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Electric vehicles and psychology

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Abstract: The high diffusion of electric vehicles is evidenced by every sector magazine or by the catalog of all the manufacturers inserting incessantly new models of plug-in hybrid vehicles and battery vehicles. The revolution, or rather rebirth should be said, of electric vehicles is it is always hanging by a thread, as it lacks the involvement of a large number of users. Many psychological mechanisms hinder it. What are the user's most hidden reactions to the new world of vehicles? Is the user ready for the fifth level of automation (fully automatic driving and absence of the driving position)? The purpose of this paper is to present and discuss the psychological aspects that influence the adoption of electric vehicles by users and beyond. Topics such as the egg and chicken paradox (electric vehicles and charging stations, who was born first) but also performance anxiety (range anxiety) will be addressed. Contradictions and irony will characterize this review.

Keywords: electric vehicles, range anxiety, egg and chicken paradox, battery, public perception, key motivators and barriers.)

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1. Introduction

Psychology is an integral part of our daily life. The perception of reality is the result of conditioning, often positive as the favor encountered by renewable energy, to which the human being is subject. The car user is hammered by information that exalts aspects that often have little to do with driving itself.

On the other hand, an ideology of the present reigns, which tries to replicate the actual in order to maintain it in the future. An ideology that sometimes paralyzes the effort to think of the present as son of history, an ideology in which the teachings of the past are obsolete, but also the desire of a new coming future is neglected to a more comfortable present. The scientific aspect is often self-centered, if not hegemonic. The public perception of new coming electric cars is that they are low ranged vehicles, due to the battery, not that electricity is more spread than gasoline stations.

The autonomy of a vehicle with battery is proportional to the capacity of the battery which is proportional to the cost of the vehicle (40-48% of its battery). This is a scientific way of thinking that did not foresee why or how to use battery power, but only exalted the solution: to buy a vehicle with greater autonomy and more expensive. The present is hegemonic, the user often considers battery swapping as a definitive solution to the limited battery charge. This idea represents a transposition of the present into a future, not the future way of transportation.

Can a different approach change the rules of the game, or we will be prisoners of the rules themselves? A general discussion, such as the one addressed in this review, aims to face some problems by highlighting scientific aspects , but also recalling psychological aspects that can reduce the starting scientific basis, not in terms of validity, but in quantity.

To change the point of view, and break the rule of the game, two fundamental tools should be used: pop culture and irony. So a pop aspect is considered as first.

The new millennium began with the strange idea of replacing the internal combustion engine (ICE) of vehicles, characterized by extremely high energy reserve in the tank, with an electric motor, powered by limited size batteries. This choice has already put in crisis the comics industry, which had not already found a single onomatopoeia for the noise of the cars: "Brooomm", "Drooow", "Vroom" and "Roammm" were the most accredited noises, but now we will have to find something more significant than a "Zzzz!".

The matter is serious, to solve the problem the iconic German manufacturer of performance machines Bayerische Motoren Werke (BMW), asked the help of one of the greatest modern composers of movies soundtrack, Hans Florian Zimmer, to create a sound of electric cars, worthy of the ICE sisters [1].

In order to face the issue of silent arrival of vehicles and pedestrian protection, the European Parliament delegated a Commission [2], the result is a noise device to be adopted, called "Audible Vehicle Alert System" and has already triggered a war of noise. Maserati, the luxury brand of the FCA group, which in 2021 will introduce its first electric car on the market, the Granturismo, in order to study the "soundtrack of the Trident" of its electric vehicle (EV), is developing an iconic and distinctive sound at its Innovation Lab development center in Modena. The same philosophy has been adopted by Porsche in its Taycan luxury electric sports car. The buyer can in fact decide to add to his car the Electric Sport Sound, an optional item with cost of € 500, which adds, reproducing both inside and outside the car, a real soundtrack capable of increasing involvement in the guide. Instead, the Jaguar Land Rover has opted for a more ordinary sound, which for its I-Pace SUV, despite using expert sound engineers, has chosen for a simple acoustic warning. The debate is therefore quite open: the sound of the car of the upcoming era must have its roots in the past or must it make us listen to the sound of future?

A scientific aspect lies in the fact that European Commission required to insert an acoustic alarm, but the rules of the game imply that it is more important to perceive the performance of the vehicle than vehicle itself. This is the first paradox that we can meet approaching the world of electric cars.

The great paradox that every nation has faced or is about to face is that of the "egg or chicken", who was born first [3]? The question is whether the market for EVs in a given region can develop with or without the previously creation of a dense electric recharging network. To answer this problem, various scientific works have been carried out, which have contributed to generating a profile of the first adopters of this technology or region in which find a fertile soil. So, paragraphs of this work are dedicated to the adoption phase (user definition, his fears of performance, the search for the most fertile market niches ...). But before adoption there are common phases such the perception phase and then the use phase, or "how others perceive me to drive an ecological vehicle?", such aspect will be addressed as symbolic issue in the following paragraph. Therefore, some paragraphs will be dedicated to perception of the vehicle (problem of marriage or cohabitation?), future use (silver vehicles) but also the status symbol and gender attitude (Viking man).

If the reader is looking for simple answers, the author does not recommend the subsequent reading, since few paradoxes will be solved.

Section 2 will address the problem of finding early adopters, who will help in the diffusion of the innovation. The search for a market niche will be a common theme for several sections, so it is the first faced. The concept of leaders and followers is perhaps a more efficient lever than the analytical evaluation of the total cost of ownership. More important is "how do others see me?", than "How much do I save in ten years?" Section 3 deals with the egg and chicken paradox, should came first the electric vehicles or the charging station? This survey presents some psychological aspects of strong impact. While an excellent excuse to stop innovation is to use the rhetoric of reaction, stating that the system is not ready for the adoption of innovation, on the one hand it shows ow it can develop on characteristics of exclusivity, a autopoietic system, which could also obtain a certificate of ecological friendly! Section 4 challenges a psychological fear, the range anxiety. The human being collects various anxieties, inadequacy in human or working relationships. His carriage has always distinguished him from the point of view of knights and foot soldiers. Is he ready to add another anxiety, related to the carriage, his status symbol? Section 5 tries to dispel the fear of explosion of electric vehicles. In an age of digital information, the sound of a falling tree is louder than a growing forest, so is a vehicle catching fire an original sin for all future vehicles? Section 6 address the problem of gender attitudes and how other view the owner of electric vehicles. Commonplaces are hard to dispel, but can the renaissance of electric vehicles change the rules of the game? Section 7 deals with the upcoming era of automated vehicles and the perception of them. The vehicles of the future have only one certainty, they will still have wheels for a long time. Are human beings willing to trade the pleasure of driving in favor of greater comfort and widespread well-being? Finally section 9 describe the changing of attitude after the trial of an electric vehicle, and at the end conclusions arrive.

