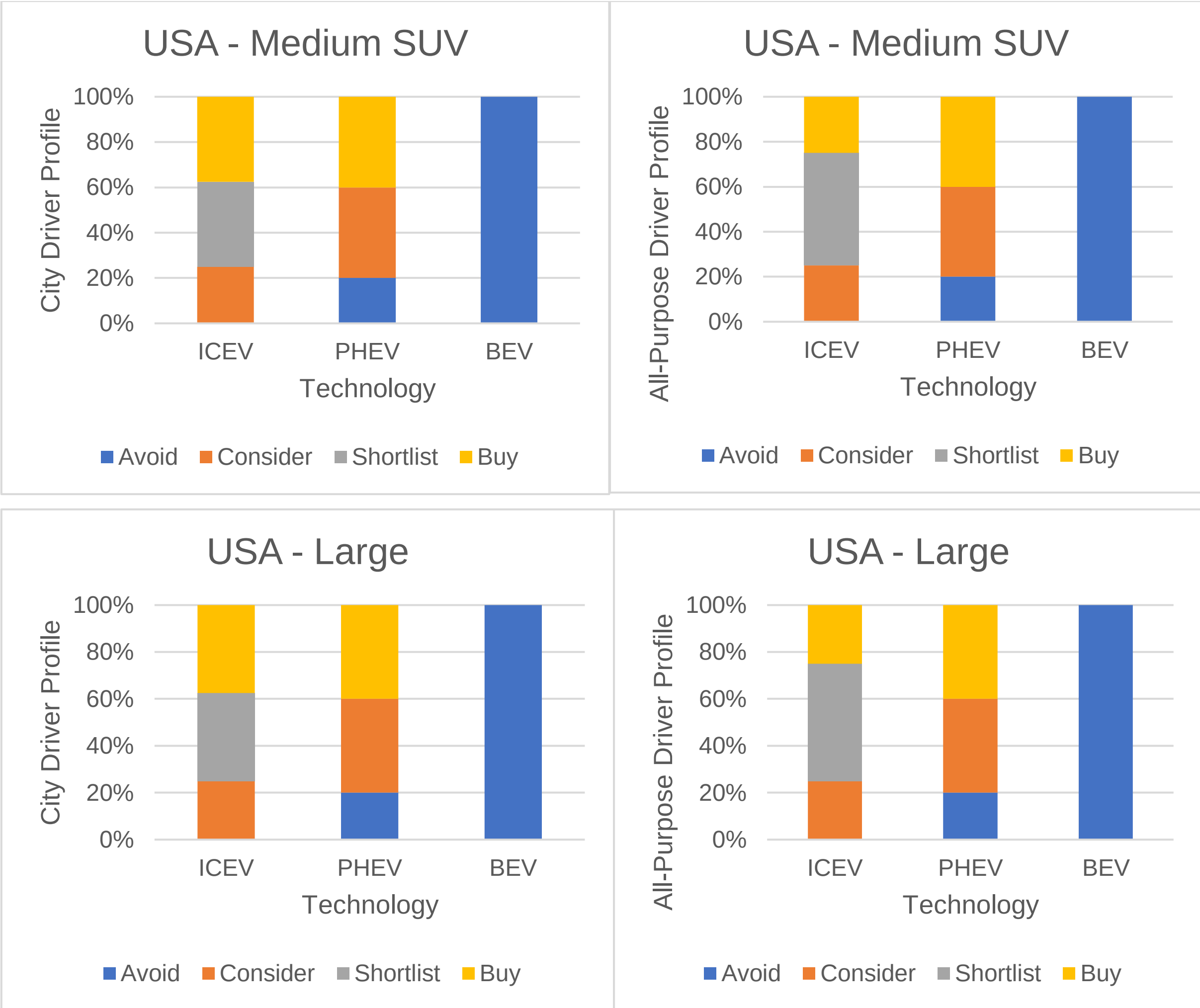

Figure 11 – ELECTRE TRI Baseline results for USA: Medium SUV and Large segments.

Table 13 – Statistical significance (p-value) for USA: Medium SUV and Large segments.

Size	Driver Profile	Tech	ICEV	PHEV	BEV	Conclusion
Medium SUV	City	ICEV	-	0.1742	0.0010*	BEV < PHEV = ICEV
		PHEV	0.1742	-	0.0237*	
		BEV	0.0010*	0.0237*	-	
	All-Purpose	ICEV	-	0.1462	0.0008*	
		PHEV	0.1462	-	0.0264*	
		BEV	0.0008*	0.0264*	-	
Large	City	ICEV	-	0.2515	0.0227*	BEV < PHEV = ICEV
		PHEV	0.2515	-	0.0494*	
		BEV	0.0227*	0.0494*	-	
	All-Purpose	ICEV	-	0.2147	0.0222*	
		PHEV	0.2147	-	0.0587*	
		BEV	0.0222*	0.0587*	-	

Crossing the Atlantic back to the old continent, the last analyzed country for the baseline scenario is Germany, that calls the attention for the large variety of models available (depending on the segment), even some cars that are not available in Portugal, and especially the attractive number of incentives offered for plug-in hybrids and electrics (ACEA, 2020c), which can open a path for interesting tendencies, depending on the segment. The small car segment (Figure 12 below) presents a distribution with most ICEVs assigned for classes 2 "consider" and 3 "shortlist" in the city driver profile, but in the all-purpose driver style, almost all of them become "shortlist" options, while for BEVs, only 1 model pulls up to "consider" rank and the rest maintains unchanged. As mentioned in the beginning of this chapter, the statistical analysis cannot express the differences between classes due to lack of dimensions, and as already known, ICEVs outrun BEVs for the same reasons, in both driving profiles. The medium cars (Figure 12 below) have an interesting tendency found, with PHEVs being equally preferred as ICEVs for the city driver profile, and in the all-purpose driver profile, plug-in hybrid cars gain total preference and surpass the combustion models, as shown in the statistical analysis. The largest evidence that support this result is a change of classes in both technologies seen more closely in Figure 12 below. Notice that almost half of the PHEVs rank up from class 1 "avoid" towards classes 2 and 3 "consider" and "shortlist" (respectively), while ICEVs take the opposite direction, even with their dominance in class 3 "shortlist" for both driving profiles.

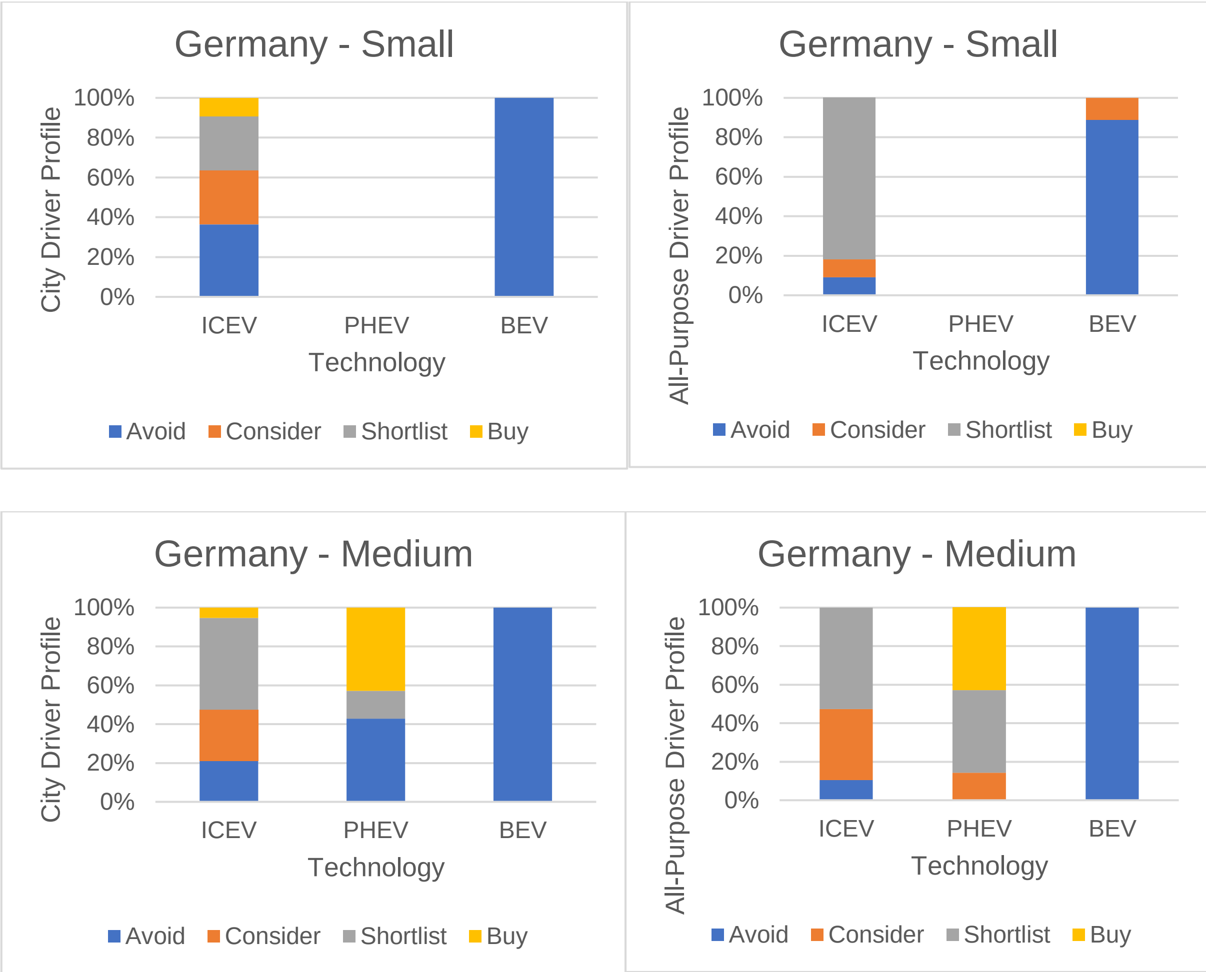

Figure 12 – ELECTRE TRI Baseline results for Germany: Small and Medium segments.

Table 14 – Statistical significance (p-value) for Germany: Small and Medium segments.

Size	Driver Profile	Tech	ICEV	PHEV	BEV	Conclusion
Small	City	ICEV	-	-	0.0000	BEV < ICEV
		BEV	0.0000	-	-	
	All-Purpose	ICEV	-	-	0.0000	
		BEV	0.0000	-	-	
Medium	City	ICEV	-	0.4119	0.0051*	BEV < PHEV = ICEV
		PHEV	0.4119	-	0.0069*	
		BEV	0.0051*	0.0069*	-	
	All-Purpose	ICEV	-	0.0276*	0.0009*	BEV < ICEV < PHEV
		PHEV	0.0276*	-	0.0000*	
		BEV	0.0009*	0.0000*	-	

In the Medium SUV segment (Figure 13 below), PHEVs and ICEVs present a slightly balanced match for city driver profile, but the same cannot be concluded for the all-purpose driver profile. A change of classes occurs in both powertrains, with almost half of PHEVs ranking up for the best classes, while some ICEVs fall from "shortlist" to "consider". At first, the impression is the preference for plug-in hybrids over combustion vehicles in this driving profile, but looking the classifications of each vehicle with attention, the tendency is inverted, due to the advantage that ICEVs have over PHEVs in most classes, especially class 3 "shortlist", in which they are clearly preferred in any driving profile. However, the statistical analysis shows both powertrains equally satisfactory, and so, this change of classes is not enough to cause significant tendencies. For BEVs, unfortunately, nothing changes so far, therefore, they cannot compete in the market as it is today. Ending this analysis, the large cars (Figure 13 below) in the German market make the scene, and at a first impression, PHEVs are more desired than ICEVs for both city and all-purpose driver profiles, confirmed by the statistical analysis, and supported by the change of classes that Figure 13 shows. Looking with more attention, is possible to notice that for class 3 "shortlist", a balance can be found in the city driver profile, while the all-purpose driver profile presents ICEVs considerably ahead of PHEVs, and for class 4 "buy", plug-in hybrids are much more attractive no mattering the driving circumstances, and so, this is the final result.

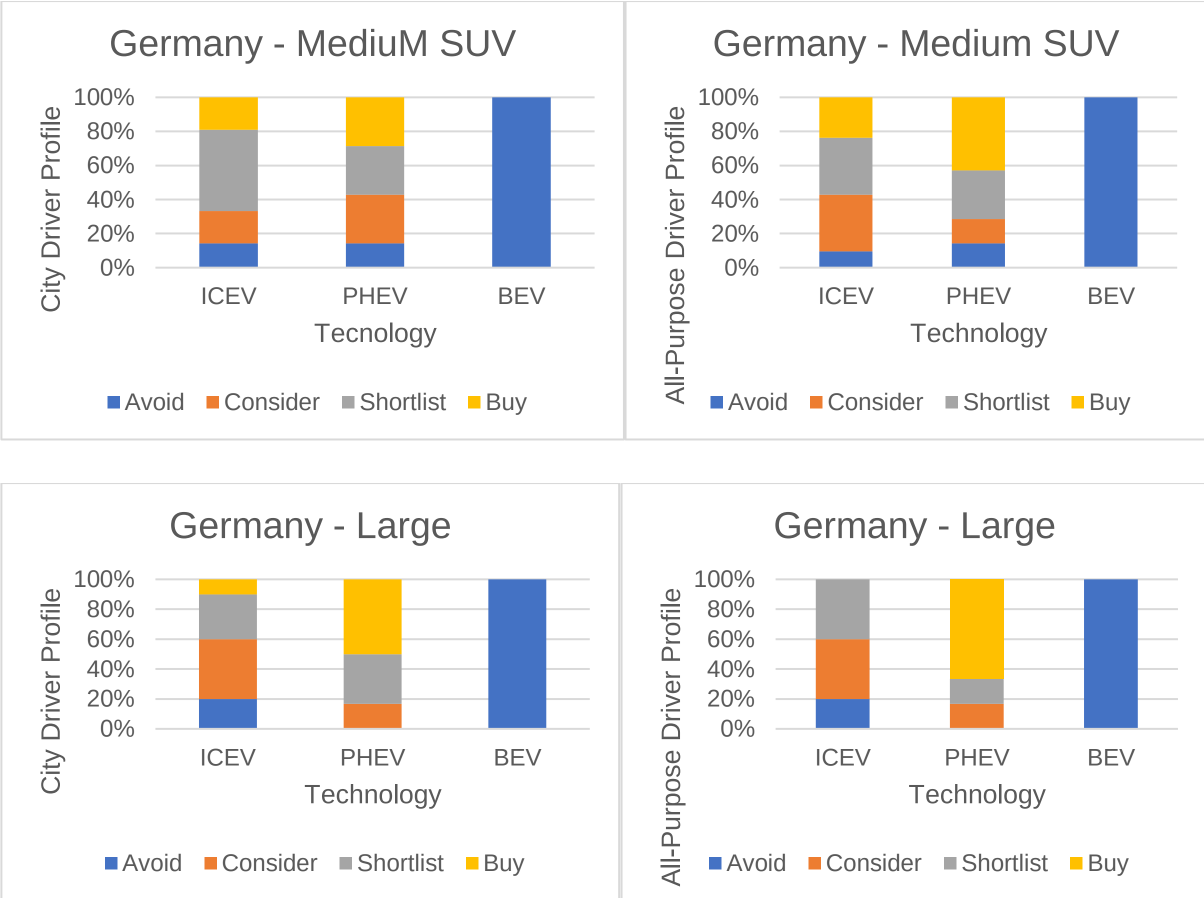

Figure 13 – ELECTRE TRI Baseline results for Germany: Medium SUV and Large segments.

Table 15 – Statistical significance (p-value) for Germany: Medium SUV and Large segments.

Size	Driver Profile	Tech	ICEV	PHEV	BEV	Conclusion
Medium SUV	City	ICEV	-	0.5000	0.0002*	BEV < PHEV = ICEV
		PHEV	0.5000	-	0.0018*	
		BEV	0.0002*	0.0018*	-	
	All-Purpose	ICEV	-	0.3026	0.0002*	
		PHEV	0.3026	-	0.0004*	
		BEV	0.0002*	0.0004*	-	
Large	City	ICEV	-	0.0389*	0.0542*	BEV < PHEV = ICEV
		PHEV	0.0389*	-	0.0046*	
		BEV	0.0542*	0.0046*	-	
	All-Purpose	ICEV	-	0.0214*	0.0473*	BEV < ICEV < PHEV
		PHEV	0.0214*	-	0.0024*	
		BEV	0.0473*	0.0024*	-	

4.2 SENSITIVE ANALYSIS

What if some or all the use restrictions were lifted in the future? What if the fuel prices were to take off? Could BEV and PHEV be more competitive against ICEVs? These are some of the questions that the sensitive analysis is able to answer. The main concept is to predict consumer behavior changes (in this case, acceptance) for multiple scenarios at once, as technology and reality evolve together in the car industry. Other changes like fiscal policies (incentives) and holding period (combined with the ones mentioned above) could turn BEV and PHEV more favorable thanks to a lower TCO. Table 16 below presents the original scenarios used.

Table 16 – Original sensitivity analysis Scenarios. Source: Sousa et al. (2020).

Scenario – S0	Baseline
Scenario – S1	Abundance of EV fast-charging points – all powertrains have max charging/fueling points.
Scenario – S2	Reduced EV charging time – all powertrain have the same charging/fueling time.
Scenario – S3	Higher battery capacity – all BEV range increased to 700 km.
Scenario – S4	No use restrictions to BEV – S1, S2 and S3 combined.
Scenario – S5	Higher fuel prices – double the baseline values for diesel and petrol fuel.
Scenario – S6	Higher holding period – considering a 10 years-holding period.
Scenario – S7	Minor purchase incentive – incentives of 5,000 EUR for BEV and 2,500 for PHEV.
Scenario – S8	Major purchase incentive – incentives of 10,000 EUR for BEV and 5,000 for PHEV.
Scenario – S9	Discount rate of 4% – on all financials except purchase price.
Scenario – S10	Half annual travelled distances – 7,500 km city, 15,000 km all-purpose.
Scenario – S11	Environmental awareness – addition of a CO2 emissions criterion with a 33% weight.
Scenario – S12	ELECTRE TRI parameter sensitivity – weights, class breaks, thresholds.

Due to a large data amount to be processed and the time that would take to do this, it was more reasonable to restrict the number of alternative scenarios to 4 (including the baseline scenario), which are presented on Table 17 below. For scenario S1, it must be noticed the possibility of BEVs becoming very attractive options in this context, as there are no other criteria beyond TCO, and consequently, the use restrictions for this powertrain literally disappear, allowing it to get significative attractiveness against the other technologies.

Table 17 – Final scenarios.

Scenario	Description
S0	Baseline
S1	TCO-only – TCO with weight of 100% and remaining criteria with weight of 0%
S2	Emissions – CO_2 with a **final** weight of 33%
S3	Economic – Holding Period of 10 years, petrol and diesel prices increased in 50% and use of minor incentives (5,000 € for BEVs and 2,500 € for PHEVs)

In Scenario S2, CO_2 emissions join the other criteria in the calculations, as it was done in the original study. Regarding to the values, the original ones were taken from the manufacturer's website or by conversion (explained earlier in item 3.3) were used for the ICEVs, HEVs and PHEVs, while for the BEVs, the end-user values were applied. To reach the final described weight, it was necessary to use a 50% initial weight for CO_2 emissions, while the other initial values are the same from the baseline scenario (as seen in subsection 3.4.1, Table 6), and as a result in this case, the final weights provided by MATRIX were changed, and are shown by Table 18 below.

Table 18 – CO_2 scenario final criteria weights.

Weights	TCO	Range	Charging Points	Charging Time	CO_2 emissions
Final – City Driver Profile	45,40%	8,20%	5,60%	7,47%	33,33%
Final - All-Purpose Driver Profile	34,96%	14,08%	8,81%	8,81%	33,36%

For scenario S3, along with shown changes, the depreciation rate also was modified, and for the 10-year holding period, it was increased from 42% to 90%. Also, and most important of all, the incentives mentioned in Table 9 for this context can play an important role in the final results, as its amount is considerable, especially if added to the "standard" subsidies found in the Portuguese American and German markets. For a better visualization and comprehension of the alternative scenarios, these are organized in the country/segment/scenario format, with Figures 14 to 17 presenting a panoramic perspective of the statistical results for each scenario and segment, and the final classification of each vehicle shown in Appendix C, represented by Tables C.1 to C.16. Referring to the previous figures, some observations must be noticed before proceeding:

- Green color: powertrain in row is preferred to powertrain in column;
- Red color: technology in row not preferred to powertrain in column;
- Yellow color: no significant differences;
- The number inside each box is the p-value for the Dunn/BH post-hoc comparison.

Portugal

The first country to be analyzed is Portugal, following the order established for the baseline context (see Figure 14 below), and the first segment is the small size, following the usual order taken for the baseline scenario. Starting with the TCO-only scenario (remembering that electric cars can become favorites for this context due to the lifting of use restrictions), a major difference is shown if compared to the baseline scenario: BEVs are equally desirable as ICEVs in both driving profiles, and in both analysis (ELECTRE-TRI and statistical), and the explanation is the lower TCO that most electric models have, influenced by existing incentives and low cost of electricity, and as mentioned before, the lift of use restrictions. Thus, both powertrains are competitive. However, for the next two scenarios (CO_2 emissions and economic), the general results point to a preference for combustion models over electrics due to their better ranks and the use restrictions that turn to penalize BEVs. A curious fact is that in the economic scenario, most ICEVs are ranked as class 1 "avoid", along with the electric cars, but although it happened, this fluctuation is not enough to change the statistical results.

Driver profile	Vehicle size	Tech	Scenarios - Portugal											
			ICEV + HEV				PHEV				BEV			
			Baseline	TCO-only	CO2 emissions	Economic	Baseline	TCO-only	CO2 emissions	Economic	Baseline	TCO-only	CO2 emissions	Economic
City	Small	ICEV + HEV									0%	30%	0%	0%
		BEV	0%	30%	0%	0%								
	Medium	ICEV + HEV					2,37%	2,25%	4,28%	35,43%	0,02%	4,75%	0,02%	0,23%
		PHEV	2,37%	2,25%	4,28%	35,43%					6,22%	0,34%	3,79%	1,31%
		BEV	0,02%	4,75%	0,02%	0,23%	6,22%	0,34%	3,79%	1,31%				
	Med. SUV	ICEV + HEV					13,42%	24,18%	49,71%	45,40%	0%	23,26%	0%	0,03%
		PHEV	13,42%	24,18%	49,71%	45,40%					0,85%	34%	0,07%	0,16%
		BEV	0%	23,26%	0%	0,03%	0,85%	34%	0,07%	0,16%				
	Large	ICEV + HEV					49,51%	39,74%	25,21%	24,30%	2,93%	41,40%	2,39%	2,64%
		PHEV	49,51%	39,74%	25,21%	24,30%					2,12%	30,07%	2,04%	2,14%
		BEV	2,93%	41,40%	2,39%	2,64%	2,12%	30,07%	2,04%	2,14%				
All-Purpose	Small	ICEV + HEV									0%	41%	0%	1%
		BEV	0%	41%	0%	1%								
	Medium	ICEV + HEV					17,82%	19,74%	45,71%	2,12%	0,03%	0,54%	0,04%	0,04%
		PHEV	17,82%	19,74%	45,71%	2,12%					1,18%	0,56%	0,22%	0%
		BEV	0,03%	0,54%	0,04%	0,04%	1,18%	0,56%	0,22%	0%				
	Med. SUV	ICEV + HEV					41,72%	42,32%	13,33%	4,27%	0,01%	45,86%	0,01%	0,08%
		PHEV	41,72%	42,32%	13,33%	4,27%					0,05%	84,96%	0,01%	0,01%
		BEV	0,01%	45,86%	0,01%	0,08%	0,05%	84,96%	0,01%	0,01%				
	Large	ICEV + HEV					12,58%	16,91%	10,77%	3,99%	3,66%	28,24%	3,60%	5,31%
		PHEV	12,58%	16,91%	10,77%	3,99%					1,27%	25,41%	1,03%	0,57%
		BEV	3,66%	28,24%	3,60%	5,31%	1,27%	25,41%	1,03%	0,57%				

Figure 14 – Powertrain comparison: Portugal.

For the next segment, the medium cars, and beginning with the TCO-only context, BEV surpass the other technologies on both driving profiles due to their lower overall costs and incentives considered, while PHEVs are affected by the higher TCO and are less desired in the city driving profile, but are so good as ICEVs on all-purpose driver profile, as proved by the statistical analysis. The main explanation for this behavior is the change of classes between combustion vehicles and plug-in hybrids from one profile to the other (see Appendix C, Table C.2) as well as the up-rank of almost all electric models to class 4 “buy” in both driving profiles, and thus, the final word is equivalency of attractivity for both powertrains. Looking now for the CO_2 emissions scenario, BEVs are the less desired technology in both driving profiles due to use restrictions, and ICEVs are preferrable over PHEVs for both analysis in the city driver profile, but for the all-purpose driver profile, these two last powertrains have the same appeal, even if the plug-in hybrids are less pollutant. Looking first to the classification results (see Appendix C, Table C.2) for city driver profile, there is a dominance of combustion models in the middle classes (respectively, classes 2 “consider” and 3 “shortlist”) and a poor general score of most plug-in hybrids, while for the all-purpose driver profile, the slightly improved ranking of a few PHEVs is enough to change the statistical results and make them competitive. From the statistical perspective, the observations for city driver profile are confirmed by the Dunn/BH test statistic, which reveals inferior scores for BEVs against all technologies and also of PHEVs against ICEVs, becoming statistically significant according to the p-value for these comparisons (p-value inferior to 0,05 [5%]). For the all-purpose driver profile, same overall results are found for BEVs, and between PHEVs and ICEVs, the Dunn/BH test statistic is very close to zero, indicating a similarity among these powertrains, and no statistical significance as pointed by the respective p-value. Heading for the last environment, the dynamic Economic scenario, electric cars have no improvements and stay behind the other technologies, but between combustion and plug-in hybrid cars, an interesting tendency can be noticed, where both powertrains are equally desirable in city driver profile, and the latter takes over the preference in all-purpose driver profile. Looking at city driver profile firstly, and the classification results (see Appendix C, Table C.4), ICEVs have advantage in both top classes (3 “shortlist” and 4 “buy”), but the small presence of PHEVs in these classes makes it difficult to assign a statistical significance (as pointed by the Dunn/BH test statistic and the p-value for this comparison), and so, both technologies are considered equally good. Now, taking the all-purpose profile, the downgrading ranks of some combustion vehicles have a considerable impact in the results, allowing that plug-in hybrids revert their disadvantage and become the preferred ones over all powertrains in both perspectives (ELECTRE TRI and statistic). Finally, the incentives mentioned before can be the largest contributors for these results.

The same picture cannot be seen for the Medium SUVs, where the statistical analysis shows a balance between all technologies in both profiles for most contexts. Starting with the TCO-only scenario, all powertrains are equally good among each other for both driver profiles. The main reason for this balance is the very small presence of PHEVs (causing lack of data in the statistical analysis, and consequently, preference similarity) in classes 3 and 4, and mostly BEVs in class 4 “buy” (despite the numerical advantage of ICEVs). Proceeding to the CO_2 emissions scenario, most vehicles keeps their baseline rankings, while a few of them have fluctuations in their positions, but in the end, the general statistical results are the same, with electrics ranking last in preference and plug-in hybrids considered equally good as combustion models in both driving profiles. Moving to the Economic scenario, medium size results for this same context, are similar, with electric cars ranking last in preference, and ICEVs and PHEVs sharing the same appeal due to the small presence of these two in the higher classes of the city driver profile, while for the all-purpose driving profile, plug-in hybrids are the best choice over all other powertrains because of their increased presence in class 3 “shortlist” and perfect balance against combustion cars in class 4 “buy”. The last segment for this market is the large size, and in advance, the same statistical results of the Medium SUVs can be found here, for the respective driving profiles and scenarios, although the lineup of vehicles is smaller than the last two segments. Looking for more details, the first analysis takes the TCO-only scenario, and as seen before, all powertrains have the same desirability for both driving profiles, although this looks strange because many BEVs in this segment have a higher TCO which are the less desired. The statistical result is supported by changes in ELECTRE-TRI classes (see Appendix C, Table C.4) where some PHEVs change classes positively and negatively, as well as ICEVs, and the less expensive BEV jumps from class 1 “avoid” to class 4 “buy” due to the low TCO. This way, the balance is explained. Moving to the CO_2 emissions scenario, the only statistical change is BEVs returning to class 1 “avoid”, while the rest keep the same in relation to the baseline context. Some rank changes occur (all of them negative), but these are not enough to cause any statistical changes. The last scenario for this country is the Economic scenario, where the changes described in Table 9 become effective. Worthnoting are the incentives, that can be decisive for the final results. For BEVs, nothing changes and they continue as “last case” options due to use restrictions, even with a bigger amount of incentives included in TCO, while ICEVs and PHEVS are tightly matched in class 4 “buy” in city driver profile, and for all-purpose driver profile, plug-in hybrids take the preference for the same class, and increase their presence in class 3 “shortlist”, supporting their preference over combustion models. In the end, both powertrains are equivalent for city driver profile, and PHEVs are favorites over all other technologies for all-purpose driver profile, as confirmed by the statistical results.

Brazil

Heading to the largest automotive market of South America, Brazil (see Figure 15 below), no difference is found when comparing alternative scenarios with the baseline, regardless of the segment. Starting with the small cars, BEVs are not competitive due to their use restrictions that are much more clear for this market (recalling that Brazil does not have any infrastructure for electric cars as described in section 4.1 for this country baseline scenario), and a higher TCO than ICEVs, due to the extremely expensive taxes applied for imported models, as is the case for BEVs (even with incentives applied in the economic scenario), keeping the general results unchanged, independently of the scenario. For the remaining sizes, the same conclusions are draw, as the number of representatives for PHEVs and BEVs does not pass three models at most for medium-sized cars and four plug-in hybrids for the last two segments (one for medium SUV and three for large cars). As explained in the baseline scenario, this small sample of alternative powertrain vehicles configures lack of data in the statistical analysis, making it difficult to find a significant difference, resulting that all powertrains are good for the TCO-only, CO_2 emissions and Economic scenarios.

Driver profile	Vehicle size	Tech	Scenarios - Brazil											
			Baseline	TCO-only	CO2 emissions	Economic	Baseline	TCO-only	CO2 emissions	Economic	Baseline	TCO-only	CO2 emissions	Economic
			ICEV + HEV				PHEV				BEV			
City	Small	ICEV + HEV									1%	1%	0%	1%
		BEV	1%	1%	0%	1%								
	Medium	ICEV + HEV					18,92%	17,38%	23,01%	18,92%	12,11%	46,38%	25,55%	12,11%
		PHEV	18,92%	17,38%	23,01%	18,92%					34,32%	31,58%	30,77%	34,32%
		BEV	12,11%	46,38%	25,55%	12,11%	34,32%	31,58%	30,77%	34,32%				
	Med. SUV	ICEV + HEV					55%	55%	100%	55%				
		PHEV	55%	55%	100%	55%								
		BEV												
	Large	ICEV + HEV					51%	43%	37%	27%				
		PHEV	51%	43%	37%	27%								
		BEV												
All-Purpose	Small	ICEV + HEV									1%	1%	0%	1%
		BEV	1%	1%	0%	1%								
	Medium	ICEV + HEV					12,62%	20,81%	23,01%	48,71%	25,14%	48,39%	25,55%	23,29%
		PHEV	12,62%	20,81%	23,01%	48,71%					31,88%	28,75%	30,77%	14,42%
		BEV	25,14%	48,39%	25,55%	23,29%	31,88%	28,75%	30,77%	14,42%				
	Med. SUV	ICEV + HEV					45%	45%	100%	88%				
		PHEV	45%	45%	100%	88%								
		BEV												
	Large	ICEV + HEV					40%	33%	78%	33%				
		PHEV	40%	33%	78%	33%								
		BEV												

Figure 15 – Powertrain comparison: Brazil.

USA

Continuing in the Americas, with the USA, all segments have a reduced lineup of vehicles (similar to the small and large segments in Portugal). Some surprising conclusions make the scene: There is a regularity in results as seen in the other markets so far, shown by Figure 16 below. Starting with small cars in the TCO-only scenario, combustion models are preferred for city driver profile; for all purpose profile however, both powertrains become statistically good; although this behavior does not seem to have a logic answer, there is: and the reason is that one of the three BEVs ranks up from city to all-purpose, and two ICEVs change ranks (one up and one down): this almost unnoticed event is enough to generate a statistical finding, explaining the same appeal for both technologies. The general results for CO_2 emissions and Economic scenarios are no different from the baseline context, for the same reasons pointed earlier, and so, combustion models are clearly the favorites for this segment.

Driver profile	Vehicle size	Tech	Scenarios - USA											
			ICEV + HEV				PHEV				BEV			
			Baseline	TCO-only	CO2 emissions	Economic	Baseline	TCO-only	CO2 emissions	Economic	Baseline	TCO-only	CO2 emissions	Economic
City	Small	ICEV + HEV									0%	1%	0%	0%
		BEV	0%	1%	0%	0%								
	Medium	ICEV + HEV					19,53%	68,87%	36,20%	43,97%	1,98%	43,48%	4,77%	9,11%
		PHEV	19,53%	68,87%	36,20%	43,97%					7,79%	34,90%	6,48%	7,89%
		BEV	1,98%	43,48%	4,77%	9,11%	7,79%	34,90%	6,48%	7,89%				
	Med. SUV	ICEV + HEV					17,42%	12,70%	36,50%	17,15%	1%	1,03%	0,46%	0,09%
		PHEV	17,42%	12,70%	36,50%	17,15%					2,37%	13,62%	1,54%	2,23%
		BEV	1%	1,03%	0,46%	0,09%	2,37%	13,62%	1,54%	2,23%				
	Large	ICEV + HEV					25,15%	24,50%	48,72%	25,15%	2,27%	5,21%	3,26%	2,27%
		PHEV	25,15%	24,50%	48,72%	25,15%					4,94%	9,61%	2,02%	4,94%
		BEV	2,27%	5,21%	3,26%	2,27%	4,94%	9,61%	2,02%	4,94%				
All-Purpose	Small	ICEV + HEV									0%	10%	0%	1%
		BEV	0%	10%	0%	1%								
	Medium	ICEV + HEV					31,07%	68,87%	44,12%	35,74%	1,53%	43,48%	4,18%	1,81%
		PHEV	31,07%	68,87%	44,12%	35,74%					3,44%	34,90%	2,34%	3,09%
		BEV	1,53%	43,48%	4,18%	1,81%	3,44%	34,90%	2,34%	3,09%				
	Med. SUV	ICEV + HEV					14,62%	15,13%	36,50%	20,24%	0,08%	1,39%	0,46%	0,12%
		PHEV	14,62%	15,13%	36,50%	20,24%					2,64%	13,15%	1,54%	2,01%
		BEV	0,08%	1,39%	0,46%	0,12%	2,64%	13,15%	1,54%	2,01%				
	Large	ICEV + HEV					21,47%	30,46%	21,47%	44,31%	2,22%	6,21%	2,22%	3,68%
		PHEV	21,47%	30,46%	21,47%	44,31%					5,87%	8,55%	5,87%	3,08%
		BEV	2,22%	6,21%	2,22%	3,68%	5,87%	8,55%	5,87%	3,08%				

Figure 16 – Powertrain comparison: USA.

For medium-sized vehicles and TCO-only scenario, the BEV and PHEV TCOs become more competitive than initially, in both driving profiles, and for this context, no ranking changes occurred in neither of the classes. However, in comparison to the baseline scenario, only the electrics had their positions improved, and PHEV degraded one class in all-purpose driver profile, and so, all technologies are equally preferable. Proceeding to CO_2 emissions scenario, there were 6 vehicles downgrading in rank (see Appendix C, Table C.10) in comparison to the baseline context; the statistical results are the same from the referred scenario, with BEVs being less preferred against ICEVs by the strong use restrictions, and the same appeal for combustion models and plug-in hybrids, just as seen in the baseline case. Looking at the economic scenario, discrete rank fluctuations occur in both driving profiles when comparing to the baseline environment, while most vehicles maintain their original positions, balancing classes 1 “avoid”, 2 “consider” and 4 “buy” for city driver profile; class 3 “shortlist” is composed by only two ICEVs, and for this case, all powertrains are statistically similar between each other. For the all-purpose driver profile, BEVs are less preferred due to the use restrictions and rank changes previously mentioned, while plug-in hybrids and combustion cars continue to keep the consumer undecided, as their desirability are the same as for city driver profile.

Now analyzing the medium SUVs for the TCO-only scenario, BEVs continue inferior to ICEVs in both driving profiles as most models have high TCOs (only two models made to the higher classes 3 “shortlist” and 4 “buy”), and when the electrics are compared to PHEVs, the results are statistically inconclusive for both cases. Although this happens, analyzing the Dunn BH test result (as exemplified in Table 7 of section 4.1) for these two situations, BEVs are inferior to plug-in hybrids in both driver profiles. When talking about combustion cars and plug-in hybrids, the statistical analysis also points inconclusion in both driving profiles, but the Dun BH test shows that these two technologies are identical in preference, for both driving profiles. Looking at once for the two final scenarios (CO_2 emissions and economic), their statistical results are the same from the baseline context, explained by some downgrades in the ranks for CO_2 emissions case (see Appendix C, Table C.11) and no change of positions between baseline and Economic scenarios, and so, the results are inferiority of BEVs against all powertrains, and equality between ICEVs and PHEVs, regardless of the driver profile.