2. Finding early adopters

In 1962 Everett Rogers published his “Diffusion of Innovations” [4], defining five different categories/customer types, shown in Figure 1:

1. **Innovator**. They are a small group of people exploring new ideas and technologies, also bored by the previous ones. It includes "gadget fetishists!". In an online marketing context, there are a lot of specialist blogs and media sites to engage them.

2. **Early Adopters**. Considered to be “Opinion Leaders” who may share positive testimonials about new products and services, they can show the efficiency of EVs.

3. **Early Majority**. These are “Followers” who will read reviews by earlier adopters about new products before purchasing, sometimes they can buy used EVs.

4. **Late Majority**. To generalize, these are sceptics who are not keen on change and will only adopt a new product or service if there is a strong feeling of being left behind or missing out. They should buy an EVs but are not enthusiastic.

5. **Laggards**. The descriptor says it all! Typically, they prefer traditional ICE and will adopt new EVs when there are no alternatives. Laggards are convinced of machinations and have their own ideas on everything, often supported by pseudo-scientific reasoning.

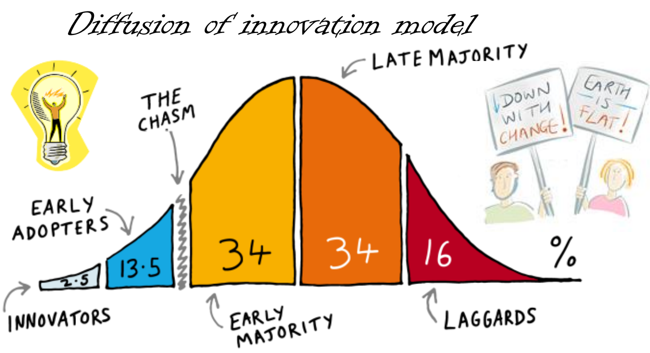

Figure 1 – Diffusion innovation model of Rogers.

For a new technology diffusion is necessary to surpass the so called “Chasm”, so different efforts have been dedicated to understand which incentive policy can help in this phase.

In this paragraph we devote our attention to a review on how some surveys were carried out to define the profile of Early Adopters. Most surveys are carried out by providing a questionnaire to possible categories interested in the change and analyzing the answers with clustering algorithms, to highlight if possible, the category that best responds to the figure of Early Adopters. It is curious to note how similar surveys, changing Countries, define different profiles. Some investigations have a broad spectrum, encompassing entire nations, but others use a narrow band, as in the first case we will address, limited to only one city.

It is well known that there are barriers to purchasing an EV that fall within the socio-economic classification. In [5] a clustering algorithm was undertaken, basing on characteristics of users such age, income, car ownership, home ownership, socio-economic status and education. Nearly 60% of zones of the city of Birmingham fitted the profile of an alternative fuel vehicle driver, and them were found to be located across four areas uttermost from city center. The areas with the poorest people lives, were located in the central part of Birmingham, situation that is common to many cities. By following Rogers's model, the early adopters desire to be the foremost individuals to own alternative fuel vehicles (AFV) and want to see themselves as protagonist models in society. The early majority embraces the ones who will spend longer time deliberating over buying the AFV, waiting the response of early adopters. The late majority adopters are somewhat careful and skeptical about purchasing an AFV, but found that has come a surpass of a mixture of economic conditions and/or social so leading the way to the bought. Finally arrive Laggards, which remain linked to traditional vehicles, or have not the resources to have an AFV, or lack in knowledge and understanding of AFV. The research, concentrated in early stage on the following items 1) age 25-59; 2) home owners; 3) home detached or semi-detached; 4) drive to work; 5) owning two cars; 6) high income level and socio-economic status; 7) higher education. The survey finally defined the profile of Birmingham early adopter user: people with greater affluence, higher car ownership, higher income, higher home ownership (points 2,3,5 and 6).

A national survey in USA profiled the early adopter as young, very high-income individual, house owner, has the perception of EVs are green and clean, has an own car and drives 100 miles per week [6]. The profile of "non adopters" have low incomes and are price sensitive, almost have not a garage, so creating the challenge for safe and secure home charging. So, the lack of infrastructures reveals the problem of "egg and chicken", to be faced in the next section.

Again in USA, another survey [7] profiled the early adopter user as younger to middle aged; having a Bachelor's or higher degree; imagining higher gasoline bills in the following years; making the help of environment a lifestyle; having a garage or a space to charge at home; propended to buy new goods that come on the market.

Instead, an investigation [8], involving buyers of Toyota Prius in UK, shows that the age of the early adopters of Prius owners were men aged 50 and over, an accurate picture of Toyota hybrid customers.

In [9] a study compares the behaviors of early adopters in China and Korea. The performed analysis embraced three factors: functional, symbolic and experimental motives. It finally draws profiles for the two countries. Both embrace the small-sized EV principally and also for the replacement of the main ICEVs. Chinese's preference is for the first-time purchase, showing a level of environmental care higher compared to that of the Korean early adopters, also due to a good electric taxi experience, that cannot be found in Korean case. A very impressive psychological factor is due to the EV usage, the perception related to "how others see me" or "how one thinks about someone else driving an EV" was analyzed, such items show the motives to adopt an EV: *EV differentiates me from others, EV suits my lifestyle, EV makes me seem environmentally friendly, EV shows that I am technologically advanced EV shows that I am a socially responsible*. Chinese early adopters showed the highest degree of importance placed on environmental reasons, whereas for Korean early adopters it was the economic reasons. For the Chinese early majority, economic reasons only placed third; while for Korean early adopters, the environmental reasons placed third. The demographic profile of Chinese responders showed a female percentage of 51%, 64% in the windows 31-40 ages, bachelor degree 71.1%, monthly incomes 1500-3100 $ 49.7%, and for Korean case male 82.5 %, 31-40 ages 49.7%, bachelor degree 73.4%, monthly incomes 3101- 6000 $ 37.9% is the higher percentage, near 1500 -3000 $ 36.7%.

Again, a study confirms the above described profile of Chinese first adopter user: female (57.5%), age 26-35 (48.7%), college education (49.8%), income 2001-4000 $ (30.7%), [10].

Also, Switzerland was analyzed in finding the early adopter users in [11]. The analysis described the barriers present for diffusion, different were the reasons to not buy an EV as one and only family car, only one family out of nine would buy an EV, six families out of nine would buy an

EV as second (or third!) family car, five families out of nine would not buy an EV, preferring instead a HEV.

In [12] the analysis faces attitudes of UK drivers regarding the forthcoming ban on the sale of ICEVs. Profile is about 46% of female drivers, with media age of 38, bachelor degree 28%, with children 42%, little prior knowledge of EVs 7%, environmental care 14% median income 25.200.

In order to look for a common behavior among early adopters, perhaps only the economic parameter is a common denominator, both age and gender fail. Very often research carried out on the same country has shown opposite behaviors.

Last but not least, the analysis is performed on the northern countries of Europe. This is an important issue, since Norway surpass other countries in registrations [13, 14]. European Environment Agency (EEA) [15] reports that 22.5% of sales of EVs of all new cars sold in 2015 were electric. In [16] the analysis reports that the respondents are equal in percentage for the gender, for age the similar percentages were obtained: <25 (18.2%), 25-34 (18.0%), 35-44 (18.1%), 45-54 (19.2%), 55-64 (15.6%), 65+ (10.9%), so generating a transverse profile, describing a common user.

In conclusion, it can be said that the most suitable user perhaps does not exist, the sales data of vehicles in the regions with the highest registration, do not show a greater percentage in age, sex or education; but perhaps because it has passed naturally from early adopters to early majority, thus becoming transversal. The first study that was considered, had the merit of presenting that among the items discussed, the only one that has not been confirmed is that of a higher education, offering the opportunity to claim that it is not necessary to study to have an EV. Fortunately, subsequent studies have shown that higher education is often accompanied by an environmental sensitivity. Across the vary surveys, however, studies have shown a tendency to possess EV as an additional vehicle, a possibility for the wealthier persons. The same studies will question the gender identity of the electric vehicle and will be addressed in the paragraph "Viking men paradox".

A question arises: why did not Stockholm become the city with the greatest number of EVs, despite all the favorable conditions to incentivize early adopters [17]?. European Commission's Innovation Scoreboard placed Sweden as the first of EU's member states in 2013 and 2020 [18,19], so why does Stockholm lag behind Oslo and Copenhagen, capitals both of neighboring Norway and Denmark? In [17] different hypotheses arise, principally divided in three lack of initiatives with different discretization levels, from niche initiative to national directives. 1) Niche initiatives: very few home-grown niche initiatives occur in Stockholm, resulting in very incomplete awareness, experience and knowledge of battery EV (BEV). Local stores did not perform demonstrations. 2) Lack in regime patchworking initiatives: mainly initiatives supported alternative fuels and PHEVs, opposing to BEVs. For the cognitive dimension is probably very important to explain the differences between Stockholm and Oslo, in which a higher observability of BEV is highlighted since EVs are easily recognizable for their license plates, diffuse charging infrastructure visible on-street, not in underground parking structures as Stockholm [16] and access to bus lines, see figure 2. 3) Lack in wide scenario policies: policy directions, visions and economic incentives confuse users, they do not know if in the next years will be supported the private vehicles or collective ones. A solution? As many studies have shown, the driving experience of a BEV makes them unforgettable, "once you try a BEV, you never go back" will be discussed in section 8. A promotion of demonstrations and pilots, kidnapping people and lock them in BEVs, awarding them with an encouraging experience, creating a positive "Stockholm syndrome".

Figure 2 – Proud Norwegian license plate (EL indicates electric vehicle) and use of bus lines.

3. Egg or Chicken paradox

The main paradox that every nation has faced or is about to face in helping the diffusion of EVs is the lack of charging infrastructures. Private and also public infrastructures wait for an initial circulation of EVs, before their construction. But users wait the construction of a net of charging station before the purchase. This situation falls in a typical paradox, named the "egg or chicken paradox", who was born first?

The paradox is already mentioned by ancient Greek philosophers such as Aristotle and Plutarch. But the first who formulates it in the way we know it today is Ambrogio Teodosio Macrobio in his work Saturnalia: "Ovumne prius extiterit an gallina? [3]". The question is whether the market for electric vehicles in a given region can develop without the creation of a dense electric recharging network previously. As for the egg and the hen, neither of the two subjects can exist in the absence of the other.

It is not trivial to tackle this problem, as it lends itself to a cross-sectional analysis, whether it addresses early adopters, range anxiety and other typical grievances towards EVs. The common man is still inclined to think that the EVs will have to be recharged like the ICEs, that is, at a service station that can guarantee autonomy for hundreds of kilometers, all within a few minutes, thus still feeding the idea of the battery swapping. This point of view falls into the hegemonic present. Battery swapping in some cases could expose the batteries to the risk of explosion following an impact accident: 1) since the batteries should be placed not in the inner part of vehicle; 2) since the electrical-thermal control action risks being less efficient on a system that is not necessarily the one exclusively projected for the electric vehicle. This part will be discussed in "my cousin told me EVs explode" section.

Let us consider a scientific point of view. Viola et al in [20] described the performance of different cities in Italy to face this issue. Figure 3 shows a chart in which on the abscissa the number of initial users (early adopters) per coverage station, namely divided by the size of cities, while on the ordinate the quantity of initial user density weighted by the quantity of charging infrastructures. In this chart we can find three levels. In the first one the cities that performed best, surpassed the weight of large number of charging stations and density. Level 2 shows the median attitude of different cities. Level 3 show the performances of laggard cities. This is a direct correlation between EVs and Charging stations. But in view of a research for early adopters conducted with the parameters of the previous paragraph, the cities present in level 1 collect at least two of the four items obtained in previously survey: greater affluence, higher car ownership, higher income, higher home ownership.