Finally, the large cars are viewed, and the usual order will be followed. Starting by the TCO-only scenario, in relation to the baseline context, all powertrains statistically have the same desire for both driver profiles, even if it should not be like this. Taking the ELECTRE-TRI results, only one BEV climbs from class 1 “avoid” to class 2 “consider” in both driving profiles, while the remaining lineup keeps in the same positions of the baseline scenario. Also, there is a similarity in number of representatives between all technologies in classes 1 and 2, and looking separately for PHEVs, these last have at least one representative in each class, which configures “lack of data” for this technology, and so, it is treated as equally good against all powertrains, and hence, the statistical findings are explained. Advancing for the CO_2 emissions scenario, the results from the baseline are exactly the same, with electric cars behind all technologies for all driver profiles, even if the statistical results show inconclusion between them for the all-purpose context, but taking the Dun BH test results, the doubt is eliminated and the previously mentioned conclusion is noticed. Between ICEVs and PHEVs, the statistical results also show inconclusion, but analyzing the same variable described above (Dunn BH test), the final result is that both powertrains are similar in appeal, regardless of the driving profile. The last scenario for this segment is the Economic scenario, and contrary to what happened in the other contexts, the results are the same for both driving profiles, with BEVs as less preferred technology, and a similar appeal for PHEVs and ICEVs. Comparing the rankings with the baseline scenario, the only change is one plug-in hybrid going from class 2 “consider” to class 3 “shortlist”, keeping the relations between powertrains for each class nearly untouched, and consequently, identical conclusions for city driver profile, and eliminating the inconclusion seen for all-purpose profile in the baseline scenario.

Germany

Now going back to Germany (see Figure 17 below), some interesting things can be seen from the start. Taking first the small segment and TCO-only scenario, statistical analysis show that BEVs take the preference from ICEVs and become the favorites in the city driver profile, influenced by the "generous" amount of incentives already "standardized" by the government, and so, they become the best options. However, in the all-purpose driver profile, both powertrains are equally competitive, even with the financial advantages of BEVs taking place. The first conclusion is supported by an equal number of representatives in class 3 "shortlist" (two for each tech) and advantage of electrics over combustion cars in class 4 "buy", making clear that this last becomes inferior for city driver profile. However, for all-purpose driver profile, an increased number of ICEVs in class 3 and "solo" representation for this powertrain in class 2 "consider" transforms the advantage of electric vehicles into a similar preference, and so, the general results are very different from the baseline. Looking at CO_2 emissions and Economic scenarios at once, the final result for this size is the clear desirability for combustion models over electric, as the use restrictions of this last returns and penalizes its performance.

Driver profile	Vehicle size	Tech	Scenarios - Germany											
			ICEV + HEV				PHEV				BEV			
			Baseline	TCO-only	CO2 emissions	Economic	Baseline	TCO-only	CO2 emissions	Economic	Baseline	TCO-only	CO2 emissions	Economic
City	Small	ICEV + HEV									0%	7%	0%	0%
		BEV	0%	7%	0%	0%								
	Medium	ICEV + HEV					41,19%	23,43%	37,41%	23,04%	0,51%	0,05%	0,53%	0,09%
		PHEV	41,19%	23,43%	37,41%	23,04%					0,69%	1,32%	0,56%	0,15%
		BEV	0,51%	0,05%	0,53%	0,09%	0,69%	1,32%	0,56%	0,15%				
	Med. SUV	ICEV + HEV					50,00%	58,67%	30,43%	50,00%	0,02%	98,40%	0,03%	0,02%
		PHEV	50,00%	58,67%	30,43%	50,00%					0,18%	45,51%	0,05%	0,19%
		BEV	0,02%	98,40%	0,03%	0,02%	0,18%	45,51%	0,05%	0,19%				
	Large	ICEV + HEV					3,89%	10,79%	2,35%	3,81%	5,42%	36,21%	4,52%	4,08%
		PHEV	3,89%	10,79%	2,35%	3,81%					0,46%	7,53%	0,25%	0,35%
		BEV	5,42%	36,21%	4,52%	4,08%	0,46%	7,53%	0,25%	0,35%				
All-Purpose	Small	ICEV + HEV									0%	13%	0%	0%
		BEV	0%	13%	0%	0%								
	Medium	ICEV + HEV					2,76%	10,50%	2,76%	2,43%	0,09%	0,01%	0,09%	0,30%
		PHEV	2,76%	10,50%	2,76%	2,43%					0%	11,20%	0%	0,01%
		BEV	0,09%	0,01%	0,09%	0,30%	0%	11,20%	0%	0,01%				
	Med. SUV	ICEV + HEV					30,26%	38,01%	13,22%	9,70%	0,02%	45,29%	0,02%	0,04%
		PHEV	30,26%	38,01%	13,22%	9,70%					0,04%	75,59%	0,01%	0,02%
		BEV	0,02%	45,29%	0,02%	0,04%	0,04%	75,59%	0,01%	0,02%				
	Large	ICEV + HEV					2,14%	3,45%	2,35%	0,62%	4,73%	41,54%	4,52%	8,25%
		PHEV	2,14%	3,45%	2,35%	0,62%					0,24%	4,73%	0,25%	0,19%
		BEV	4,73%	41,54%	4,52%	8,25%	0,24%	4,73%	0,25%	0,19%				

Figure 17 – Powertrain comparison: Germany.

Following to the medium size and starting with the TCO-only scenario, this criterion makes a considerable difference for BEVs here, and turns them into the favorites of all powertrains for the city driver profile, while ICEVs and PHEVs maintain their equal preferability like seen in the baseline. For the all-purpose driver style, combustion cars are the less preferred, and electrics lose their competitive advantage, being equally attractive as plug-in hybrids. Analyzing the ELECTRE-TRI results for this scenario in comparison to the baseline, all electric exemplars are in class 4 “buy” in both driver profiles (except one which is in class 3 “shortlist” for the all-purpose driver profile) and the remaining lineup kept unchanged, while some PHEVs ranked up from class 1 “avoid” to classes 2 and 3, coming closer to the electric models, and thus, this event explains the new results. Taking on the next scenario, CO_2 emissions, there are no ELECTRE TRI changes here when compared to the baseline context, except one combustion car that falls from class 4 “buy” to class 3 “shortlist” in the city driver profile, but this event does not modify the conclusions. As the rest of the lineup follows “untouched”, the results consequently keep the same, and hence, plug-in hybrids are equally competitive against combustion models for city driver profile, and preferred over the competition in all-purpose driver profile, as the statistical results conclude. The characteristics of the last scenario, Economic, indeed caused some interesting moves in the ELECTRE TRI results (see Appendix

C, Table C.14), and comparing to the baseline, ICEVs clearly dominate class 3 “shortlist” in both driving profiles. However, PHEVs have a slightly bigger presence in classes 2 and 3 (for both driving profiles and all-purpose driver profile, respectively), and are the only technology in class 4 “buy” for both cases, repeating the statistical results of the baseline scenario, where BEVs are inferior to all powertrains, and PHEVs create the same purchase appeal as the ICEVs for city driver profile, becoming the favorite options in the all-purpose driver profile.

Focusing in the medium SUV segment and TCO-only scenario this time, the only significant change in the segment against the baseline context is the up-ranking of the cheapest electric cars (most of them) from class 1 “avoid” to class 4 “buy” (also, one of the expensive electric climbs to classes 2 “consider” and 3 “shortlist”, respectively, for city and all-purpose driver profiles), while in the other powertrains, nothing changed (except for one plug-in hybrid that degraded from class 3 to class 2) and in the end, from the statistical point of view, all technologies have the same appeal in both driving profiles. Heading for the CO_2 emissions scenario, this criterion seems to have some influence in the rankings, as some combustion exemplars have an inferior score when compared to the baseline scenario, while the rest of the lineup remains the same, but these moves are not enough to change the statistical results, which appoints ICEVs and PHEVs as equally good options, and BEVS being inferior against the competition. For the last scenario, the Economic, the characteristics of this environment also have effect in the ELECTRE TRI result (see Appendix C, Table C.15), where combustion models have preference in the upper classes for city driver profile, and have the same number of exemplars as plug-in hybrids in class 4 “buy” in all-purpose driver profile, while for the other classes, these last have at least one car present, enough to configure statistical lack of data (as commented in other cases), and turn both powertrains equally good in the end. Thus, this is the final result, with PHEVs and ICEVs statistically equivalent, while BEVs are penalized by the use restrictions, and the “massive” incentives do not show any effect for this powertrain.

The last set of analysis belongs to the large cars, and as seen in the Portuguese and USA markets, the statistical analysis reveals that, for city driver profile, all technologies are equally desirable, differently from the baseline result where a “supremacy” impression was left. The evidence that explains this is the entrance of the cheapest electric model in class 4 “buy”, that as seen in other situations, turns more difficult to predict a statistical difference, and in the end, all cars are attractive among each other. For the all-purpose driver profile however, all PHEVs models (except one) have the highest ranking, while the majority of the ICEVs and BEVs are located between classes 1 “avoid” and 2 “consider”, even with almost no changes in the rankings from one driving profile to the other (compared against the baseline). Thus, plug-in hybrids are the favorite choice for all-purpose profile, while electric and combustion models have the same attractivity. Taking the CO_2 emissions scenario, the environmental concern once more has no effect in the results when comparing against the baseline, and only three changes in the ranks are seen, where two ICEVs are downgraded for class 2 "consider" in city driver profile (with one downgrade in all-purpose driver profile as well) and one PHEV degrades in all-purpose driver profile from class 4 "buy" to class 3 "shortlist", while the rest keeps unchanged, and consequently, the results are the same as the initial picture, with electric cars as the less preferred option, combustion models as a "middle choice", and plug-in hybrids becoming favorites for both driver profiles. The last scenario of this segment, Economic, does not influence the final results either, just ensuring the preference of PHEVs over all other powertrains in both driving profiles, while BEVs keep suffering the effects of use restrictions. The rankings show only three combustion exemplars changing classes in all-purpose driver profile (two downgrades and one climb) and two plug-in hybrids moving up (one for city driver profile and the other for all-purpose driver profile), but this discrete event does not change anything in the final results, and so, BEVs are once more penalized by the use restrictions, ICEVs are a "secondary" option, and PHEVs are the best choice above the other technologies.

4.3 DISCUSSIONS

Looking at the baseline context and the alternative scenarios, it is possible to identify some clues that lead to general conclusions about consumer acceptance for alternative powertrains. The baseline scenario reflects the 2020 markets of Portugal, Brazil, USA and Germany, as well as their respective fiscal realities, and most of the observations represent tendencies possible of happening anywhere in the world. The method can be applied for any case, in any region, as long as the relevant data is collected and processed.

The discussion about the collected results will be done in two parts. Firstly, some general findings will be commented (which can apply to all markets or not), and then, a closer approach at a regional level will be done, where some cases called the attention (depending on the country) and observations for each market are assigned. Starting with the general findings and financial context, the higher price of BEVs and PHEVs does not seem to affect all models, as some of them (especially the medium-sized and medium SUV exemplars) have a competitive or better TCO than ICEVs, and the extra price dilutes itself for these segments, in the cheapest models of course. However, it must be observed that, for electric cars, this performance is only possible when there are no use restrictions applied, the next topic. The use restrictions, as shown in the results, affect the performance of BEVs regardless of driver profile and segment, and the only environment where this factor has no influence is the TCO-only scenario, which reduces the weight of use restrictions to zero, and literally eliminates them, allowing BEVs (especially the cheaper models) to become good options and even turn the favorite choice, as seen in the medium size for the Portuguese and German markets However, these results do not mean that this powertrain has a competitive potential, and for all other scenarios for all markets, they are not an option at all, at least for the current reality. For PHEVs, the situation is different, because this powertrain is free of use restrictions, and with similar capabilities as ICEVs (i.e., charging time and charging points and even range, depending on the model), the competitive capability depends mostly on the TCO of the vehicle.

Discussing incentives with more attention, the results show that this item has an important contribution for turning alternative powertrains more competitive, especially for BEVs, due to the high purchase prices that its technology charges, as well as PHEVs. This conclusion is more evident in the USA and German markets, where the incentives have a considerable value (see subsection 3.2.1 for details and references), regardless of being an electric car or a plug-in hybrid. Portugal also has incentives, but only for electric cars, and in a smaller amount, differently from Brazil, where there are no incentives at all, independently if applied directly on the purchase price or in other format (for example, reduced or free parking taxes, or zero circulation taxes or highway tolls…). So important as commenting the findings for this work, other examples of cases with applied incentives deserve attention, and some studies show that the values proposed go beyond the minor incentives used in this study, as is the case from Prud'homme & Koning (2012) and the Norwegian case (Holtsmark & Skonhoft, 2014), which show that an exemption of VAT for BEVs can generate savings of around 7,000 €, when combining these measures with an adequate charging infrastructure, the market share of PHEVs and BEVs together can reach extremely high values, like today, where this mark is of almost 70% for the mentioned country (EAFO, 2020). Other studies (Bubeck et al., 2016; Hoen & Koetse, 2014) show that major incentives like, respectively, 20,000 € and even 32,000 €, are proposed to increase the attractivity of BEVs. To solve the issues of BEVs, a joint participation of manufactures and governments is needed, reinforcing the importance of these entities needing to work together in order to turn these technologies accessible to everyone. The results of most cases from Scenario S1 (TCO-only) show that, with the lifting of use restrictions, BEVs start to become competitive and even surpass the other technologies, but there still is a long way to go until this scenario becomes a reality, and for a short-term, is unlikely that electric cars will be seen in a large scale, being purchased only by consumers who can handle its shortcomings. All these observations derive from real market conditions.

Advancing to the regional level approach mentioned before, some interesting cases and facts called the attention and will be shared here. But before reaching that point, some general conclusions for all markets. The European markets of Portugal and Germany and also USA (with a smaller quantity) present a lineup of electric cars capable of delivering an adequate use for both driving profiles, as the TCO-only scenario proves, but as mentioned before, only in this situation. However, the TCO reduces their attractivity when compared with small ICEVs and also for bigger cars depending on the model. A conclusion provided by the sensitive analysis and also found by Sousa et al. (2020) is that solving one use restriction issue alone will not improve BEVs acceptance, and hence, more measures are necessary to turn them more attractive. Recent studies also appoint this conclusion (Rietmann & Lieven, 2019; Santos & Davies, 2020) as well as the importance of charging infrastructure and financial incentives factors to drive a bigger preference for electric cars. An extremely important finding is that the slightest change in positions within the ELECTRE TRI rankings can modify completely the statistical results, as happened several times when running the multiple analysis, especially in the USA market, where some cases showed partial inconclusive results, and the move of ranks of one single vehicle from one driver profile to the other replaced the inconclusions with definitions, and vice versa. Taking firstly the lineup of Portugal, BEVs start to become competitive against ICEVs for the small segment, and also when compared to PHEVs in the other sizes, especially the medium size, where electrics are the favorites against all powertrains, valid for both driving profiles and TCO-only scenario, but this does not go beyond that, and in general, electric cars cannot be considered as an option. Comparing only combustion models and plug-in hybrids this time, these two technologies present slight differences between them (like range (some PHEVs have similar range to ICEVs), CO_2 emissions (plug-in hybrids are less pollutant than combustion cars) and TCO (also some plug-in hybrid models have similar or even cheaper TCOs than combustions vehicles)) and also the similarities, like charging points coverage and charging time. These aspects can influence the final results, together with the minor incentives (only for the Economic scenario). Focusing on the statistical results, both powertrains are equally preferrable for all scenarios of the medium SUV and large segments, and the economic scenario of medium cars, all for city driver profile. However, when talking about all-purpose driver profile, PHEVs become the favorite options against all others in the Economic scenario from medium to large cars, influenced by the incentives provided in the respective scenario (described in section 4.2). This finding can also indicate that, while there are not adequate conditions to disseminate electric cars, plug-in hybrids can work as a "transition" between the current reality and the new era of electricity, thanks to its freedom of use restrictions and similar or close flexibility as offered by combustion cars, especially when using this technology in the all-purpose driver profile. In general, Portugal has an attractive market, as seen by the results in Figure 14 (section 4.2), with possibilities to make this characteristic more notorious, but to get there, the issues of BEVs must be solved (or at least minimized), a bigger lineup of large electric cars could be offered, and last but not least, incentives should be offered for PHEVs, especially injected directly on the purchase price of the vehicle.

Looking out the Brazilian market, the results for small cars were expected due to the high taxes and lack of infrastructure mentioned for the baseline scenario of this market in section 4.1, while the other segments presented surprising results, but not for the expected reasons. As mentioned before, Brazil has a very limited lineup of plug-in hybrid and electric cars available, and their high TCOs (affected by the excessive purchase prices) penalizes their overall performance, even with good technical specifications making part of it. As pointed by the statistical result, these technologies are competitive only due to their lack of options, which makes it difficult to assign a significant difference, and all powertrains are treated equally in the end. These conclusions are disappointing, because with results that are the same almost all the time, this market becomes unattractive, especially for automobile manufactures that want to introduce new products, by importing the models or even opening factories, and the economy also suffers. To revert this tendance, is necessary to invest in infrastructure for BEVs and PHEVs, review import tax structure or offer adequate conditions to nationalize the production of these models, and also create incentives to make these technologies more accessible to all. Maybe with a bigger lineup of PHEVs and BEVs for this country, there would be some interesting conclusions to observe. Still in the Americas, the USA market calls the attention this time. Surprisingly, the small electric cars have a better performance for the all-purpose driver profile, when normally the opposite happens, justified by a discrete change of positions in the rankings, which caused another surprising observation: the appearance of partial inconclusive results, not seen before in the other markets until then, and only found in this country, at both driving profiles, for medium, medium SUV and large sizes, but following the steps described for Table 7 in section 4.1, these uncertainties are eliminated and conclusions can be drawn. Also, taking a closer look in PHEVs, they are equally competitive as ICEVs in all cases, and against BEVs too (only in TCO-only scenario), but do not have preference over the other powertrains at any time. Despite this, plug-in hybrids seem to be particularly good options for medium and bigger cars, by the same reasons appointed in the Portuguese market for this observation, and for electric cars, unfortunately, are not an option in this country, at least for now.

Finally, the German automotive sector seems to have the greatest findings, where statistical results point to a larger tendency for greener technologies, heavily influenced by federal incentives. Looking at the small size first, the TCO-only scenario shows superiority of BEVs over ICEVs in the city driver profile, differently from Portugal where both powertrains have the same appeal for this scenario, but for all-purpose driving profile, all models are equally good. For medium SUVs, all technologies are equivalent in both driving profiles for TCO-only scenario, and in the remaining scenarios, combustion models and plug-in hybrids have the same desirability. For medium cars, BEVs are the favorites in TCO-only scenario against ICEVs for both driving profiles, and compared to PHEVs, electrics are ahead for city driver profile, but lose the advantage in the all-purpose profile and are equally good. However, comparing combustion cars and plug-in hybrids between each other, both technologies are statistically good for city driver profile in all scenarios, but in all-purpose driver profile, plug-in hybrids are clearly preferred regardless of the scenario. This strong presence is even more expressive for large cars, where with the exception of TCO-only context for city driver profile, PHEVs overtake all other powertrains in any scenario and any driver profile, a characteristic found only for this country. These results are strongly influenced by the “standard” incentives, and perhaps by technical aspects (the same appointed for the Portuguese market), because in Germany, the emissions controls are stronger than in Portugal, and also this market seems to have a better infrastructure for AFVs. Combining all these factors, PHEVs lean towards an increasing adoption, and possibly indicating a tendance for beginning a transition into a new era in Germany, the all-electric mobility.

Taking the discussion to a global level, some important and interesting conclusions can be done, even complementing the findings in the sensitive analysis. The first observation is that ICEVs are always a good option, as most models have a competitive TCO, and especially the best flexibility use in the market, although some PHEVs have a range as good as combustion models.

Talking about this technology, if comparing the results with the original study (with a 2017 market reality), the attractivity of plug-in hybrids improved a lot, as some scenarios and markets revealed, but still have a way to go in order to become a massively adopted option, while for electrics, the conclusions are that this powertrain only starts to become competitive when all use restrictions are lifted (TCO-only scenario) and kept this way, proving that they cannot be considered an option. The second observation is that the need of improving the infrastructure for BEVs is not only increasing the number of charging stations and their capacity, but also upgrade the whole national electric system, in order to support such a massive demand for this technology and continue to feed the other sectors of the economy, like the industry, transportation, general commerce and our own houses. Last but not least, some observations on a regional level, agreed with Sousa et al. (2020). As discussed earlier, the ELECTRE-TRI method is appliable for any case on any region, but attention must be paid to the fact that the criteria involved can vary depending on the chosen region, as different countries have a variety of vehicles on sale, as well as different financial realities and charging infrastructure. Comparing the results of the selected markets for this study against other findings for specific countries obtained by different methods, it is possible to share some conclusions with these studies, like the fact that in Germany, BEV require high subsidies to become monetarily competitive (Bubeck et al., 2016; Letmathe & Suares, 2017), the existence of a correlation between higher incentives and higher BEV sales (Lévay et al., 2017) (a conclusion that this work supports as well, although indirectly) and the need for a combination of factors to increase the market share of BEVs in Italy (Valeri & Danielis, 2015), confirming what was discussed earlier: in summary, solving one BEV issue alone may not be enough to make it more attractive. To close this section, a remark is established in relation to the non-compensatory nature of the method: the results derived from this approach may not be directly comparable with other studies depending on the region due to different financial conditions, and thus, this leads towards different conclusions. Even having common findings like the need of incentives to turn BEV more competitive (Jenn et al., 2018; Sharma et al., 2012; Wee et al., 2018), others sometimes can deviate.

5. CONCLUSIONS

Everyday, since the first industrial revolution, the world has been dealing with an increasing demand for fuel and energy, and at some time the natural resources will be depleted, challenging humanity to look for alternative sources. Now is the time to bring these alternatives to life, particularly petroleum, which relates to this work. From the first mass-production vehicle in the world (the Ford Model T), through the first HEV for mass adoption (the Toyota Prius) till the newest BEVs, cars are more efficient and greener (lower or no emissions) everyday, and a full fleet of private electric vehicles will become part of the daily routine in our lives. However, along with the new era, comes the uncertainties of whether and how people will accept and how to prepare to adopt it, what are the necessary steps to deploy it. To help devising ways to overcome such challenges, providing a tool that enables people and governments to find the proper and most suitable processes and policies to be implemented and find the proper direction is the main objective of this study.

Differently from a conventional approach (like a typical consumer survey based on abstract or limited vehicle sets), a new and efficient method for this type of research has been introduced by Sousa et al. (2020): the Multicriteria Non-compensatory ELECTRE TRI method. We now apply it to extend their analysis. This study estimated the consumer acceptance level of acquiring a new car to be the main vehicle on the household, considering three powertrain technologies (ICEV+HEV, PHEV and BEV) for four countries: Portugal, Brazil, USA and Germany. It takes into account the costs of ownership and use restrictions for electric cars as criteria, segmented by vehicle size and driver profile and presenting the context of each country, as the respective market stands in 2020. Three alternative scenarios were investigated in the analysis as well: TCO-only, CO_2 emissions at 33% and Economic.

The results achieved have considerable policy implications. Firstly, the use restrictions create a massive barrier that turns the large-scale adoption of electric cars a lot more difficult, and joint initiatives from governments and the manufactures are necessary to overcome these challenges, with the final objective of creating a greener private transportation future. In addition, only financial incentives are not enough to make these car types more popular. Going beyond that, having infrastructure to support massive BEV adoption is crucial, and even more than investing and/or improving charging stations, the whole electric network needs to be capable of offering a reliable, safe and efficient consumption. A study by Nykvist et al. (2019) show that the manufacturers are working in improving the electric car range already. If all the restrictions can be lifted, this powertrain technology becomes the best option due to its lower running costs. However, an alert must be made: governments must not think about elevating charging prices of public charging points or charging higher taxes in BEVs so they can finance investments in an adequate infrastructure: if that approach is taken, the economic advantages of electric cars may no longer exist. The findings of PHEVs having similar appeal against ICEVs in most cases reinforce the previous alert, and also presents a plausible scene where only BEVs can make a difference in a long run status-quo.

Another clear fact is the importance of incentives for plug-in hybrid cars and electric vehicles in order to make these technologies competitive while an adequate and mature infrastructure does not exist, being more evident for small cars, as conventional models are noticeably cheaper to buy than other options. Attention is required with incentives specified for PHEVs. One side shows that this technology turns this powertrain more complex and expensive, making difficult to recover this cost during the holding period. The other side presents an uncertainty relative to where drivers will charge these vehicles, being aware that they become much more attractive when supported by generous incentives.

Finally, the ELECTRE TRI methodology has shown that it is general, and can be applied for any case, in any country or region, or even more, for groups of countries as it was made here, and also for the buyer himself, to select the vehicles considered more closely and calibrate ELECTRE TRI according to her own preferences and requirements. A study like this for other markets (Japan, China, Australia) or even other EU countries would be interesting, using powertrain or country (if possible) as disaggregating factors. The analysis can also be repeated with an updated model lineup, as more and more new vehicles heat the market in a rapid pace, and most general models are sold in various countries worldwide. Another suggestion would be comparing the ELECTRE TRI results with another multicriteria methodology, accessing the degree of agreement between them.

Summarizing, this work provides a tool that can be used, and certainly be improved in the future, to help Government and Industry sectors to address technical and public policy issues for transitioning to a better world for humanity.

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APPENDIX

APPENDIX A – BASELINE DECISION MATRIX

Table A.1 – Vehicle set for Portugal – Part 1.

ID	Model	Tech	Size	TCO (City)	TCO (All-Purpose)	Range	Charging Points	Charging Time (City / All-Purpose)	CO2 emissions
1	Audi A3 Sportback Base 30 TFSI 1.0	ICEV	Medium	18211,04	23881,04	1	1	0,1	123
2	Audi A3 Sportback Base 30 TDI 2.0	ICEV	Medium	18704,59	22610,59	1	1	0,1	111
3	Audi A3 Limousine Base 35 TFSI 1.5	ICEV	Medium	21271,58	27046,58	1	1	0,1	124
4	Audi A3 Limousine Base 35 TDI 2.0	ICEV	Medium	22626,91	26718,91	1	1	0,1	116
5	Audi E-Tron Base 55 Quattro	BEV	Med. SUV	41102,82	46192,32	0,62	0,19	19,13 / 6,41	0
6	Audi Q3 Base 35 TFSI 1.5	ICEV	Med. SUV	25532,61	32462,61	1	1	0,1	149
7	Audi Q3 Base 35 TDI 2.0	ICEV	Med. SUV	27409,63	32803,63	1	1	0,1	153
8	Audi Q5 TFSIe Business Line Sport 55 Quattro	PHEV	Med. SUV	33199,13	35737,23	1	1	0,1	49
9	BMW i3 120 Ah	BEV	Small	17665,5	20649	0,44	0,19	8,38 / 2,81	0
10	BMW 225xe Active Tourer	PHEV	Medium	20777,52	22780,07	0,88	1	0,1	38
11	BMW 216i Active Tourer	ICEV	Medium	20132,25	26642,25	1	1	0,1	142
12	BMW 216d Active Tourer	ICEV	Medium	20016,21	24387,21	1	1	0,1	123
13	BMW 330e	PHEV	Medium	26350,31	28158,28	0,99	1	0,1	31
14	BMW 320i	ICEV	Medium	26875,65	33490,65	1	1	0,1	142
15	BMW 316d	ICEV	Medium	23789,65	27974,65	1	1	0,1	117
16	BMW 530e	PHEV	Large	30902,51	32654,07	0,99	1	0,1	27
17	BMW 520d	ICEV	Large	30784,45	35155,45	1	1	0,1	124
18	BMW X3 xDrive 30e	PHEV	Med. SUV	30454,91	33043,71	0,97	1	0,1	49
19	Citroën C-Zero	BEV	Small	13186,74	16501,74	0,21	0,19	3,21 / 1,07	0
20	Citroën C1 Feel 1.0 Vti 72 S&S CVM	ICEV	Small	10186,94	15226,94	1	1	0,1	109
21	Citroën C5 Aircross Plug-in Hybrid Feel	PHEV	Med. SUV	21440,16	23446,7	0,92	1	0,1	32
22	Citroën C5 Aircross Feel 1.2 PureTech 130 S&S	ICEV	Med. SUV	18406,94	25336,94	1	1	0,1	149
23	Citroën C5 Aircross Live 1.5 BlueHDi 130 S&S	ICEV	Med. SUV	17046,99	21975,99	1	1	0,1	138
24	DS 3 Crossback E-Tense	BEV	Medium	16806	20316	0,46	0,19	9,95 / 3,33	0
25	DS 7 Crossback E-Tense 4x4	PHEV	Med. SUV	24890,51	26881,57	0,91	1	0,1	30
26	Fiat 500 "La Prima" (to be launched)	BEV	Small	15052,5	17607	0,46	0,19	9,29 / 3,11	0
27	Fiat Panda Easy 1.2 8V	ICEV	Small	12012,26	17997,26	0,93	1	0,1	132
28	Ford Mondeo Titanium 2.0 HEV	HEV	Large	21656,55	27536,55	1	1	0,1	127
29	Ford Mondeo Titanium 2.0 TDCi MT	ICEV	Large	19011,37	23661,37	1	1	0,1	132
30	Ford Mustang Mach-E SR RWD	BEV	Large	19915,5	23133	0,64	0,19	15,48 / 5,18	0
31	Honda E (to be launched)	BEV	Small	15630	19140	0,31	0,19	6,30 / 2,11	0
32	Honda Civic Comfort 1.0 I-VTEC	ICEV	Medium	15646,1	20686,1	1	1	0,1	110
33	Honda Civic Sport 1.5 I-VTEC	ICEV	Medium	20100,2	25980,2	1	1	0,1	128
34	Honda Civic Comfort 1.6 i-DTEC	ICEV	Medium	15511,05	18673,05	1	1	0,1	91
35	Honda Civic Sedan Elegance Navi 1.5 I-VTEC	ICEV	Medium	19848,35	26043,35	1	1	0,1	134
36	Honda Civic Sedan Executive 1.6 I-DTEC	ICEV	Medium	18293,55	21455,55	1	1	0,1	118
37	Honda CR-V Elegance i-MMD 2WD	HEV	Med. SUV	26690,85	33935,85	1	1	0,1	156
38	Honda CR-V Elegance 2WD	ICEV	Med. SUV	24672,45	32442,45	1	1	0,1	167

Table A.2 – Vehicle set for Portugal – Part 2.

39	Hyundai Ioniq EV	BEV	Medium	14590,5	17281,5	0,44	0,19	8,47 / 2,84	0
40	Hyundai Ioniq Plug-in	PHEV	Medium	16031,52	17218,18	1	1	0,1	26
41	Hyundai Inoiq Hybrid	HEV	Medium	16837,22	21667,22	1	1	0,1	104
42	Hyundai Kauai EV (64 kW)	BEV	Med. SUV	16038,6	18905,1	0,64	0,19	14,16 / 4,74	0
43	Hyundai Tucson 1.6 GDi	ICEV	Med. SUV	21125,97	29630,97	1	1	0,1	184
44	Hyundai Tucson 1.6 CRDi	ICEV	Med. SUV	19339,9	24454,9	1	1	0,1	144
45	Jaguar I-Pace	BEV	Med. SUV	38640,96	42930,96	0,67	0,19	18,74 / 6,27	0
46	Kia e-Niro Tech (64 kW)	BEV	Med. SUV	19210,5	22311	0,65	0,19	14,16 / 4,74	0
47	Kia Niro 1.6 GDI PHEV Urban	PHEV	Med. SUV	16635,42	18194,11	1	1	0,1	31
48	Kia Niro 1.6 GDI HEV Urban	HEV	Med. SUV	16381,1	21421,1	1	1	0,1	110
49	Kia e-Soul (64 kW)	BEV	Med. SUV	18121,5	21183	0,64	0,19	14,16 / 4,74	0
50	Kia Sportage 1.6 CRDI ISG MHEV Urban	HEV	Med. SUV	17204,25	22319,25	1	1	0,1	143
51	Kia Sportage 1.6 GDI ISG 6MT TECH	ICEV	Med. SUV	20732,85	29237,85	1	1	0,1	183
52	Kia Optima SW PHEV	PHEV	Large	21726,71	23391,03	1	1	0,1	37
53	Lexus UX 250h Business	HEV	Med. SUV	24628,05	30193,05	1	1	0,1	120
54	Lexus NX 300h FWD	HEV	Med. SUV	30848,85	37988,85	1	1	0,1	155
55	Lexus ES 300h Business	HEV	Large	31359,05	36924,05	1	1	0,1	120
56	Lexus RX 450h Business	HEV	Large	45888,45	53868,45	1	1	0,1	173
57	Mazda MX-30 (to be launched)	BEV	Med. SUV	15209,7	18914,7	0,29	0,19	7,08 / 2,37	0
58	Mercedes B 250e	PHEV	Medium	21888,42	23793,56	0,93	1	0,1	32
59	Mercedes B 160	ICEV	Medium	20005,7	26305,7	1	1	0,1	137
60	Mercedes B 180d	ICEV	Medium	19021,05	23299,05	1	1	0,1	122
61	Mercedes C 300de Limousine	PHEV	Medium	26997,66	28563,72	1	1	0,1	33
62	Mercedes C 200 Limousine	ICEV	Medium	26373,45	33303,45	1	1	0,1	150
63	Mercedes C 180d Limousine	ICEV	Medium	23404,05	28054,05	1	1	0,1	130
64	Mercedes EQC 400 4MATIC	BEV	Med. SUV	33531,78	37880,28	0,6	0,19	17,70 / 5,92	0
65	Mercedes E 300de Limousine	PHEV	Large	32846,16	34441,85	1	1	0,1	32
66	Mercedes E 200 Limousine	ICEV	Large	34424,43	41984,43	1	1	0,1	164
67	Mercedes E 200d Limousine	ICEV	Large	28960,05	33517,05	1	1	0,1	129
68	Mini Cooper S E	BEV	Small	14958	18468	0,33	0,19	6,39 / 2,14	0
69	Mitsubishi Outlander PHEV Intense	PHEV	Large	16967,81	18952,81	0,92	1	0,1	46
70	Mitsubishi Outlander Kaiteki 2.0	ICEV	Large	21587,85	30092,85	1	1	0,1	184
71	Nissan Leaf Acenta Access (40 kWh)	BEV	Medium	12766,5	16101	0,39	0,19	7,96 / 2,67	0
72	Nissan Leaf e+ Acenta (62 kWh)	BEV	Medium	16735,5	20343	0,55	0,19	12,39 / 4,15	0
73	Opel Corsa-E	BEV	Small	12910,8	16225,8	0,47	0,19	9,95 / 3,33	0
74	Peugeot e-208 Active	BEV	Small	12806,4	16004,4	0,49	0,19	9,95 / 3,33	0
75	Peugeot 108 Active 1.0 Vti 72 S&S CVM	ICEV	Small	9978,2	15018,2	1	1	0,1	110
76	Peugeot 3008 GT Plug-in Hybrid	PHEV	Med. SUV	26499,72	28424,5	0,91	1	0,1	30
77	Peugeot 3008 Style 1.2 PureTech	ICEV	Med. SUV	19588,4	26308,4	1	1	0,1	146

Table A.3 – Vehicle set for Portugal – Part 3.

78	Peugeot 3008 Active 1.5 BlueHDi	ICEV	Med. SUV	18634,05	23470,05	1	1	0,1	136
79	Peugeot 508 Allure Plug-in Hybrid	PHEV	Large	22841,52	24766,3	1	1	0,1	28
80	Peugeot 508 GT 1.6 PureTech	ICEV	Large	27671,25	35126,25	1	1	0,1	161
81	Poeugeot 508 Active 1.5 BlueHDi	ICEV	Large	18109,65	22387,65	1	1	0,1	120
82	Peugeot 5008 Style 1.2 PureTech	ICEV	Med. SUV	20558,6	27488,6	1	1	0,1	150
83	Peugeot 5008 Style 1.5 BlueHDi	ICEV	Med. SUV	19877,85	24806,85	1	1	0,1	139
84	Porsche Taycan 4S	BEV	Large	50368,26	54482,76	0,45	0,19	15,71 / 5,26	0
85	Renault ZOE ZEN R110 Z.E. 40 (battery hire)	BEV	Small	13848,3	17260,8	0,45	0,19	9,07 / 3,04	0
86	Renault Clio E-Tech Hybrid Intens	HEV	Small	14774,6	19289,6	1	1	0,1	98
87	Smart EQ ForTwo (4,6 kW charger)	BEV	Small	9271,5	12313,5	0,19	0,19	3,69 / 1,24	0
88	Smart EQ ForFour (4,6 kW charger)	BEV	Small	10151,4	13329,9	0,19	0,19	3,69 / 1,24	0
89	Tesla Model 3 Standard Range Plus	BEV	Medium	20443,5	23349	0,58	0,19	10,51 / 3,52	0
90	Tesla Model S Long Range	BEV	Large	39400,8	43105,8	0,87	0,19	21,01 / 7,03	0
91	Tesla Model Y Long Range	BEV	Med. SUV	30108	32916	0,72	0,19	16,04 / 5,37	0
92	Tesla Model X Long Range	BEV	Med. SUV	42622,8	47029,8	0,72	0,19	21,01 / 7,03	0
93	Toyota Aygo X-play 5-door 1.0 VVT-i	ICEV	Small	11278,1	16528,1	1	1	0,1	113
94	Toyota Corolla Active 1.2 Turbo	ICEV	Medium	15594,2	22104,2	1	1	0,1	141
95	Toyota Corolla Active 1.8 Hybrid	HEV	Medium	16303,65	21028,65	1	1	0,1	101
96	Toyota Corolla Comfort 2.0 Hybrid	HEV	Medium	19176,45	24636,45	1	1	0,1	118
97	Toyota Corolla Touring Sports Active 1.2 Turbo	ICEV	Medium	16749,2	23364,2	1	1	0,1	143
98	Toyota Corolla Touring Sports Active 1.8 Hybrid	HEV	Medium	17353,65	22078,65	1	1	0,1	101
99	Toyota Corolla Touring Sports Comfort 2.0 Hybrid	HEV	Medium	20604,45	26064,45	1	1	0,1	119
100	Toyota RAV4 Hybrid Comfort	HEV	Med. SUV	23767,05	29752,05	1	1	0,1	129
101	Toyota Prius Exclusive Liftback 1.8 Hybrid	HEV	Medium	19142,85	23447,85	1	1	0,1	94
102	Toyota Pruis Plus Luxury 1.8 Hybrid	HEV	Medium	23069,85	29159,85	1	1	0,1	132
103	Toyota Prius Plug-in Exclusive 1.8 Hybrid	PHEV	Medium	19216,61	20617,49	1	1	0,1	28
104	Toyota Yaris Active 1.0 VVT-i	ICEV	Small	12071,9	18161,9	1	1	0,1	131
105	Toyota Yaris Active 1.5 Hybrid	HEV	Small	13247,9	18287,9	1	1	0,1	108
106	Volkswagen e-Golf VII	BEV	Medium	17979,48	20976,44	0,33	0,19	7,08 / 2,37	0
107	Volkswagen Golf VII GTE 1.4 TSI Plug-in Hybrid	PHEV	Medium	22537,47	24773,91	1	1	0,1	46
108	Volkswagen Golf VII Stream 1.0 TSI	ICEV	Medium	17380,28	23123,78	1	1	0,1	124
109	Volkswagen Golf VII Stream 1.6 TDI	ICEV	Medium	18397,65	22982,55	1	1	0,1	129
110	Volkswagen Passat GTE 1.4 TSI Plug-in Hybrid	PHEV	Large	22586,81	24262,67	1	1	0,1	28
111	Volkswagen ID.3 1st	BEV	Medium	15989,64	19012,14	0,61	0,19	12,83 / 4,29	0
112	Volkswagen Passat 1.5 TSI	ICEV	Large	19543,7	25728,2	1	1	0,1	134
113	Volkswagen Passat 1.6 TDI	ICEV	Large	21485,62	26526,22	1	1	0,1	142
114	Volkswagen e-Up!	BEV	Small	9413,58	12241,08	0,37	0,19	7,14 / 2,39	0
115	Volkswagen Up! Move 1.0	ICEV	Small	12002,42	17117,42	0,91	1	0,1	124
116	Volvo S60 Recharge R-Design Expression T8	PHEV	Medium	29385,53	31378,78	1	1	0,1	38

Table A.4 – Vehicle set for Portugal – Part 4.