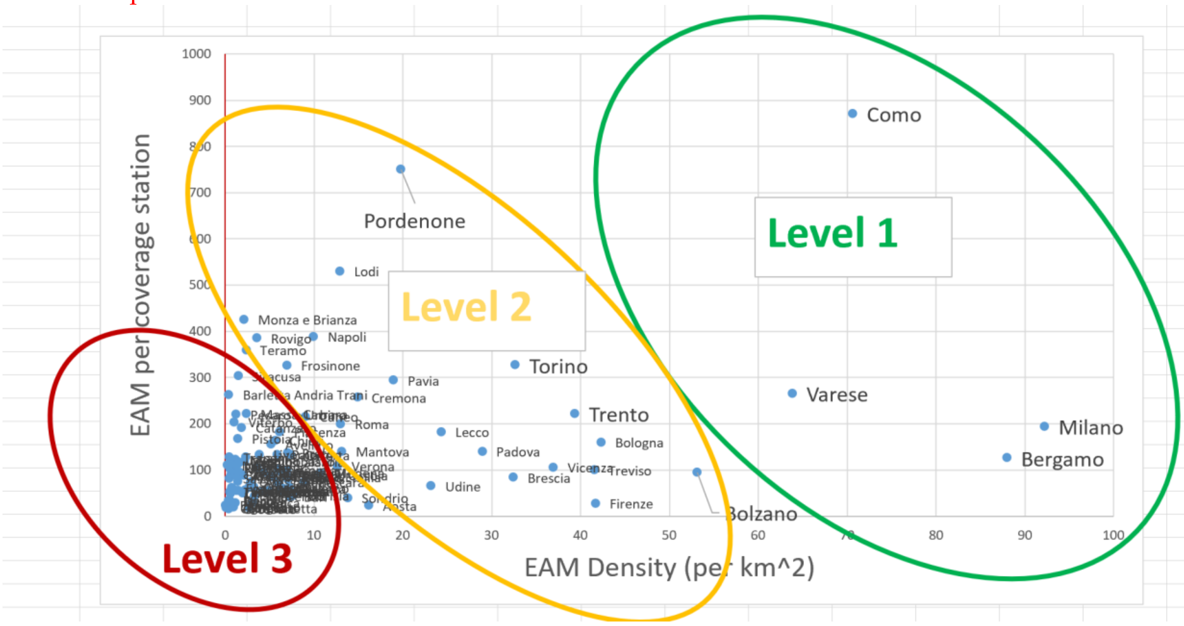

Figure 3 – The egg and chicken paradox: performance of different Italian cities by considering the number of early adopters weighted by number of charging station and dimension of city.

This graph allows us to understand which cities were most favorable to the adoption of EVs, and can be used to predict the adoption of auxiliary systems for the same, such as those on the roadside necessary for the coordination of autonomous driving vehicles. It is necessary to recall to mind that in order to gain the greenhouse gas mitigation targets, plug-in electric vehicles (PEV), both BEV and PHEV, have to be powered with renewable energy. Cities in level 1 of figure 3 require a better quality of the air [20].

Different reviews faced the "egg and chicken" problem and highlighted the different trends in various countries [21-22] but also for gender and age [23].

By following the approach held in [21], we can distinguish demand of charging infrastructure and needs. Roughly these two categories differ as subjective and objective necessities. The demand is indicated by empirical charging behavior of users (generally inside the city), while needs are estimated basing on the required charging refueling to travel certain distances (inter cities). Charging infrastructure needs are affected by influence of subjective parameters such comfort and range anxiety (faced in following section). Once again it is necessary to make a distinction between habits of the hegemonic present, and real perception. High power fast charging stations should be used to ensure continuity corridors, not as a substitute for a full of tank for convenience.

The importance of a strong and pervasive charging infrastructure is fundamental to catch early majority after early adopters' users.

In [21,22], it was shown that 50–80% of all charging events occur at home, second furthermost significant charging place is at work, where 15–25% of PEVs find their energy; less than 10% of all charging actions happen at the remaining sites. In the competition between EVs and Charging stations, Plug-in EVs born first, the numbers show it. By returning to the 10%, although the use of this structure may seem reduced, its action is mainly to convince people of the existence of the alternative to the use of ICEs: Hybrid vehicles, in the definition of micro and mild, they are not the bearers of a revolution, Plug-in ones substantially independent from the charging infrastructure, but only for a limited number of users, those who fall within the category detached house and garage owners, are not able to support the passage to the early majority. To inform of the presence of an ecological alternative to vehicles that use fossil fuels, battery vehicles are necessary that show themselves in the recharging phase: avoiding autopoietic errors, as in domestic recharging for detached houses of wealthy people, or as in the case of Stockholm with underground charging stations, which will be perceived by women as dangerous areas (see gender attitudes paragraph).

So, the 10% is more important than the 90%, and charging stations should born first!

In order to perform a better analysis on the role of charging infrastructure, the attention is focused on the light duty EVs and by considering three types of public charging infrastructures: 1) near home as substitute of private charging; 2) charging near point of interest (grocery stores, cinemas, etc.); 3) fast charging station, to ensure long travel corridors (typically DC stations for the needs).

The near home charging is required for users different from owners of detached houses and garage. By considering large cities with high number of inhabitants per square kilometers (or high number of light vehicles per inhabitants), a widespread public charging network is needed. A parameter to establish the efficiency of this charging network is the vehicle-to-refueling index (VRI), number of PEV per charging point [21]. High VRI indicates either a developed PEV market and low developed infrastructure; a low VRI indicates either a less developed PEV market or a high share of public charging stations. Sweden, the US and Norway showed a high VRI, ranging between 12-19 PEV [21], for Norway a strong contribution is due to the incentives of free use of ferries, car parks and public charging stations [14] so crowding the charging stations. A low VRI was found for Netherlands (4 PEV per charge point) which indicate a diffuse public charging infrastructure. In order to combine the VRI index with the graph of figure 3, it can be understood that a high VRI conforms to the high abscissa; a low VRI could describe very large cities, for which charging stations are easy to find.

An interesting aspect is that for VRIs of a few units, a station for ICEVs has two thousand users, so the presence of a PEV at the ICEV station could be a good advertisement, but it would be like asking a chain of junk food restaurants to support vegetarian and healthy food.

In order to better define the VRI, the following figure, obtained by recent data [24] can be discussed. On abscissa the number of vehicles sharing a charging station, on ordinate the number of charging stations in the long corridors. Norway case is not represented correctly, Norway has 905 charging stations for 100 kms in highway; the number is affected by the fear of being stuck in an uncharged frozen region, as discussed below. Similar VRI for the abscissa as Netherlands and Italy, or France and Germany, can show a similar performance, but in Netherlands the low number is due to high developed charging station network, in Italy not. This can be seen by considering the charging stations that solve the needs [21].