117	Volvo V60 Recharge R-Design Expression T8	PHEV	Medium	28249,01	30324,02	1	1	0,1	41
118	Volvo XC60 Recharge R-Design Expression T8	PHEV	Med. SUV	31932,2	34808,31	1	1	0,1	55
119	Volvo XC60 Momentum Plus B4 Hybrid	HEV	Med. SUV	34071,51	42051,51	1	1	0,1	171
120	Volvo XC60 Momentum Plus D4	ICEV	Med. SUV	30379,03	35773,03	1	1	0,1	153
121	Volvo XC90 Recharge R-Design Expression T8	PHEV	Large	40837,05	44070,4	1	1	0,1	60

Table A.5 – Vehicle set for Brazil – Part 1.

ID	Model	Tech	Size	TCO (City)	TCO (All-Purpose)	Range	Charging Points	Charging Time (City/All-Purpose)	CO2 emissions
1	Audi A3 Sportback Prestige Plus 1.4 TFSI	ICEV	Medium	21327,67	25191,9	0,93	1	0,1	180
2	Audi A3 Sedan Prestige 35 TFSI Flex	ICEV	Medium	18723,4	22602,7	0,92	1	0,1	181
3	A3 Sedan Performance Black 45 TFSI	ICEV	Medium	25635,55	29987,2	0,82	1	0,1	203
4	Audi Q3 Prestige 35 TFSI	ICEV	Med. SUV	22284,51	24922,64	1	1	0,1	123
5	BMW i3 120 Ah Full	BEV	Small	27358,29	28742,79	0,41	0	8,38 / 2,81	0
6	BMW 320i Sport	ICEV	Medium	29219,85	33666,97	0,95	1	0,1	207
7	BMW 330e M Sport	PHEV	Medium	35852,48	36731,93	1	1	0,1	31
8	BMW 530e M Sport	PHEV	Large	42476,66	44632,62	1	1	0,1	96
9	BMW 540i M Sport	ICEV	Large	57317,79	62342,79	0,97	1	0,1	234
10	BMW X5 xDrive 45e M Sport	PHEV	Large	55848,89	58240,37	0,97	1	0,1	27
11	Chevrolet Bolt	BEV	Small	24583,73	26246,1	0,59	0	13,14 / 4,40	0
12	Chevrolet Joy 1.0 MT Flex	ICEV	Small	9279,92	12867,77	1	1	0,1	167
13	Chevrolet Joy Plus 1.0 MT Flex	ICEV	Small	9650,05	13177,6	1	1	0,1	164
14	Chevrolet Onix 1.0 MT Flex	ICEV	Small	9358,62	12926,37	0,89	1	0,1	166
15	Chevrolet Onix 1.0 Turbo Flex	ICEV	Small	10315,34	14038,87	0,85	1	0,1	173
16	Citroën C3 Attraction 1.2 PureTech	ICEV	Small	10102,49	13690,34	1	1	0,1	167
17	Citroën C3 Attraction 1.6 VTi Flex Start	ICEV	Small	11668,28	15839,03	0,95	1	0,1	194
18	Citroën C4 Lounge Shine THP Flex	ICEV	Medium	15592	19833,1	1	1	0,1	197
19	Fiat Mobi Easy 1.0 Flex	ICEV	Small	7430,64	10933,06	0,96	1	0,1	163
20	Fiat Uno Attractive 1.0 Flex	ICEV	Small	8931,1	12951,1	0,86	1	0,1	187
21	Fiat Uno Way 1.3 Flex	ICEV	Small	9622,89	13210,74	0,96	1	0,1	167
22	Honda Accord 2.0 Turbo	ICEV	Large	25229,07	28083,27	1	1	0,1	133
23	Honda CR-V Touring 1.5 Turbo Flex	ICEV	Med. SUV	23891,91	26509,93	1	1	0,1	122
24	Hyundai Azera GDI 3.0 V6	ICEV	Large	32692,6	35913,62	1	1	0,1	150
25	Hyundai Tucson GLS 1.6 T-GDI Flex	ICEV	Med. SUV	19923,64	24576,79	0,96	1	0,1	217
26	Jac Motors iEV20	BEV	Small	16027,31	17002,31	0,57	0	9,07 / 3,04	0
27	Kia Sportage 2.0 Flex	ICEV	Med. SUV	18650,85	23886,9	0,85	1	0,1	244
28	Lexus UX 250h Dynamic	HEV	Med. SUV	24484,82	27685,74	0,96	1	0,1	112
29	Lexus NX 300h Dynamic	HEV	Med. SUV	32054,79	36275,79	0,95	1	0,1	112
30	Lexus ES 300h	HEV	Large	35032,19	38192,91	1	1	0,1	81
31	Lexus RX 450h L Luxury	HEV	Large	47474,16	52051,93	1	1	0,1	121
32	Mercedes C 300 Sport	ICEV	Medium	34890,3	39337,42	1	1	0,1	207
33	Mercedes E 300 Avantgarde	ICEV	Large	46220,79	49009,66	1	1	0,1	130
34	Mercedes S 560 L	ICEV	Large	113659,52	117629,27	1	1	0,1	185
35	Mitsubishi Eclipe Cross 1.5 Turbo GLS	ICEV	Large	18821,06	23343,56	1	1	0,1	211
36	Mitsubishi Outlander HPE 2.0	ICEV	Large	22742,11	27375,16	0,98	1	0,1	216
37	Mitsubishi Outlander HPE 2.2 Di-D	ICEV	Large	28926,81	32868,36	0,98	1	0,1	216
38	Nissan Leaf Tekna 40 kWH	BEV	Medium	22951,43	24618,68	0,34	0	7,96 / 2,67	0

Table A.6 – Vehicle set for Brazil – Part 2.

39	Peugeot 3008 Allure 1.6 THP	ICEV	Med. SUV	24725,15	29312,97	0,83	1	0,1	214
40	Peugeot 5008 Griffe Pack 1.6 THP	ICEV	Med. SUV	28840,45	33493,6	0,86	1	0,1	217
41	Renault ZOE Life	BEV	Small	17859,5	19565,75	0,43	0	9,07 / 3,04	0
42	Toyota Camry XLE 3.5 V6	ICEV	Large	35309,21	40384,46	0,85	1	0,1	236
43	Toyota Corolla Altis Hybrid 1.8 (Petrol/Ethanol)	HEV	Medium	17995,18	21256,4	0,95	1	0,1	152
44	Toyota Corolla Gli 2.0 Flex	ICEV	Medium	15508,73	19448,33	0,91	1	0,1	183
45	Toyota Etios X 1.3	ICEV	Small	9554,18	13302,83	0,86	1	0,1	175
46	Toyota Etios X Plus 1.5	ICEV	Small	10341,43	14135,3	0,85	1	0,1	177
47	Toyota Prius 1.8 Hybrid	HEV	Medium	20807,85	23606,77	1	1	0,1	131
48	Toyota RAV4 Hybrid S Connect	HEV	Med. SUV	27502,61	31211,06	1	1	0,1	173
49	Toyota Yaris Hatch XL Live 1.3 Flex	ICEV	Small	11294,9	15113,9	0,85	1	0,1	178
50	Toyota Yaris Hatch XL Plus Connect 1.5 Flex	ICEV	Small	11868,39	15551,71	0,88	1	0,1	171
51	Volkswagen Golf VII GTE 1.4 TSI Plug-in Hybrid	PHEV	Medium	23160,26	25209,38	1	1	0,1	105
52	Volkswagen Jetta 250 TSI 1.4 Flex	ICEV	Medium	14948,57	18983,64	0,89	1	0,1	188
53	Volkswagen Passat Highline 2.0 TSI	ICEV	Large	22280,11	26591,56	0,92	1	0,1	201
54	Volkswagen Up! MPI 1.0 Flex	ICEV	Small	8880,58	12347,83	1	1	0,1	161
55	Volkswagen Up! Connect 170 TSI Flex	ICEV	Small	9278,14	12564,49	1	1	0,1	153
56	Volvo S60 R-Design T8 Plug-in Hybrid	PHEV	Medium	33042,23	34009,07	1	1	0,1	52
57	Volvo S60 Inscription T5	ICEV	Medium	25897,64	29314,64	1	1	0,1	153
58	Volvo XC60 Momentum T8	PHEV	Med. SUV	33757,85	36179,01	1	1	0,1	117
59	Volvo XC60 Momentum T5	ICEV	Med. SUV	34812,58	40159,18	0,81	1	0,1	249
60	Volvo XC60 Momentum D5	ICEV	Med. SUV	35701,11	38988,58	1	1	0,1	180
61	Volvo XC90 Momentum T8 Plug-in Hybrid	PHEV	Large	43408,06	47892,47	1	1	0,1	79
62	Volvo XC90 Momentum T6	ICEV	Large	41668,77	47759,07	0,84	1	0,1	169
63	Volvo XC90 Momentu D5	ICEV	Large	44342,67	48194,44	1	1	0,1	181

Table A.7 – Vehicle set for the USA – Part 1.

ID	Model	Tech	Size	TCO (City)	TCO (All-Purpose)	Range	Charging Points	Charging Time (City/All-Purpose)	CO2 emissions
1	Audi A3 Sedan Sport Premium 40 TFSI	ICEV	Medium	26689,85	30159,05	0,91	1	0,1	183
2	Audi E-Tron Premium Plus	BEV	Med. SUV	47803,31	49837,31	0,47	0,08	19,13 / 6,41	0
3	Audi Q5 Premium 55 TFSI Plug-in Hybrid	PHEV	Med. SUV	32741,45	33840,73	1	1	0,1	49
4	BMW i3 120 Ah	BEV	Small	26055,62	27432,62	0,35	0,08	8,38 / 2,81	0
5	BMW 330e	PHEV	Medium	27503,65	28888,27	0,99	1	0,1	73
6	BMW 330i	ICEV	Medium	31893,42	35362,62	1	1	0,1	183
7	BMW 530e Sedan	PHEV	Large	34035,17	35524,52	0,94	1	0,1	80
8	BMW X3 xDrive 30e	PHEV	Med. SUV	30564,1	31686,78	0,97	1	0,1	49
9	BMW X5 xDrive 45e iPerformance	PHEV	Large	41345,78	43439,06	0,91	1	0,1	27
10	Chevrolet Bolt EV LT	BEV	Small	27151,24	28685,74	0,59	0,08	13,14 / 4,40	0
11	Chevrolet Spark LS MT	ICEV	Small	13188,48	16339,08	0,7	1	0,1	167
12	Chevrolet Sonic Sedan LS MT	ICEV	Small	15858,33	19447	0,81	1	0,1	190
13	Fiat 500e	BEV	Small	24552,31	25916,71	0,19	0,08	5,31 / 1,78	0
14	Fiat 500 Pop	ICEV	Small	14899,89	18369,09	0,71	1	0,1	183
15	Ford Escape SE Sport Hybrid	HEV	Med. SUV	22251,39	24786,91	1	1	0,1	134
16	Ford Escape SE Plug-in Hybrid	PHEV	Med. SUV	18641,11	20927,44	1	1	0,1	130
17	Ford Fusion Hybrid SE	HEV	Large	21987,32	24465,32	1	1	0,1	131
18	Ford Fusion Plug-in Hybrid Titanium	HEV	Large	18948,3	21182,82	1	1	0,1	131
19	Ford Mustang Mach-E Select Standard Range	BEV	Large	32024,36	33466,16	0,53	0,08	15,04 / 5,04	0
20	Honda Accord Hybrid	HEV	Large	20019,51	22187,76	1	1	0,1	115
21	Honda Civic Sedan LX	ICEV	Medium	17554,91	20705,51	0,94	1	0,1	167
22	Honda Clarity Plug-in Hybrid	PHEV	Large	18452,98	20726,5	0,88	1	0,1	131
23	Honda CR-V Hybrid LX	HEV	Med. SUV	21995,81	24834,88	1	1	0,1	145
24	Honda Fit LX 6MT	ICEV	Small	14650,07	18008,64	0,75	1	0,1	128
25	Honda Insight LX	HEV	Large	17967,49	19958,74	1	1	0,1	105
26	Hyundai Ioniq EV SE	BEV	Medium	18785,95	20027,95	0,39	0,08	8,47 / 2,84	0
27	Hyundai Ioniq Plug-in Hybrid SE	PHEV	Medium	15216,65	16906,66	1	1	0,1	106
28	Hyundai Kona SE	ICEV	Med. SUV	17629,36	21098,56	0,91	1	0,1	186
29	Hyundai Kona EV SEL	BEV	Med. SUV	20854,18	22177,18	0,59	0,08	14,16 / 4,74	0
30	Hyundai Sonata Hybrid Blue	HEV	Large	21377,8	23369,05	1	1	0,1	105
31	Hyundai Sonata Plug-in Hybrid	PHEV	Large	24440,41	26757,96	0,54	1	0,1	141
32	Hyundai Tucson SE	ICEV	Med. SUV	20586,54	24746,04	0,94	1	0,1	220
33	Hyundai Veloster 2.0 MT	ICEV	Small	16827,09	20544,09	0,85	1	0,1	197
34	Jaguar I-Pace	BEV	Med. SUV	44296,03	46276,03	0,53	0,08	18,74 / 6,27	0
35	Kia Niro LX	HEV	Med. SUV	19232,13	21311,88	1	1	0,1	110
36	Kia Niro Plug-in Hybrid LXS	PHEV	Med. SUV	17571,95	19523,75	1	1	0,1	120
37	Kia Niro EV EX	BEV	Med. SUV	22286,83	23717,83	0,55	0,08	14,16 / 4,74	0
38	Kia Optima Hybrid EX	HEV	Large	22953,61	25431,61	1	1	0,1	131
39	Kia Optima Plug-in Hybrid EX	PHEV	Large	22114,78	23147,12	1	1	0,1	54

Table A.8 – Vehicle set for the USA – Part 2.

40	Kia Rio S	ICEV	Small	14597,21	17486,73	0,98	1	0,1	153
41	Lexus IS 300 RWD	ICEV	Medium	31233,31	35569,81	0,96	1	0,1	229
42	Lexus UX 250h	HEV	Med. SUV	26733,04	29401,31	0,95	1	0,1	141
43	Lexus NX 300h	HEV	Med. SUV	30855,69	34214,27	1	1	0,1	178
44	Lexus ES 300h	HEV	Large	31476,03	33821,28	1	1	0,1	127
45	Lexus RX 450h AWD	HEV	Large	39598,88	43068,08	1	1	0,1	183
46	Mercedes C 300 Sedan	ICEV	Medium	32404,93	35931,65	1	1	0,1	186
47	Mercedes E 350 Sedan	ICEV	Large	41442,68	45216,05	1	1	0,1	200
48	Mini Cooper S E (to be launched)	BEV	Small	16063,49	17683,49	0,25	0,08	6,39 / 2,14	0
49	Mitsubishi Mirage ES MT	ICEV	Small	12648,95	15538,47	0,76	1	0,1	150
50	Mitsubishi Outlander PHEV	PHEV	Large	22828,84	24469,04	0,71	1	0,1	74
51	Mitsubishi Outlander ES 2.4	ICEV	Large	21195,43	25015,18	1	1	0,1	204
52	Nissan Kicks	ICEV	Small	15678,11	18828,71	0,82	1	0,1	153
53	Nissan Leaf S Plus (62 kWh)	BEV	Medium	22093,49	23947,49	0,52	0,08	12,39 / 4,15	0
54	Porsche Taycan 4S	BEV	Large	68007,08	69906,08	0,4	0,08	15,71 / 5,26	0
55	Tesla Model 3 Standard Plus	BEV	Medium	27840,36	29181,36	0,57	0,08	10,51 / 3,52	0
56	Tesla Model Y Long Range	BEV	Med. SUV	33825,29	35121,29	0,72	0,08	16,04 / 5,37	0
57	Tesla Model X Long Range Plus	BEV	Med. SUV	54070,97	56104,97	0,8	0,08	21,01 / 7,03	0
58	Tesla Model S Long Range	BEV	Large	54097,51	55807,51	0,69	0,08	21,01 / 7,03	0
59	Toyota Camry Hybrid LE	HEV	Large	21852,74	23843,99	1	1	0,1	105
60	Toyota Corolla Hybrid LE	HEV	Medium	18322,19	20322,29	1	1	0,1	106
61	Toyota Prius L Eco	HEV	Medium	18826,25	20684,75	1	1	0,1	98
62	Toyota Pruis Prime LE	PHEV	Medium	16335,24	17990,08	1	1	0,1	102
63	Toyota Rav 4 Hybrid XLE	HEV	Med. SUV	23256,03	25857,93	1	1	0,1	141
64	Toyota Yaris Sedan L	ICEV	Small	13974,77	17036,87	0,91	1	0,1	162
65	Volkwagen Beetle S	ICEV	Small	18158,72	21747,39	0,97	1	0,1	190
66	Volkswagen Golf VII 1.4 TSI	ICEV	Medium	19533,03	22887,18	0,94	1	0,1	177
67	Volvo S60 Plug-in Hybrid R-Design T8	PHEV	Medium	35750,09	37200,05	1	1	0,1	80
68	Volvo V60 Plug-in Hybrid Polestar T8	PHEV	Medium	43601,13	45051,09	1	1	0,1	80
69	Volvo XC60 Momentum T8 Plug-in Hybrid	PHEV	Med. SUV	35355,5	37200,32	1	1	0,1	97

Table A.9 – Vehicle set for Germany – Part 1.