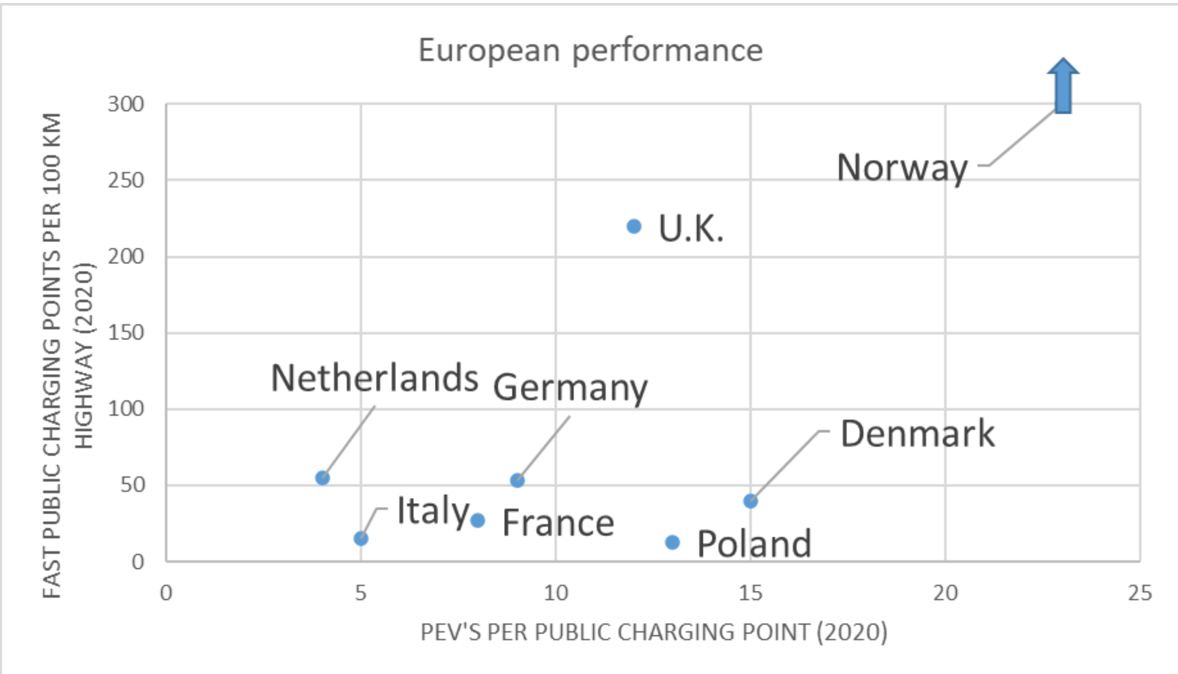

Figure 4 – The egg and chicken paradox: vehicle-to-refueling index VRI for European countries.

In order to address the study of the charging at point of interest, an interesting paradigm has been offered in [25], a recharge area in a University campus has been designed by following the users' attitudes, thus maximizing the energy produced by the photovoltaic system. Similar study has been faced in [22] for home recharging and public one (grocery stores, shopping malls, and in parking lots). In this way an ever-greater vision of PEV can be guaranteed.

Figure 5 reproduces the level of interest of EV users for placing the charging station found in [26].

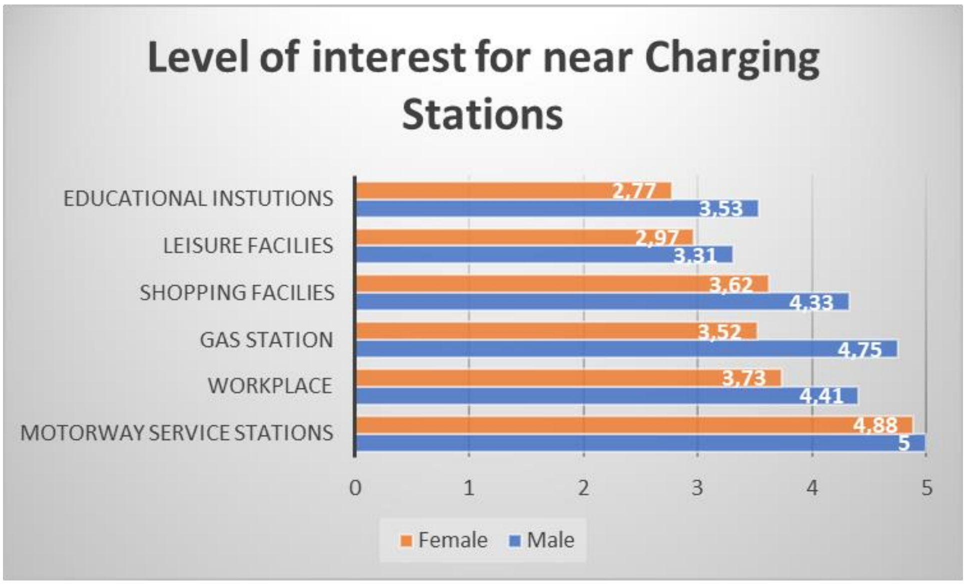

Figure 5 – The egg and chicken paradox: interest level of user for vehicle refueling. Women beat men in recharge employment at educational institutions!

Previously we said that PEVs born first. This however is not a goal, since the result is found on early adopters leading to an autopoietic system, a system capable of reproducing and maintaining itself without external contacts, completely autonomous from the external system and not interacting with it. If the owner of an electric vehicle owns a detached house and a photovoltaic system, he may not be interested to a public recharge, not stimulating the transition from early adopters to early majority, as the case of Stockholm with underground stations [16], not able to involve the interests, attention and awareness, of battery EV [17]. So the remaining 10%, leads to an allopoietic system, in which PEV should stay near the activities of people such physical activity, hiking or otherwise without introducing emissions into the surrounding environment. The following figure 6 shows an allopoietic system. In Italy there is the tradition of lowering a basket, "panaro", from the upper floors to have bread delivered. Even if from a safety point of view the panaro is not a safe method, the same allows to spread the culture of electric vehicles.

Figure 6 – The egg and chicken paradox: solving the absence of charging station problem, the “panaro” solution.

From these arguments it can be estimated that the PEVs were born before the public charging infrastructure, on the other hand the first speeding infraction in the U.S. was committed by a New York city taxi driver in an EV on May 20, 1899, when there was still no idea of public charging stations [27].