ID	Model	Tech	Size	TCO (City)	TCO (All-Purpose)	Range	Charging Points	Charging Time (City/All-Purpose)	CO2 emissions
1	Audi A3 Sportback Base 30 TFSI 1.0	ICEV	Medium	16834,58	22197,08	1	1	0,1	124
2	Audi A3 Sportback Base 30 TDI 2.0	ICEV	Medium	17252,22	20799,72	1	1	0,1	112
3	Audi E-Tron Base 55 Quattro	BEV	Med. SUV	31218,9	36570,9	0,62	0,19	19,13 / 6,41	0
4	Audi Q3 Base 35 TFSI 1.5	ICEV	Med. SUV	21533,4	27968,4	1	1	0,1	149
5	Audi Q3 Base 35 TDI 2.0	ICEV	Med. SUV	22412,88	27197,88	1	1	0,1	153
6	Audi Q5 TFSIe Base 55 Quattro	PHEV	Med. SUV	20965,64	23501,16	1	1	0,1	50
7	BMW 225xe Active Tourer	PHEV	Medium	15159,06	17203,7	0,88	1	0,1	38
8	BMW 216i Active Tourer	ICEV	Medium	18300,54	24345,54	1	1	0,1	141
9	BMW 216d Active Tourer	ICEV	Medium	17813,44	21690,94	1	1	0,1	123
10	BMW 330e	PHEV	Medium	19779,8	21619,56	0,99	1	0,1	30
11	BMW 320i	ICEV	Medium	24065,98	30208,48	1	1	0,1	142
12	BMW 318d	ICEV	Medium	13603,74	17563,74	1	1	0,1	125
13	BMW 530e	PHEV	Large	21471,86	23301,22	0,99	1	0,1	30
14	BMW 520d	ICEV	Large	26290,02	30167,52	1	1	0,1	124
15	BMW i3 120 Ah	BEV	Small	10638,72	14310,72	0,44	0,19	8,38 / 2,81	0
16	BMW X3 xDrive 30e	PHEV	Med. SUV	22620,74	25030,42	0,98	1	0,1	43
17	Citroën C1 Live 1.0 Vti 72 S&S CVM	ICEV	Small	8374,96	11982,46	1	1	0,1	85
18	Citroën C5 Aircross Plug-in Hybrid Feel	PHEV	Med. SUV	14842,24	16964,93	0,92	1	0,1	32
19	Citroën C5 Aircross Live 1.2 PureTech 130 S&S	ICEV	Med. SUV	16132,02	21202,02	1	1	0,1	119
20	Citroën C5 Aircross Live 1.5 BlueHDi 130 S&S	ICEV	Med. SUV	15948,18	19165,68	1	1	0,1	102
21	DS 3 Crossback E-Tense	BEV	Medium	11109,24	15501,24	0,46	0,19	9,95 / 3,33	0
22	DS 7 Crossback E-Tense 4x4	PHEV	Med. SUV	19300,24	21267,92	0,91	1	0,1	36
23	Fiat 500 "La Prima" (to be launched)	BEV	Small	8802	11946	0,46	0,19	9,29 / 3,11	0
24	Fiat 500 Hybrid Pop	HEV	Small	9778,3	13580,8	1	1	0,1	88
25	Fiat Panda City Cross Hybrid	HEV	Small	9665,8	13565,8	1	1	0,1	89
26	Ford Mondeo Titanium 2.0 HEV	HEV	Large	20339,8	25799,8	1	1	0,1	127
27	Ford Mondeo Titanium 2.0 TDCi MT	ICEV	Large	19216,8	23341,8	1	1	0,1	132
28	Ford Mustang Mach-E SR RWD	BEV	Large	15661,14	19621,14	0,64	0,19	15,48 / 5,18	0
29	Honda Civic Comfort	ICEV	Medium	15941,14	21693,64	1	1	0,1	134
30	Honda E (to be launched)	BEV	Small	8986,32	13114,32	0,31	0,19	6,30 / 2,11	0
31	Honda CR-V Elegance i-MMD 2WD	HEV	Med. SUV	20475	25642,5	1	1	0,1	120
32	Honda CR-V Elegance 2WD	ICEV	Med. SUV	20073,9	26216,4	1	1	0,1	143
33	Hyundai Ioniq EV Basic	BEV	Medium	8784,36	12096,36	0,44	0,19	8,47 / 2,84	0
34	Hyundai Ioniq Plug-in Hybrid Basic	PHEV	Medium	8983,06	10353,78	1	1	0,1	26
35	Hyundai Ioniq Hybrid Basic	HEV	Medium	14837,58	18932,58	1	1	0,1	97
36	Hyundai Kona EV	BEV	Med. SUV	13161,48	16689,48	0,64	0,19	14,16 / 4,74	0
37	Hyundai Kona Hybrid Trend	HEV	Med. SUV	29978,32	34170,82	1	1	0,1	99

Table A.10 – Vehicle set for Germany – Part 2.

38	Hyundai Tucson Trend 1.6 GDi	ICEV	Med. SUV	18632,8	25360,3	1	1	0,1	158
39	Hyundai Tucson Trend 1.6 CRDi	ICEV	Med. SUV	17280,98	20910,98	1	1	0,1	117
40	Jaguar I-Pace	BEV	Med. SUV	29427,42	34707,42	0,67	0,19	18,74 / 6,27	0
41	Kia e-Niro Edition 7	BEV	Med. SUV	9264	13080	0,65	0,19	14,16 / 4,74	0
42	Kia Niro 1.6 GDI PHEV Edition 7	PHEV	Med. SUV	10445,86	11978,82	1	1	0,1	29
43	Kia Niro 1.6 GDI HEV Edition 7	HEV	Med. SUV	15417,28	19024,78	1	1	0,1	86
44	Kia Optima SW PHEV	PHEV	Large	16437,5	18139,98	1	1	0,1	33
45	Kia e-Soul Edition 7	BEV	Med. SUV	10239,54	14007,54	0,65	0,19	14,16 / 4,74	0
46	Kia Sportage 1.6 CRDI MHEV Edition 7	HEV	Med. SUV	15148,22	18778,22	1	1	0,1	117
47	Kia Sportage 1.6 GDI Edition 7	ICEV	Med. SUV	16888,54	23616,04	1	1	0,1	158
48	Lexus UX 250h Basic	HEV	Med. SUV	19058,78	23056,28	1	1	0,1	94
49	Lexus NX 300h FWD	HEV	Med. SUV	23572,5	28935	1	1	0,1	127
50	Lexus ES 300h Business	HEV	Large	27357,6	31745,1	1	1	0,1	103
51	Lexus RX 450h Entry	HEV	Large	31492,26	37147,26	1	1	0,1	132
52	Mazda MX-30 (to be launched)	BEV	Med. SUV	9270,9	13830,9	0,29	0,19	7,08 / 2,37	0
53	Mercedes B 250e	PHEV	Medium	13819,1	15666,14	0,93	1	0,1	26
54	Mercedes B 160	ICEV	Medium	18377,9	24227,9	1	1	0,1	137
55	Mercedes B 180d	ICEV	Medium	17588,64	21383,64	1	1	0,1	122
56	Mercedes C 300de Limousine	PHEV	Medium	19389,14	21018,02	1	1	0,1	33
57	Mercedes C 200 Limousine	ICEV	Medium	23750,62	30185,62	1	1	0,1	151
58	Mercedes C 180d Limousine	ICEV	Medium	19706,32	23748,82	1	1	0,1	130
59	Mercedes E 300de Limousine	PHEV	Large	27803	29468,28	1	1	0,1	32
60	Mercedes E 200 Limousine	ICEV	Large	33487,58	40507,58	1	1	0,1	164
61	Mercedes E 200d Limousine	ICEV	Large	25336,04	29378,54	1	1	0,1	135
62	Mercedes EQC 400 4MATIC	BEV	Med. SUV	27035,28	32387,28	0,6	0,19	17,70 / 5,92	0
63	Mini Cooper S E	BEV	Small	7857,6	11409,6	0,33	0,19	6,39 / 2,14	0
64	Mitsubishi Outlander PHEV Base	PHEV	Large	13975,44	16367,44	0,92	1	0,1	46
65	Mitsubishi Outlander Spirit MT 2WD	ICEV	Large	19136,8	27034,3	1	1	0,1	184
66	Mitsubishi Space Star Base 1.0	ICEV	Small	7745,3	12132,8	1	1	0,1	102
67	Nissan Leaf Visia Option (40 kWh)	BEV	Medium	7381,86	11485,86	0,39	0,19	7,96 / 2,67	0
68	Nissan Leaf e+ Acenta Option (62 kWh)	BEV	Medium	11079,12	15519,12	0,55	0,19	12,39 / 4,15	0
69	Opel Corsa-E	BEV	Small	7273,32	11305,32	0,48	0,19	9,95 / 3,33	0
70	Opel Ampera-E Plus	BEV	Small	14060,52	18020,52	0,6	0,19	12,83 / 4,29	0
71	Peugeot 108 Active 1.0 Vti 72 S&S CVM	ICEV	Small	9377,92	12985,42	1	1	0,1	85
72	Peugeot 3008 GT Plug-in Hybrid	PHEV	Med. SUV	20259,22	22458,82	0,91	1	0,1	35
73	Peugeot 3008 Active 1.2 PureTech	ICEV	Med. SUV	17119,3	21994,3	1	1	0,1	114
74	Peugeot 3008 Active 1.5 BlueHDi	ICEV	Med. SUV	18044,16	22169,16	1	1	0,1	114
75	Peugeot 508 Allure Plug-in Hybrid	PHEV	Large	17445,22	19492,98	1	1	0,1	28

Table A.11 – Vehicle set for Germany – Part 3.

76	Peugeot 508 GT 1.6 PureTech	ICEV	Large	27087,28	34009,78	1	1	0,1	161
77	Peugeot 508 Active 1.5 BlueHDi	ICEV	Large	18142,92	21937,92	1	1	0,1	120
78	Peugeot 5008 Active 1.2 PureTech	ICEV	Med. SUV	18209,02	23181,52	1	1	0,1	117
79	Peugeot 5008 Active 1.5 BlueHDi	ICEV	Med. SUV	19118,88	23326,38	1	1	0,1	117
80	Porsche Taycan 4S	BEV	Large	41640,9	47544,9	0,45	0,19	15,71 / 5,26	0
81	Renault Clio Hybrid	HEV	Small	12857,08	16367,08	1	1	0,1	82
82	Renault ZOE Life R110 Z.E. 40 (battery hire)	BEV	Small	4093,74	8221,74	0,45	0,19	9,07 / 3,04	0
83	Smart EQ ForTwo (4,6 kW charger)	BEV	Small	4093,5	7957,5	0,19	0,19	3,69 / 1,24	0
84	Smart EQ ForFour (4,6 kW charger)	BEV	Small	4932,9	8892,9	0,19	0,19	3,69 / 1,24	0
85	Tesla Model 3 Standard Range Plus	BEV	Medium	14094	17670	0,58	0,19	10,51 / 3,52	0
86	Tesla Model S Long Range	BEV	Large	30655,8	35215,8	0,87	0,19	21,01 / 7,03	0
87	Tesla Model X Long Range	BEV	Med. SUV	34039,8	39463,8	0,72	0,19	21,01 / 7,03	0
88	Tesla Model Y Long Range	BEV	Med. SUV	20576,4	24032,4	0,72	0,19	16,04 / 5,37	0
89	Toyota Aygo X-play 5-door 1.0 VVT-i	ICEV	Small	10505,8	15380,8	1	1	0,1	113
90	Toyota Corolla Comfort 1.2 Turbo	ICEV	Medium	16580,74	22723,24	1	1	0,1	141
91	Toyota Corolla Comfort 1.8 Hybrid	HEV	Medium	15918,78	20306,28	1	1	0,1	101
92	Toyota Corolla Comfort 2.0 Hybrid	HEV	Medium	17317,78	22095,28	1	1	0,1	118
93	Toyota Corolla Touring Sports Comfort 1.2 Turbo	ICEV	Medium	17092,14	23234,64	1	1	0,1	143
94	Toyota Corolla Touring Sports Comfort 1.8 Hybrid	HEV	Medium	16410,18	20797,68	1	1	0,1	101
95	Toyota Corolla Touring Sports Comfort 2.0 Hybrid	HEV	Medium	18111,68	23181,68	1	1	0,1	119
96	Toyota Prius Plug-in 1.8 Hybrid	PHEV	Medium	10907,64	12310,6	1	1	0,1	28
97	Toyota RAV4 Hybrid Comfort	HEV	Med. SUV	20042,2	24429,7	1	1	0,1	101
98	Toyota Yaris Comfort 1.0 VVT-i	ICEV	Small	11520,52	16103,02	1	1	0,1	107
99	Toyota Yaris Y20 Team Germany 1.5 Hybrid	HEV	Small	12391,86	15999,36	1	1	0,1	84
100	Volkswagen e-Golf VII	BEV	Medium	7494	10590	0,33	0,19	7,08 / 2,37	0
101	Volkswagen ID.3 1st	BEV	Medium	11094,12	14814,12	0,61	0,19	12,83 / 4,29	0
102	Volkswagen Passat GTE 1.4 TSI Plug-in Hybrid	PHEV	Large	16666,88	18399,52	1	1	0,1	28
103	Volkswagen e-Up!	BEV	Small	3476,82	6956,82	0,37	0,19	7,14 / 2,39	0
104	Volkswagen Up! 1.0	ICEV	Small	11032,26	16297,26	0,93	1	0,1	122
105	Volvo XC60 Momentum Pro B4 Hybrid	HEV	Med. SUV	27204,44	33834,44	1	1	0,1	155
106	Volvo XC60 Momentum Pro D4	ICEV	Med. SUV	25004,88	29047,38	1	1	0,1	129
107	Volvo XC60 Recharge R-Design Expression T8	PHEV	Med. SUV	28670,6	31237,84	1	1	0,1	42
108	Volvo V60 Momentum Core D3	ICEV	Medium	20685,24	24315,24	1	1	0,1	117
109	Volvo V60 Recharge R-Design Expression T8	PHEV	Medium	22300,88	24258,16	1	1	0,1	36

APPENDIX B – ELECTRE TRI METHOD

ELECTRE TRI is a non-compensatory outranking multicriteria method for the sorting problematic, i.e. the assignment of alternatives (vehicles) to predefined categories ("avoid", "consider", "shortlist", "buy"). The assignment of an alternative a results from the comparison of a with the profiles defining the limits of the categories. Let F denote the set of indices of the criteria g_1, g_2, …, g_m ($F = \{1, 2, \dots, m\}$) and B the set of indices of the profiles defining $p + 1$ categories ($B = \{1, 2, \dots, p\}$), b_h being simultaneously the upper limit of category C_h and the lower limit of category $C_h + 1, h = 1,2, \dots, p$ (see Figure B.1). The profiles b_{p+1} and b_0 correspond to the ideal and the anti-ideal alternatives, respectively.

In what follows it is assumed, without any loss of generality, that the preference is maximization for all criteria. Schematically, ELECTRE TRI assigns alternatives to categories following two consecutive steps: (1) construction of an outranking relation S that characterizes how alternatives compare to the limits of the categories; and (2) exploitation of the relation S in order to assign each alternative to a specific category.

Construction of the outranking relation

ELECTRE TRI defines an outranking relation S, which validates or invalidates the assertion aSb_h (and b_hSa), whose meaning is "a is at least as good as b_h". The indifference and preference thresholds constitute the intra-criterion preferential information. They account for the imprecise nature of the evaluations $g_j(a)$.

- The indifference the indifference threshold $q_j(bh)$ specifies the largest difference $g_j(a) - g_j(b_h)$ for which a is indifferent to b_h on criterion g_j.

- The preference threshold $p_j(bh)$ represents the smallest difference $g_j(a) - g_j(b_h)$ compatible with a preference in favour of a on criterion g_j.

At the comprehensive level of preferences, in order to validate the assertion aSb_h (or b_hSa), two conditions should be verified.

- *concordance*: for all outranking aSb_h (or b_hSa) to be accepted, a sufficient majority of criteria should be in favour of this assertion;

- *non-discordance*: when the concordance condition holds, none of the criteria in the minority should oppose to the assertion aSb_h (or b_hSa) in a too strong way.

Two types of inter-criteria preference parameters intervene in the construction of S:

- the set of weight coefficients $(w_1, w_2, \dots, w_m)$ is used in the concordance test when computing the relative importance of the coalitions of criteria being in favor of the assertion aSb_h;

- the set of veto thresholds $\{v_1(b_h), v_2(b_h), \dots, v_m(b_h)\}$ is used in the discordance test; $v_j(b_h)$ represents the smallest difference $g_j(b_h) - g_j(a)$ incompatible with the assertion aSb_h.

ELECTRE TRI builds an outranking relation S using an index $\sigma(a, b_h) \in [0,1]$ ($\sigma(b_h, a)$, respectively) that represents the degree of credibility of the assertion aSb_h (b_hSa), $\forall a \in A, \forall h \in B$. The assertion aSb_h (b_hSa) is considered to be valid if $\sigma(a, b_h) \geq \lambda$ ($\sigma(b_h, a) \geq \lambda$), λ being a "cutting level" such that $\lambda \in [0.5,1]$.

Determining $\sigma(a, b_h)$ consist of the following steps (the value of $\sigma(b_h, a)$ is computed analogously):

1. compute the partial concordance indices $c_j(a, b_h)$ $\forall_j \in F$

$$c_j(a, b_h) = \begin{cases} 0 & \text{if } g_j(b_h) - g_j(a) \geq p_j(b_h) \\ 1 & \text{if } g_j(b_h) - g_j(a) \leq q_j(b_h) \\ \dfrac{p_j(b_h) + g_j(a) - g_j(b_h)}{p_j(b_h) - q_j(b_h)} & \text{otherwise} \end{cases}$$

2. compute the comprehensive concordance index $c(a, b_h)$

$$c(a, b_k) = \frac{\sum_{j \in F} w_j c_j(a, b_h)}{\sum_{j \in F} w_j}$$

3. compute the discordance indices $d_j(a, b_h)\ \forall_j \in F$

$$d_j(a,b_h) = \begin{cases} 0 & \text{if } g_j(b_h) - g_j(a) \le p_j(b_h) \\ 1 & \text{if } g_j(b_h) - g_j(a) \le v_j(b_h) \\ \dfrac{g_j(b_h) - g_j(a) - p_j(b_h)}{v_j(b_h) - p_j(b_h)} & \text{otherwise} \end{cases}$$

4. compute the credibility index $\sigma(a, b_h)$ of the outranking relation

$$\sigma(a,b_h) = c(a,b_h) \prod_{j \in F} \frac{1 - d_j(a,b_h)}{1 - c(a,b_h)}$$

where

$$\bar{F} = \{j\ \in F: d_j(a,b_h) > c(a,b_h)\}$$

The values of $\sigma(a, b_h)$, $\sigma(b_h, a)$ and λ determine the preference situation between a and b_h:

- $\sigma(a, b_h) \ge \lambda$ and $\sigma(b_h, a) \ge \lambda \Rightarrow aSb_h$ and $b_hSa \Longrightarrow aIb_h$, i.e. a is indifferent to b_h;
- $\sigma(a, b_h) \ge \lambda$ and $\sigma(b_h, a) < \lambda \Rightarrow aSb_h$ and not $b_hSa \Rightarrow a \succ b_h$, i.e. a is preferred to b_h (weakly or strongly);
- $\sigma(a, b_h) < \lambda$ and $\sigma(b_h, a) \ge \lambda \Rightarrow$ not aSb_h and $b_hSa \Rightarrow b_h \succ a$, i.e. b_h is preferred to a (weekly or strongly);
- $\sigma(a, b_h) < \lambda$ and $\sigma(b_h, a) < \lambda \Rightarrow$ not aSb_h and not $b_hSa \Rightarrow aRb_h$, i.e. a is incomparable to b_h.