4. Range Anxiety

Performance anxiety, in the collective imagination is the main psychological factor that constitutes the barrier for the spread of EVs in various countries. The scientific articles that address the problem of "Range anxiety" are many [26,28-35], and we believe that many of these have some of the most hilarious and amusing titles a researcher can ever find: “Does range matter?...”,“Fast-charging station here, please!...”, “Inaccuracy versus volatility – Which is the lesser evil in battery electric vehicles?”, “Running on empty…”, to cite some of them.

By range anxiety we can mean the anxiety of not succeeding, not reaching the end, an anxiety of performance. It is one of the main obstacles to the spread and social acceptance of BEVs. The battery, seen as a weak element, obscures all the many peculiarities that address a BEV as a winner (excellent reduction in consumption, very low number of moving parts, reduced maintenance, no direct emissions).

Before designing the types of user and anxiety, it is advisable to investigate into history and understand what an ICEV is in the collective imagination.

By following the research of [36] the changes that caused producers and customers to abandon bicycles, horses, EV, cable cars, trolleys, and trains for ICE powered vehicles, can be found in fifty years, from 1890 to 1940. From 1895 to 1910, EVs were more common in most regions of the USA and Europe than ICEVs. This could be considered the golden period for EVs. The decline begins in early 1910.

Ford Motor Company opened the Highland Park Plant in 1910, and subsequentially implemented the moving assembly line in 1913, reducing the costs of model T, blurring EVs. By the 1930s the popularity of the EVs had completely subsided. Looking for a simple reasoning, many engineers and technical experts, explain the decease of the EVs and the rise of the ICEVs as solely a technical matter. They note that EVs suffered insurmountable’ technical handicaps, among these expensive batteries with limited cycle lives and long recharging times, poor acceleration, a limited range.

In 1890 the primary means of transport were horses and horse-drawn carriage. In a day, a horse team might cover up to twenty, miles, with an average step of 3-5 miles per hour. Also, ICEVs were limited for the lack of uniform spare parts, due to the malfunctions of rotating mechanisms. EVs with multiple benefits, became the users’ choice from 1900 to 1910. Commercial workers saw numerous profits in employing EVs. Commodity suppliers of coal, ice, and beer (which we would call energy carriers) trusted predominately on EVs to distribute goods to customers. Electric trucks had an operating range greater than a horse wagon, but less than an ICEVs, so the distribution should increase delivery range while maintaining the equivalent distribution system, and do not radically rearrange whole service and delivery routes. From 1910 ICEVs overcame EVs due to four interconnected categories: technical, economic, political, and socio-cultural issues. Technical factors: ICEVs turned from 3 horsepower noisy and unreliable motor into 30 horsepower efficient motor in 1905, as well as the presence of a wider availability of spare parts. Economic factors: Ford model N was the cheapest car on the market in 1905 ($500). Political errors: Electric companies lacked the momentum, mainly focusing attention on large-scale rural electrification projects and building alliances with electric appliance manufacturers, paving the way to of oil companies and gasoline automakers. Socio-cultural factors: the coup de grace to the dominance of the EVs was dealt by a set of socio-cultural aspects; EVs were associated with conservatism and femininity [36], EVs operated in an easily way and lady drivers especially liked the cleanliness and simplicity of them, and the lack of power was laughed by men operating with ICEVs (this aspect will be taken up again in the gender attitudes section). In the same years was witnessed the “end of the frontier”, more and more complex industrial and capitalist realities arose, increasingly discontented farmers and workers, the United States were becoming too European. In a such scenario, the limited range of EVs cooled the desire of journeys into the wilderness. ICEVs fulfilled the wish for the lost frontier. A longer range also allowed different trips: between 1915 and 1924, Henry Ford, Thomas Edison, Harvey Firestone, and John Burroughs, calling themselves the Vagabonds, embarked on a series of summer camping trips, creating the myth of pastoral and family camping. Social and cultural forces played a fundamental role in transportation decisions, ICEVs build a connection between wilderness and re-humanization, BEVs suffered for the first time the Range anxiety syndrome.

In the same years the European countries experienced the vicissitudes of the great world war, for whose war needs in terms of logistics, the ICE trucks were very useful at the front, so accelerating the decline of means of transport with horses and electric motors.

Range anxiety is defined as the psychological anxiety a consumer experiences in response to the limited range of an electric vehicle [30]. In [32] Authors defined three range levels named competent, performant and comfortable ranges: the first and second are based on technical knowledge of the user on his vehicle and driving skills, competent is due to the self-regulating learning, performance also employs subjective sub-scores due to the idea of range starting from fully charged vehicle and the possibility of reaching new goals, and finally comfortable range is a psychological one, users allow a personal buffer of range resource about 20-25%. The relations between the range levels indicate the probable user information and training for covering a more practically usable range. A higher comfortable range could make drivers reduce their efforts to increase their available range in everyday driving.

In order to explore the Range anxiety Authors in [30] extend the technical and phycological motivation of anxiety in a third category: the one of intransigence derived by Hirschman’s Rhetoric of reaction [37].

The technical anxiety is “when the required range is higher than the range of EVs, and the simplest response includes an investment in charging infrastructures or in increase of batteries capacity”; a phycological anxiety is “when required range is below the one of EVs, but users irrationally are worried about the possibility to finish the charge”, and a simple response to this attitude has given with the experience and driving education (see section of cohabitation or marriage); the rhetorical anxiety is very different, the previous responses fail in solving this problem. The rhetoric reaction “masks” a deeper insecurity, so creating distances from the purchase and use of EVs.

In his The Rhetoric of Reaction: Perversity, futility, jeopardy [37], Hirschman analyzes the rhetoric of "intransigence" or conservatism by contrast to innovation. On the one hand, conservatives will believe that reformism generates perverse effects (the final effect of a reform is the exact opposite of what the reform wanted to pursue), futile (the final effect of a reform is nil, not modifying the pre-existing situation) and / or dangerous (the final effect of a reform is harmful, in the sense that it involves a reduction in general well-being). So the innovation of EVs will create a paradox in generating electric energy from dirty energy sources (perversity); the expensive EVs are not changing this world (futility); overpriced EVs and policies will exclude not rich men and their lifestyle (jeopardy). For the Range anxiety the synthesis of [30] is that EVs lack the range to make safe trips, persons fear being stuck frozen in mountains (jeopardy, Norway has the higher number of charging stations on figure 4 for this issue), even if the a battery could cover 300 kms people need 400 kms and so long (perversity), charging infrastructure fails in fast recharge, people fear to stand in line for hours, to wait for the turn to charge (futility).