Two assignment procedures are then available. The role of these exploitation procedures is to analyze the way in which an alternative a compares to the profiles so as to determine the category to which a should be assigned.

Pessimistic (or conjunctive) procedure:

- compare a successively to b_i, for $i = p, p - 1, \dots, 1$
- b_h being the first profile such that aSb_h, assign a to category C_{h+1} $(a \longrightarrow C_{h+1})$

Optimistic (or disjunctive) procedure:

- compare a successively to b_i, for $i = 1, 2, p,$
- b_h being the first profile such that $b_h \succ a$, assign a to category C_h $(a \longrightarrow C_h)$

If b_{h-1} and b_h denote the lower and upper profile of category C_h, the pessimistic (or conjunctive) procedure assigns alternative a to the highest category C_h such that a outranks b_{h-1}, i.e., aSb_{h-1}. When using this procedure with $\lambda = 1$, an alternative a can be assigned to category C_h only if $g_j(a)$ equals or exceeds $g_j(b_h)$ (up to threshold) for each criterion (conjunctive rule).

The optimistic (or disjunctive) procedure assigns a to the lowest category C_h for each the lowest profile b_h is preferred to a, i.e., $b_h \succ a$. When using this procedure with $\lambda = 1$, an alternative a can be assigned to category C_h when $g_j(b_h)$ exceeds $g_j(a)$ (up to a threshold) at least for one criterion (disjunctive rule). When λ decreases, the conjunctive and disjunctive characters of these rules are weakened.

APPENDIX C – STATISTICAL X ELECTRE TRI ANALYSIS

This section is intended to take a closer look on the results from the ELECTRE-TRI (via Matrix) and compare them with the statistical analysis, in order to understand and predict possible tendances, both at regional and global levels. To better organize the results, these were separated in the country/segment/scenario format.

Table C.1 – ELECTRE TRI x Statistical results: Portugal – Small cars.

Model - Portugal - Small	Tech	Baseline Scenario		TCO Scenario		CO2 Scenario		Economic Scenario	
		City	All-Purpose	City	All-Purpose	City	All-Purpose	City	All-Purpose
BMW i3	BEV	1	1	1	1	1	1	1	1
Citroën C-Zero	BEV	1	1	3	3	1	1	1	1
Citroën C1	ICEV	4	4	4	4	3	3	4	2
Fiat 500	BEV	1	1	1	3	1	1	1	1
Fiat Panda	ICEV	3	3	3	2	3	3	2	1
Honda E	BEV	1	1	1	1	1	1	1	1
Mini Cooper	BEV	1	1	1	2	1	1	1	1
Opel Corsa-E	BEV	1	1	3	4	1	1	1	1
Peugeot e-208	BEV	1	1	3	4	1	1	1	1
Peugeot 108	ICEV	4	4	4	4	3	3	4	3
Renault ZOE	BEV	1	1	2	3	1	1	1	1
Renault Clio	ICEV	2	1	2	1	2	2	1	1
Smart EQ ForTwo	BEV	1	1	4	4	1	1	1	1
Smart EQ ForFour	BEV	1	1	4	4	1	1	1	1
Toyota Aygo	ICEV	3	3	3	3	3	3	3	2
Toyota Yaris	ICEV	3	2	3	2	3	3	2	1
Toyota Yaris Hybrid	ICEV	3	2	3	2	3	2	2	2
Volkswagen e-Up!	BEV	1	1	4	4	1	1	1	1
Volkswagen Up!	ICEV	3	3	3	3	3	3	2	1
Statistical Result		BEV < ICEV		BEV = ICEV		BEV < ICEV		BEV < ICEV	

Table C.2 – ELECTRE TRI x Statistical results: Portugal – Medium cars.

Model - Portugal - Medium	Tech	Baseline Scenario		TCO Scenario		CO2 Scenario		Economic Scenario	
		City	All-Purpose	City	All-Purpose	City	All-Purpose	City	All-Purpose
Audi A3 Sportback	ICEV	3	3	3	3	3	3	3	3
Audi A3 Sportback Diesel	ICEV	3	3	3	3	3	3	3	3
Audi A3 Limousine	ICEV	2	2	2	2	2	2	2	2
Audi A3 Limousine Diesel	ICEV	2	2	2	2	2	2	1	2
BMW 225xe	PHEV	2	3	2	3	2	3	4	4
BMW 216i	ICEV	3	2	3	2	2	2	2	2
BMW 216d	ICEV	3	3	3	3	3	3	2	3
BMW 330e	PHEV	1	2	1	1	1	2	1	3
BMW 320i	ICEV	1	1	1	1	1	1	1	1
BMW 316d	ICEV	1	2	1	2	1	2	1	2
DS 3 Crossback	BEV	1	1	4	4	1	1	1	1
Honda Civic	ICEV	4	4	4	4	3	3	4	3
Honda Civic Sport	ICEV	3	2	3	2	3	2	2	2
Honda Civic Diesel	ICEV	4	4	4	4	3	3	4	4
Honda Civic Sedan	ICEV	3	2	3	2	3	2	2	2
Honda Civic Sedan Diesel	ICEV	3	4	3	4	3	3	3	3
Hyundai Ioniq EV	BEV	1	1	4	4	1	1	1	1
Hyundai Ioniq Plug-in	PHEV	4	4	4	4	4	4	4	4
Hyundai Inoiq Hybrid	ICEV	4	4	4	4	3	3	4	3
Mercedes B 250e	PHEV	2	3	2	3	2	3	3	4
Mercedes B 160	ICEV	3	2	3	2	3	2	2	2
Mercedes B 180d	ICEV	3	3	3	3	3	3	3	3
Mercedes C 300de Limo	PHEV	1	1	1	1	1	1	1	3
Mercedes C 200 Limo	ICEV	1	1	1	1	1	1	1	1
Mercedes C 180d Limo	ICEV	1	2	1	1	1	2	1	2
Nissan Leaf 40 kWh	BEV	1	1	4	4	1	1	1	1
Nissan Leaf 62 kWh	BEV	1	1	4	4	1	1	1	1
Tesla Model 3 Standard Range Plus	BEV	1	1	2	3	1	1	1	1
Toyota Corolla	ICEV	4	4	4	4	3	3	4	3
Toyota Corolla Hybrid	ICEV	4	4	4	4	3	3	4	3
Toyota Corolla Hybrid 2.0	ICEV	3	3	3	2	3	3	3	2
Toyota Corolla Touring	ICEV	4	3	4	3	3	3	4	2
Toyota Corolla Touring Hybrid	ICEV	4	4	4	4	3	3	4	3
Toyota Corolla Touring Hybrid 2.0	ICEV	2	2	2	2	2	2	2	2
Toyota Prius Liftback	ICEV	3	3	3	3	3	3	3	3
Toyota Pruis Plus	ICEV	2	1	2	1	2	1	1	1
Toyota Prius Plug-in	PHEV	3	4	3	4	3	4	4	4
Volkswagen e-Golf VII	BEV	1	1	3	4	1	1	1	1
Volkswagen Golf VII GTE	PHEV	2	2	2	2	2	3	3	3
Volkswagen Golf VII	ICEV	4	3	4	3	3	3	3	3
Volkswagen Golf VII Diesel	ICEV	3	3	3	3	3	3	3	3
Volkswagen ID.3	BEV	1	1	4	4	1	1	1	1
Volvo S60 Recharge	PHEV	1	1	1	1	1	1	1	2
Volvo V60 Recharge	PHEV	1	1	1	1	1	1	1	2
Statistical result		BEV = PHEV < ICEV	BEV < PHEV = ICEV	PHEV < ICEV < BEV	PHEV = ICEV < BEV	BEV < PHEV < ICEV	BEV < PHEV = ICEV	BEV < PHEV = ICEV	BEV < ICEV < PHEV

Table C.3 – ELECTRE TRI x Statistical results: Portugal – Medium SUVs.

Model - Portugal - Med. SUV	Tech	Baseline Scenario		TCO Scenario		CO2 Scenario		Economic Scenario	
		City	All-Purpose	City	All-Purpose	City	All-Purpose	City	All-Purpose
Audi E-Tron	BEV	1	1	1	1	1	1	1	1
Audi Q3	ICEV	2	2	2	2	2	2	2	2
Audi Q3 Diesel	ICEV	2	2	2	2	2	2	2	2
Audi Q5 Plug-in Hybrid	PHEV	1	2	1	2	1	2	1	2
BMW X3 Plug-in Hybrid	PHEV	2	2	2	2	2	2	2	3
Citroën C5 Aircross Plug-in Hybrid	PHEV	3	4	3	4	3	4	4	4
Citroën C5 Aircross	ICEV	4	3	4	3	2	2	4	3
Citroën C5 Aircross Diesel	ICEV	4	4	4	4	3	3	4	4
DS 7 Crossback Plug-in Hybrid	PHEV	3	3	3	3	3	3	3	4
Honda CR-V Hybrid	ICEV	2	2	2	2	2	2	2	1
Honda CR-V	ICEV	3	2	3	2	2	2	2	2
Hyundai Kauai EV	BEV	1	1	4	4	1	1	1	1
Hyundai Tucson	ICEV	3	3	3	3	2	2	3	2
Hyundai Tucson Diesel	ICEV	4	3	4	3	3	3	3	3
Jaguar I-Pace	BEV	1	1	1	1	1	1	1	1
Kia e-Niro	BEV	1	1	4	4	1	1	1	1
Kia Niro PHEV	PHEV	4	4	4	4	4	4	4	4
Kia Niro HEV	ICEV	4	4	4	4	3	3	4	4
Kia e-Soul	BEV	1	1	4	4	1	1	1	1
Kia Sportage Hybrid	ICEV	4	4	4	4	3	3	4	4
Kia Sportage	ICEV	3	3	3	3	2	2	3	2
Lexus UX 250h	ICEV	3	3	3	3	3	3	2	2
Lexus NX 300h	ICEV	2	1	2	1	2	1	1	1
Mazda MX-30	BEV	1	1	4	4	1	1	1	1
Mercedes EQC 400	BEV	1	1	1	1	1	1	1	1
Peugeot 3008 Plug-in Hybrid	PHEV	2	3	2	3	2	3	3	4
Peugeot 3008	ICEV	4	3	4	3	2	2	3	3
Peugeot 3008 Diesel	ICEV	4	4	4	4	3	3	4	4
Peugeot 5008	ICEV	3	3	3	3	2	2	3	3
Peugeot 5008 Diesel	ICEV	3	3	3	3	3	3	3	3
Tesla Model Y	BEV	1	1	2	2	1	1	1	1
Tesla Model X	BEV	1	1	1	1	1	1	1	1
Toyota RAV4 Hybrid	ICEV	3	3	3	3	3	3	2	3
Volvo XC60 Recharge	PHEV	2	2	1	2	2	2	2	3
Volvo XC60 Hybrid	ICEV	1	1	1	1	1	1	1	1
Volvo XC60 Diesel	ICEV	2	2	2	2	2	2	1	1
Statistical result		BEV < PHEV = ICEV		BEV = PHEV = ICEV		BEV < PHEV = ICEV		BEV < PHEV = ICEV	BEV < ICEV < PHEV

Table C.4 – ELECTRE TRI x Statistical results: Portugal – Large cars.

Model - Portugal - Large	Tech	Baseline Scenario		TCO Scenario		CO2 Scenario		Economic Scenario	
		City	All-Purpose	City	All-Purpose	City	All-Purpose	City	All-Purpose
BMW 530e	PHEV	2	3	2	3	2	3	2	3
BMW 520d	ICEV	2	2	2	2	2	2	2	2
Ford Mondeo Hybrid	ICEV	4	3	4	3	3	3	3	3
Ford Mondeo	ICEV	4	4	4	4	3	3	4	3
Ford Mustang Mach-E SR RWD	BEV	1	1	4	4	1	1	1	1
Kia Optima SW PHEV	PHEV	4	4	4	4	3	3	4	4
Lexus ES 300h	ICEV	2	2	2	2	2	2	2	2
Lexus RX 450h	ICEV	1	1	1	1	1	1	1	1
Mercedes E 300de Limo	PHEV	2	2	2	2	2	2	2	3
Mercedes E 200 Limo	ICEV	1	1	1	1	1	1	1	1
Mercedes E 200d Limo	ICEV	2	2	2	2	2	2	2	2
Mitsubishi Outlander PHEV	PHEV	4	4	4	4	3	3	4	4
Mitsubishi Outlander	ICEV	4	3	4	3	2	2	3	2
Peugeot 508 Plug-in Hybrid	PHEV	3	4	3	4	3	4	4	4
Peugeot 508	ICEV	2	2	2	2	2	2	2	2
Poeugeot 508 Diesel	ICEV	4	4	4	4	3	3	4	4
Porsche Taycan	BEV	1	1	1	1	1	1	1	1
Tesla Model S	BEV	1	1	1	1	1	1	1	1
Volkswagen Passat GTE	PHEV	4	4	3	4	4	4	4	4
Volkswagen Passat	ICEV	4	3	4	3	3	3	4	3
Volkswagen Passat Diesel	ICEV	4	3	4	3	3	3	3	3
Volvo XC90 Recharge	PHEV	1	1	1	1	1	1	1	1
Statistical Resut		BEV < PHEV = ICEV		BEV = PHEV = ICEV		BEV < PHEV = ICEV		BEV < PHEV = ICEV	BEV < ICEV < PHEV

Table C.5 – ELECTRE TRI x Statistical results: Brazil – Small cars.

Model - Brazil - Small	Tech	Baseline Scenario		TCO Scenario		CO2 Scenario		Economic Scenario	
		City	All-Purpose	City	All-Purpose	City	All-Purpose	City	All-Purpose
BMW i3	BEV	1	1	1	1	1	1	1	1
Chevrolet Bolt	BEV	1	1	1	1	1	1	1	1
Chevrolet Joy	ICEV	4	4	4	4	2	2	4	4
Chevrolet Joy Plus	ICEV	4	4	4	4	2	2	4	4
Chevrolet Onix	ICEV	4	3	4	4	2	2	4	3
Chevrolet Onix Turbo	ICEV	3	3	3	3	2	2	3	3
Citroën C3 1.2	ICEV	3	3	3	3	2	2	3	3
Citroën C3 Attraction 1.6	ICEV	2	2	2	2	2	2	2	1
Fiat Mobi	ICEV	4	4	4	4	2	2	4	4
Fiat Uno	ICEV	4	3	4	4	2	2	4	3
Fiat Uno Way	ICEV	4	4	4	4	2	2	4	4
Jac Motors Iev20	BEV	1	1	1	1	1	1	1	1
Renault ZOE	BEV	1	1	1	1	1	1	1	1
Toyota Etios X 1.3	ICEV	4	3	4	4	2	2	4	3
Toyota Etios X Plus 1.5	ICEV	3	3	3	3	2	2	3	2
Toyota Yaris	ICEV	2	2	2	2	2	2	2	2
Toyota Yaris Connect	ICEV	2	2	2	2	2	2	2	2
Volkswagen Up!	ICEV	4	4	4	4	2	2	4	4
Volkswagen Up! Turbo	ICEV	4	4	4	4	2	2	4	4
Statistical result		BEV < ICEV		BEV < ICEV		BEV < ICEV		BEV < ICEV	

Table C.6 – ELECTRE TRI x Statistical results: Brazil – Medium cars.

Model - Brazil - Medium	Tech	Baseline Scenario		TCO Scenario		CO2 Scenario		Economic Scenario	
		City	All-Purpose	City	All-Purpose	City	All-Purpose	City	All-Purpose
Audi A3 Sportback	ICEV	3	3	3	3	2	2	3	2
Audi A3 Sedan	ICEV	4	3	4	3	2	2	4	3
A3 Sedan Performance	ICEV	2	2	2	2	2	2	2	2
BMW 320i	ICEV	1	1	1	1	1	1	1	1
BMW 330e	PHEV	1	1	1	1	1	1	1	2
Citroën C4 Lounge	ICEV	4	4	4	4	2	2	4	4
Mercedes C 300	ICEV	1	1	1	1	1	1	1	1
Nissan Leaf 40 kWh	BEV	1	1	3	3	1	1	1	1
Toyota Corolla Hybrid (Petrol/Ethanol)	ICEV	4	4	4	4	2	2	4	4
Toyota Corolla	ICEV	4	4	4	4	2	2	4	4
Toyota Prius	ICEV	3	3	3	3	3	3	3	3
Volkswagen Golf VII GTE	PHEV	3	3	3	3	3	3	3	4
Volkswagen Jetta	ICEV	4	3	4	4	2	2	4	3
Volvo S60 Plug-in Hybrid	PHEV	1	1	1	1	1	1	1	2
Volvo S60	ICEV	2	2	2	2	2	2	2	2
Statistical result		BEV = PHEV = ICEV		BEV = PHEV = ICEV		BEV = PHEV = ICEV		BEV = PHEV = ICEV	

Table C.7 – ELECTRE TRI x Statistical results: Brazil – Medium SUVs.

Model - Brazil - Med. SUV	Tech	Baseline Scenario		TCO Scenario		CO2 Scenario		Economic Scenario	
		City	All-Purpose	City	All-Purpose	City	All-Purpose	City	All-Purpose
Audi Q3	ICEV	4	4	4	4	3	3	4	4
Honda CR-V	ICEV	4	4	4	4	3	3	4	4
Hyundai Tucson	ICEV	4	4	4	4	2	2	4	4
Kia Sportage	ICEV	4	3	4	4	1	1	4	3
Lexus UX 250h	ICEV	3	3	3	3	3	3	3	3
Lexus NX 300h	ICEV	2	2	2	2	2	2	2	2
Peugeot 3008	ICEV	3	3	3	3	2	2	3	3
Peugeot 5008	ICEV	2	2	2	2	2	2	2	2
Toyota RAV4 Hybrid	ICEV	2	3	2	3	2	2	2	3
Volvo XC60 Plug-in Hybrid	PHEV	2	2	2	2	2	2	2	3
Volvo XC60	ICEV	1	1	1	1	1	1	1	1
Volvo XC60 Diesel	ICEV	1	1	1	1	1	1	1	1
Statistical result		PHEV = ICEV		PHEV = ICEV		PHEV = ICEV		PHEV = ICEV	

Table C.8 – ELECTRE TRI x Statistical results: Brazil – Large cars.

Model - Brazil - Large	Tech	Baseline Scenario		TCO Scenario		CO2 Scenario		Economic Scenario	
		City	All-Purpose	City	All-Purpose	City	All-Purpose	City	All-Purpose
BMW 530e	PHEV	3	3	3	3	3	3	3	3
BMW 540i	ICEV	1	1	1	1	1	1	1	1
BMW X5 Plug-in Hybrid	PHEV	1	1	1	1	1	1	1	1
Honda Accord	ICEV	4	4	4	4	3	3	4	4
Hyundai Azera	ICEV	3	3	3	3	2	2	3	3
Lexus ES 300h	ICEV	3	3	3	3	3	3	3	3
Lexus RX 450h	ICEV	2	1	2	1	2	2	2	2
Mercedes E 300	ICEV	2	2	2	2	2	2	2	2
Mercedes S 560	ICEV	1	1	1	1	1	1	1	1
Mitsubishi Eclipe Cross	ICEV	4	4	4	4	2	2	4	4
Mitsubishi Outlander	ICEV	4	4	4	4	2	2	4	4
Mitsubishi Outlander Diesel	ICEV	4	4	4	4	2	2	4	4
Toyota Camry	ICEV	3	3	3	3	1	1	3	3
Volkswagen Passat	ICEV	4	4	4	4	2	2	4	4
Volvo XC90 Plug-in Hybrid	PHEV	3	2	3	2	3	2	2	2
Volvo XC90	ICEV	2	1	3	2	2	1	2	1
Volvo XC90 Diesel	ICEV	2	2	2	2	2	2	2	2
Statistical result		PHEV = ICEV		PHEV = ICEV		PHEV = ICEV		PHEV = ICEV	

Table C.9 – ELECTRE TRI x Statistical results: USA – Small cars.

Model - USA - Small	Tech	Baseline Scenario		TCO Scenario		CO2 Scenario		Economic Scenario	
		City	All-Purpose	City	All-Purpose	City	All-Purpose	City	All-Purpose
BMW i3	BEV	1	1	1	1	1	1	1	1
Chevrolet Bolt EV	BEV	1	1	1	1	1	1	1	1
Chevrolet Spark	ICEV	4	3	4	4	2	2	4	3
Chevrolet Sonic Sedan	ICEV	3	2	3	2	2	2	3	2
Fiat 500e	BEV	1	1	1	1	1	1	1	1
Fiat 500	ICEV	4	3	4	3	2	2	3	3
Honda Fit	ICEV	4	3	4	4	3	3	3	3
Hyundai Veloster	ICEV	2	2	2	2	2	2	2	2
Kia Rio	ICEV	4	4	4	4	2	2	4	4
Mini Cooper	BEV	1	1	3	4	1	1	1	1
Mitsubishi Mirage	ICEV	4	3	4	4	2	2	4	3
Nissan Kicks	ICEV	3	3	3	3	2	2	3	3
Toyota Yaris	ICEV	4	4	4	4	2	2	4	4
Volkwagen Beetle	ICEV	2	2	2	2	2	2	2	2
Statistical result		BEV < ICEV		BEV < ICEV	BEV = ICEV	BEV < ICEV		BEV < ICEV	

Table C.10 – ELECTRE TRI x Statistical results: USA – Medium cars.

Model - USA - Medium	Tech	Baseline Scenario		TCO Scenario		CO2 Scenario		Economic Scenario	
		City	All-Purpose	City	All-Purpose	City	All-Purpose	City	All-Purpose
Audi A3 Sedan	ICEV	2	2	2	2	2	2	2	2
BMW 330e	PHEV	2	2	2	2	2	2	3	2
BMW 330i	ICEV	2	2	2	2	2	2	1	2
Honda Civic	ICEV	4	4	4	4	2	2	4	3
Hyundai Ioniq EV	BEV	1	1	4	4	1	1	1	1
Hyundai Ioniq Plug-in Hybrid	PHEV	4	4	4	4	3	3	4	4
Lexus IS 300	ICEV	2	2	2	2	1	1	2	2
Mercedes C 300 Sedan	ICEV	2	2	2	2	2	2	1	2
Nissan Leaf 62 kWh	BEV	1	1	3	3	1	1	1	1
Tesla Model 3 Standard Plus	BEV	1	1	2	2	1	1	1	1
Toyota Corolla Hybrid	ICEV	4	4	4	4	3	3	4	4
Toyota Prius	ICEV	4	4	4	4	3	3	4	4
Toyota Pruis Prime	PHEV	4	4	4	4	3	3	4	4
Volkswagen Golf VII	ICEV	3	3	3	3	2	2	3	3
Volvo S60 Plug-in Hybrid	PHEV	1	2	1	1	1	2	1	2
Volvo V60 Plug-in Hybrid	PHEV	1	1	1	1	1	1	1	1
Statistical result		BEV < PHEV = ICEV		BEV = PHEV = ICEV		BEV < PHEV = ICEV		BEV = PHEV = ICEV	BEV < PHEV = ICEV

Table C.11 – ELECTRE TRI x Statistical results: USA – Medium SUVs.

Model - USA - Med. SUV	Tech	Baseline Scenario		TCO Scenario		CO2 Scenario		Economic Scenario	
		City	All-Purpose	City	All-Purpose	City	All-Purpose	City	All-Purpose
Audi E-Tron	BEV	1	1	1	1	1	1	1	1
Audi Q5 Plug-in Hybrid	PHEV	2	2	2	2	2	2	2	2
BMW X3 Plug-in Hybrid	PHEV	2	2	2	2	2	2	2	2
Ford Escape Hybrid	ICEV	3	3	3	3	3	3	3	3
Ford Escape Plug-in Hybrid	PHEV	4	4	4	4	3	3	4	4
Honda CR-V Hybrid	ICEV	3	3	3	3	2	2	3	3
Hyundai Kona	ICEV	4	4	4	4	2	2	4	4
Hyundai Kona EV	BEV	1	1	4	4	1	1	1	1
Hyundai Tucson SE	ICEV	4	3	4	3	1	1	4	3
Jaguar I-Pace	BEV	1	1	1	1	1	1	1	1
Kia Niro Hybrid	ICEV	4	4	4	4	3	3	4	4
Kia Niro Plug-in Hybrid	PHEV	4	4	4	4	3	3	4	4
Kia Niro EV	BEV	1	1	3	4	1	1	1	1
Lexus UX 250h	ICEV	2	2	2	2	2	2	2	2
Lexus NX 300h	ICEV	2	2	2	2	2	2	2	2
Tesla Model Y Long Range	BEV	1	1	2	2	1	1	1	1
esla Model X Long Range Plu	BEV	1	1	1	1	1	1	1	1
Toyota Rav 4 Hybrid	ICEV	3	3	3	3	3	3	3	3
Volvo XC60 Plug-in Hybrid	PHEV	1	1	1	1	1	1	1	1
Statistical result		BEV < PHEV = ICEV		BEV < PHEV = ICEV		BEV < PHEV = ICEV		BEV < PHEV = ICEV	

Table C.12 – ELECTRE TRI x Statistical results: USA – Large cars.

Model - USA - Large	Tech	Baseline Scenario		TCO Scenario		CO2 Scenario		Economic Scenario	
		City	All-Purpose	City	All-Purpose	City	All-Purpose	City	All-Purpose
BMW 530e	PHEV	2	2	2	2	2	2	2	2
BMW X5 Plug-in Hybrid	PHEV	1	1	1	1	1	1	1	1
Ford Fusion Hybrid	ICEV	4	3	4	3	3	3	4	3
Ford Fusion Plug-in Hybrid	PHEV	4	4	4	4	3	4	4	4
Ford Mustang Mach-Standard Range	BEV	1	1	2	2	1	1	1	1
Honda Accord Hybrid	ICEV	4	4	4	4	3	4	4	4
Honda Clarity Plug-in Hybrid	PHEV	4	3	4	4	3	3	4	3
Honda Insight	ICEV	4	4	4	4	3	4	4	4
Hyundai Sonata Hybrid	ICEV	4	4	4	4	3	4	4	4
Hyundai Sonata Plug-in Hybrid	PHEV	2	2	2	2	2	2	3	3
Kia Optima Hybrid	ICEV	3	3	3	3	3	3	3	3
Kia Optima Plug-in Hybrid	PHEV	4	4	4	4	3	4	4	4
Lexus ES 300h	ICEV	2	2	2	2	2	2	2	2
Lexus RX 450h	ICEV	1	1	1	1	1	1	1	1
Mercedes E 350 Sedan	ICEV	1	1	1	1	1	1	1	1
Mitsubishi Outlander PHEV	PHEV	3	3	3	3	3	3	3	3
Mitsubishi Outlander	ICEV	4	3	4	3	2	3	4	3
Porsche Taycan	BEV	1	1	1	1	1	1	1	1
Tesla Model S Long Range	BEV	1	1	1	1	1	1	1	1
Toyota Camry Hybrid	ICEV	4	4	4	4	3	4	4	4
Statistical result		BEV < PHEV = ICEV		BEV = PHEV = ICEV		BEV < PHEV = ICEV		BEV < PHEV = ICEV	

Table C.13 – ELECTRE TRI x Statistical results: Germany – Small cars.

Model - Germany - Small	Tech	Baseline Scenario		TCO Scenario		CO2 Scenario		Economic Scenario	
		City	All-Purpose	City	All-Purpose	City	All-Purpose	City	All-Purpose
BMW i3	BEV	1	1	2	1	1	1	1	1
Citroën C1	ICEV	3	3	3	3	3	3	4	3
Fiat 500 EV	BEV	1	1	3	3	1	1	1	1
Fiat 500 Hybrid	ICEV	2	3	2	3	2	3	3	2
Fiat Panda Hybrid	ICEV	3	3	2	3	3	3	3	2
Honda E	BEV	1	1	3	3	1	1	1	1
Mini Cooper	BEV	1	1	4	4	1	1	1	1
Mitsubishi Space Star	ICEV	4	3	4	3	3	3	4	3
Opel Corsa-E	ICEV	1	1	4	4	1	1	1	1
Opel Ampera	BEV	1	1	1	1	1	1	1	1
Peugeot 108	ICEV	3	3	3	3	3	3	3	3
Renault Clio Hybrid	ICEV	1	2	1	1	1	2	1	2
Renault ZOE	BEV	1	1	4	4	1	1	1	1
Smart EQ ForTwo	BEV	1	1	4	4	1	1	1	1
Smart EQ ForFour	BEV	1	1	4	4	1	1	1	1
Toyota Aygo	ICEV	2	3	2	2	2	2	2	2
Toyota Yaris	ICEV	1	3	1	2	1	2	2	2
Toyota Yaris Hybrid	ICEV	1	3	1	2	1	2	1	2
Volkswagen e-Up!	BEV	1	2	4	4	1	1	1	1
Volkswagen Up!	ICEV	2	3	2	2	2	2	2	1
Statistical result		BEV < ICEV		ICEV < BEV	BEV = ICEV	BEV < ICEV		BEV < ICEV	

Table C.14 – ELECTRE TRI x Statistical results: Germany – Medium cars.

Model - Germany - Medium	Tech	Baseline Scenario		TCO Scenario		CO2 Scenario		Economic Scenario	
		City	All-Purpose	City	All-Purpose	City	All-Purpose	City	All-Purpose
Audi A3 Sportback	ICEV	3	3	3	2	3	3	3	2
Audi A3 Sportback Diesel	ICEV	3	3	3	3	3	3	3	3
BMW 225xe	PHEV	3	3	3	3	3	3	3	4
BMW 216i	ICEV	2	2	2	1	2	2	2	1
BMW 216d	ICEV	2	3	2	3	2	3	3	3
BMW 330e	PHEV	1	3	1	3	1	3	2	3
BMW 320i	ICEV	1	1	1	1	1	1	1	1
BMW 318d	ICEV	4	3	4	3	3	3	3	3
DS 3 Crossback	BEV	1	1	4	4	1	1	1	1
Honda Civic	ICEV	3	3	3	3	3	3	3	2
Hyundai Ioniq EV	BEV	1	1	4	4	1	1	1	1
Hyundai Ioniq Plug-in Hybrid	PHEV	4	4	4	4	4	4	4	2
Hyundai Ioniq Hybrid	ICEV	3	3	3	3	3	3	3	3
Mercedes B 250e	PHEV	4	4	4	4	4	4	4	4
Mercedes B 160	ICEV	2	2	2	2	2	2	2	1
Mercedes B 180d	ICEV	2	3	2	3	2	3	3	3
Mercedes C 300de Limo	PHEV	1	3	1	3	1	3	2	3
Mercedes C 200 Limo	ICEV	1	1	1	1	1	1	1	1
Mercedes C 180d Limo	ICEV	1	2	1	2	1	2	2	2
Nissan Leaf 40 kWh	BEV	1	1	4	4	1	1	1	1
Nissan Leaf 62 kWh	BEV	1	1	4	4	1	1	1	1
Tesla Model 3 Standard Range Plus	BEV	1	1	4	3	1	1	1	1
Toyota Corolla	ICEV	3	2	3	2	3	2	3	2
Toyota Corolla Hybrid	ICEV	3	3	3	3	3	3	3	3
Toyota Corolla Hybrid 2.0	ICEV	3	3	3	2	3	3	3	2
Toyota Corolla Touring	ICEV	3	2	3	2	3	2	3	2
Toyota Corolla Touring Hybrid	ICEV	3	3	3	3	3	3	3	3
Toyota Corolla Touring Hybrid 2.0	ICEV	2	2	2	2	2	2	2	2
Toyota Prius Plug-in Hybrid	PHEV	4	4	4	4	4	4	4	4
Volkswagen e-Golf VII	BEV	1	1	4	4	1	1	1	1
Volkswagen ID.3	BEV	1	1	4	4	1	1	1	1
Volvo V60	ICEV	1	2	1	2	1	2	1	2
Volvo V60 Recharge	PHEV	1	2	1	2	1	2	1	2
Statistical result		BEV < PHEV = ICEV	BEV < ICEV < PHEV	PHEV = ICEV < BEV	ICEV < PHEV = BEV	BEV < PHEV = ICEV	BEV < ICEV < PHEV	BEV < PHEV = ICEV	BEV < ICEV < PHEV

Table C.15 – ELECTRE TRI x Statistical results: Germany – Medium SUVs.

Model - Germany - Med. SUV	Tech	Baseline Scenario		TCO Scenario		CO2 Scenario		Economic Scenario	
		City	All-Purpose	City	All-Purpose	City	All-Purpose	City	All-Purpose
Audi E-Tron	BEV	1	1	1	1	1	1	1	1
Audi Q3	ICEV	2	2	2	2	2	2	2	1
Audi Q3 Diesel	ICEV	2	2	2	2	2	2	2	2
Audi Q5 Plug-in Hybrid	PHEV	2	3	2	3	2	3	2	3
BMW X3 Plug-in Hybrid	PHEV	2	2	2	2	2	2	2	3
Citroën C5 Aircross Plug-in Hybrid	PHEV	4	4	4	4	4	4	4	4
Citroën C5 Aircross	ICEV	4	4	4	4	3	3	4	3
Citroën C5 Aircross Diesel	ICEV	4	4	4	4	3	3	4	4
DS 7 Crossback Plug-in Hybrid	PHEV	3	4	3	4	3	4	3	4
Honda CR-V Hybrid	ICEV	2	2	2	2	2	2	2	2
Honda CR-V	ICEV	3	2	3	2	3	2	2	2
Hyundai Kona EV	BEV	1	1	4	4	1	1	1	1
Hyundai Kona Hybrid	ICEV	1	1	1	1	1	1	2	2
Hyundai Tucson	ICEV	3	2	3	2	2	2	3	2
Hyundai Tucson Diesel	ICEV	3	4	3	4	3	3	4	4
Jaguar I-Pace	BEV	1	1	1	1	1	1	1	1
Kia e-Niro	BEV	1	1	4	4	1	1	1	1
Kia Niro PHEV	PHEV	4	4	4	4	4	4	4	4
Kia Niro HEV	ICEV	4	4	4	4	3	3	4	4
Kia e-Soul	BEV	1	1	4	4	1	1	1	1
Kia Sportage MHEV	ICEV	4	4	4	4	3	3	4	4
Kia Sportage	ICEV	3	3	3	3	2	2	3	2
Lexus UX 250h	ICEV	3	3	3	3	3	3	3	3
Lexus NX 300h	ICEV	2	2	2	2	2	2	1	1
Mazda MX-30	BEV	1	1	4	4	1	1	1	1
Mercedes EQC 400	BEV	1	1	1	1	1	1	1	1
Peugeot 3008 Plug-in Hybrid	PHEV	3	3	2	3	3	3	3	4
Peugeot 3008	ICEV	3	3	3	3	3	3	3	3
Peugeot 3008 Diesel	ICEV	3	3	3	3	3	3	3	3
Peugeot 5008	ICEV	3	3	3	3	3	3	3	3
Peugeot 5008 Diesel	ICEV	3	3	3	3	3	3	3	3
Tesla Model X Long Range	BEV	1	1	1	1	1	1	1	1
Tesla Model Y Long Range	BEV	1	1	2	3	1	1	1	1
Toyota RAV4 Hybrid	ICEV	3	3	3	3	3	3	3	3
Volvo XC60 Hybrid	ICEV	1	1	1	1	1	1	1	1
Volvo XC60 Diesel	ICEV	1	2	1	2	1	2	1	2
Volvo XC60 Recharge	PHEV	1	1	1	1	1	1	1	1
Statistical result		BEV < PHEV = ICEV		BEV = PHEV = ICEV		BEV < PHEV = ICEV		BEV < PHEV = ICEV	

Table C.16 – ELECTRE TRI x Statistical results: Germany – Large cars.

Model - Germany - Large	Tech	Baseline Scenario		TCO Scenario		CO2 Scenario		Economic Scenario	
		City	All-Purpose	City	All-Purpose	City	All-Purpose	City	All-Purpose
BMW 530e	PHEV	3	3	3	3	3	3	3	3
BMW 520d	ICEV	2	2	2	2	2	2	2	2
Ford Mondeo Hybrid	ICEV	3	3	3	3	3	3	3	3
Ford Mondeo	ICEV	3	3	3	3	3	3	3	3
Ford Mustang Mach-E SR	BEV	1	1	4	4	1	1	1	1
Kia Optima PHEV	PHEV	4	4	4	4	4	4	4	4
Lexus ES 300h	ICEV	2	2	2	2	2	2	2	2
Lexus RX 450h	ICEV	1	1	1	1	1	1	1	1
Mercedes E 300de Limousine	PHEV	2	2	2	2	2	2	2	3
Mercedes E 200 Limousine	ICEV	1	1	1	1	1	1	1	1
Mercedes E 200d Limousine	ICEV	2	2	2	2	2	2	2	3
Mitsubishi Outlander PHEV	PHEV	3	4	3	4	3	3	4	4
Mitsubishi Outlander	ICEV	3	3	3	3	2	2	3	2
Peugeot 508 Plug-in Hybrid	PHEV	4	4	4	4	4	4	4	4
Peugeot 508	ICEV	2	2	2	2	2	2	2	1
Peugeot 508 Diesel	ICEV	4	3	4	3	3	3	4	3
Porsche Taycan	BEV	1	1	1	1	1	1	1	1
Tesla Model S Long Range	BEV	1	1	1	1	1	1	1	1
Volkswagen Passat GTE	PHEV	4	4	4	4	4	4	4	4
Statistical result		BEV < ICEV < PHEV		BEV = PHEV = ICEV	BEV = ICEV < PHEV	BEV < ICEV < PHEV		BEV < ICEV < PHEV	