In order to give a measure to the anxiety is possible to consider Figure 7, in which is reported the work of [29], the majority of daily range need is 0-80 kms, the mean daily driving range is 72 kms, with median about 48 kms. Orange line shows that 160 kms or more in a day occur only 24 days in a year.

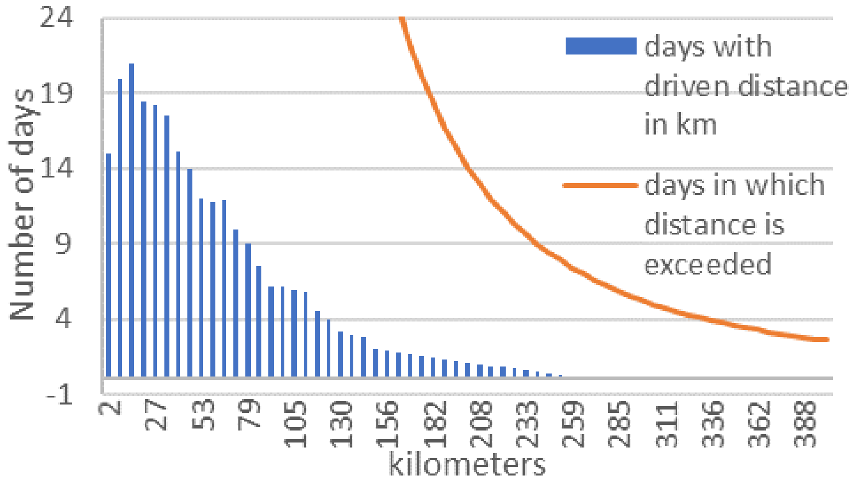

Figure 7– Average daily distance distribution [29]. Blue bars represent the number of days with a given distance is covered. Orange line represent the number of days in which a certain mileage is exceeded.

Figure 8 reproduce the work presented in [33], during travel time SoC decreases and anxiety appears after a comfortable range threshold, indicated in [32] as buffer.

In order to introduce an extremely simplified reasoning, we consider to drive an e-golf, with 300 kms of autonomy suggested by the manufacturer [38], considering a buffer of 20% of comfort level, the EV would have 240 kms of autonomy available, starting with a full SoC. Basing on Figure 6, a similar journey would be faced eight days in a year. If we then consider a future improvement of the battery pack to 400 km in the next three years, the days of anxiety would be halved to four days. The example of a family car (average behavior) in a perspective of average vehicle use, showed the analytical value of the emerging anxiety about the "need" for charging stations (see previous paragraph). The psychological factor has been evaluated in a few days per year, but in places like Norway, where the fear of running out of energy in the middle of a storm incident, many stations have been built in long-distance corridors.

Something that happens in four or eight days in a year, such as a cold, should not constitute a serious fear, to prevent the use of means that contribute to reducing the pollutants that also favor the spread of colds.

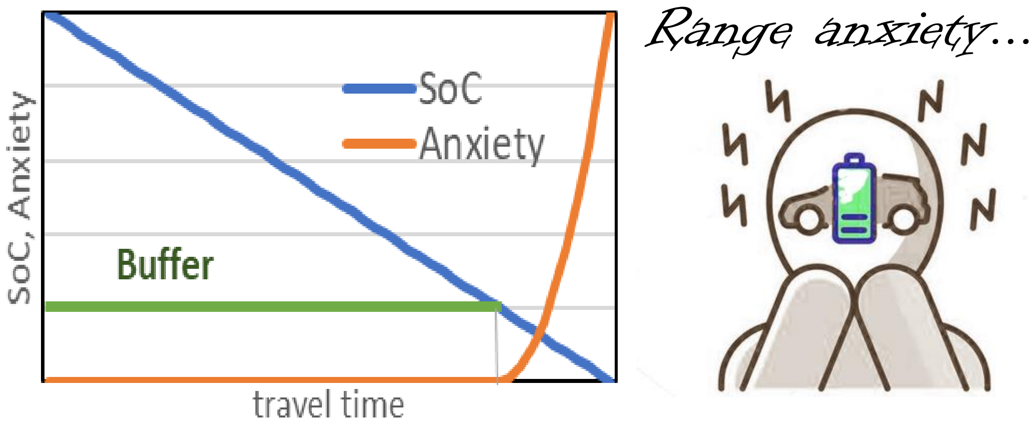

Figure 8 – Profile of SoC and drivers' range anxiety.

In conclusion range anxiety is more psychological or rhetorical, until we discover within ourselves the desire to reach the frontier. We can conclude with Eesop's famous fable about the fox and the grapes. The fox, not being able to reach the bunch of grapes, placed at a higher height , declared that it was unripe. The user who, for rhetoric of reaction, does not want to switch to an EV, will always say that his wishes are out of reach.

5. My cousin told me EVs explode...

An often-distorted view of EVs is that they can catch fire and explode, jeopardizing users; thus, enriching the feelings of rejection towards this new technology. This rejection was previously faced with the rhetoric of the reaction to innovation. There are many documented cases in the technical literature of electrical fires [39-47], even difficult to be extinguished , but generalizing the concept to all EVs is incorrect and dangerous.

To understand the risk, it is necessary to consider the elementary lithium-ion cell made by anode, cathode and electrolyte in a solid-electrolyte interface (SEI) [40]. Also, the separator has fundamental importance, which guarantees the separation between the electrodes. This element is put at risk by mechanical, electrical and thermal accidents. The breakage of the separator places the two charged elements directly in contact, the chemical reaction that is triggered requires almost no external contributions, so it is unstoppable.

The tearing of the separator following a mechanical impact has been studied and addressed in different studies. Following a mechanical abuse (accident for example) the battery pack can undergo a deformation of some cells or even a penetration by external objects, in this way the function of the separator is no longer perpetuated, and internal short circuits (ISCs) can be triggered, compromising the cell and the neighboring ones. The battery packs are therefore positioned in more internal places, making them progressively less accessible, so an improvement in safety precludes battery swapping, solution proposed by those who transport the present into the future (hegemonic present).

A mechanical abuse was found in the case studied in [42], National Highway Traffic Safety Administration (NHTSA) in 2011 opened a defect investigation on a Chevrolet Volt. NHTSA had done a side-impact test on the Volt, then parked it outside, and three weeks later PHEV caught fire. It was necessary to try to understand if the situation could happen again. Similar tests were reproduced and another Volt caught fire after a week from the accident. In the first case the batteries pack was damaged an it lost its coolant fluid, so progressively the temperature increased. That led the NHTSA to consider a ruling forcing hybrid and electric-car batteries to be drained after a wreck. However, before establishing that any road accident can lead to fire risks even after weeks, it is right to refer to other studies. In a research carried out by Dekra, [43] a company expert in road safety, in collaboration with the University Hospital of Gottingen in Germany, similar crash tests were carried out on electric cars. Despite the severe impact to which the cars were subjected, the resulting severely damaged batteries did not catch fire, as the high voltage system was effectively shut down by the safety systems during the accident. EVs were thrown against a pole, simulating a frontal crash at 84 km/h and a side crash at 75 km/h. With the second type of accident, driver would hardly survive both in the case of electric cars and in the case of conventional cars. The potential buyer may no longer be willing to purchase an EV or ICEV after seeing how the vehicle is reduced after the accident, he would prefer not to leave the house anymore, given the severity of the accident, Figure 9 and 10...

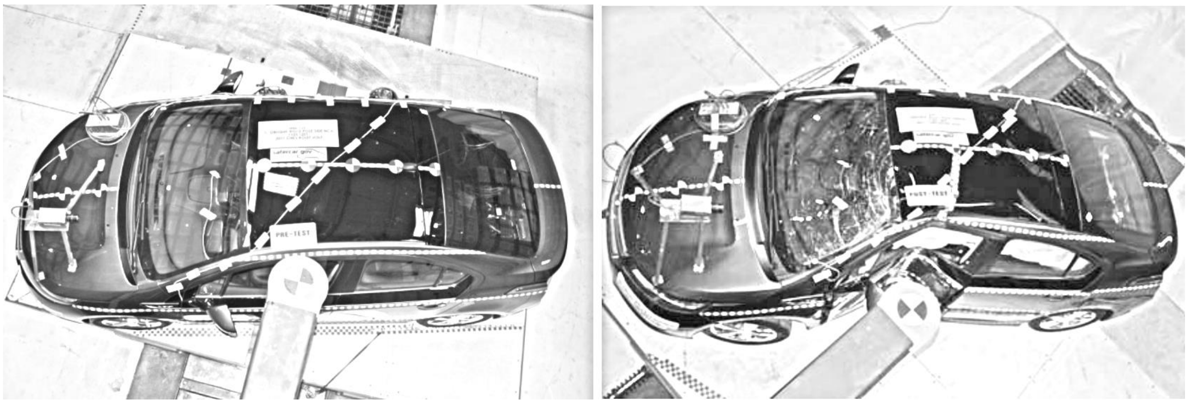

Figure 9 – Chevrolet Volt NCAP pole test, pre-test and post-test [42] .

Figure 10 – Nissan Leaf pole test by Dekra [43] .

The second abuse is the electrical one. We can distinguish an overcharge and an over-discharge abuse. The failure of the battery management system in stopping the charging process before reaching the upper voltage limit is the usual source of overcharge abuse. During the charging phenomenon the raise of voltage is accompanied by a temperature increase rate limited. After the 100% SoC there is a reduction of lithium from the cathode generating a high ramp of cell temperature [41] depending on different used cathode chemistries (varying from 100 to 200% of SoC), so leading to the thermal runaway. In addition, during the overcharge the lithium plating on the anode can create a dendrite path linking the anode to the separator, generating internal short circuits. The over-discharge process is similar, during the discharge the stability of the cell is entrusted by the solid-electrolyte interface, if the SEI is too decomposed, copper dissolution can create a short circuit breaking the separator.

Example of electrical abuses can be found in the report of aircraft malfunctions [44-46]. In the January 7, 2013, incident involving a Japan Airlines Boeing 787-8, JA8297, which was parked at a gate at General Edward Lawrence Logan International Airport, Boston, Massachusetts, when maintenance personnel observed smoke coming from the lid of the auxiliary power unit battery case, as well as a fire with two distinct flames at the electrical connector on the front of the case [44]. No passengers or crewmembers were aboard the airplane at the time, and none of the maintenance or cleaning personnel aboard the airplane was injured. The National Transportation Safety Board determines that the probable cause of this incident was an internal short circuit within a cell of the auxiliary power unit (APU) lithium-ion battery, which led to thermal runaway that cascaded to adjacent cells, resulting in the release of smoke and fire. On January 16 2013 [45], nine days after the previous incident, a Boeing 787-8, operated by All Nippon Airways Co., LTD., took off from Yamaguchi Ube Airport for Tokyo international Airport at 08:11 local time as its scheduled flight 692. When it was climbing through 32,000 foot over Shikoku Island, a message of battery failure came on at 08:27 accompanied by unusual smell in the cockpit. The airplane diverted to Takamatsu Airport and landed there at 08:47. An emergency evacuation was executed using slides on T4 taxiway at 08:49. Four passengers out of 137 occupants suffered minor injuries during the evacuation. Although the main battery was damaged, it did not lead to a fire. An internal short circuit was the cause. About one year after the first serious incident, another similar battery incident occurred at Narita International Airport on January 14, 2014 [46]. While preparing for the next departure of a JAL 787 aircraft at Narita airport from parking spot 72, a maintenance technician in the cockpit noticed white smoke coming up from under the fuselage. The technician went outside immediately but did not see any smoke. Upon returning to the cockpit, the technician noticed messages showing that the main battery and its charger had anomalies. The voltage of the main battery was 27 V. There was no record that any messages for abnormal battery voltages had been displayed during the previous flight, battery should have maximum at 32 V and minimum at 30 V. Upon opening the main battery enclosure after the aircraft was towed into a hangar, traces of spilled electrolyte were observed inside the enclosure. After the events at Boston and Takamatsu in January 2013, the design of the battery and the battery charger unit was modified and a new enclosure for the battery was additionally installed by Boeing. This event at Narita was the first case where smoke was observed from any in-service battery after these improvements were incorporated. The voltage of the main battery was 27 V, which is lower than the nominal voltage of 31 V by the voltage value equivalent to one cell, the main battery would be able to provide the required voltage for continued flight. Boeing decided to follow three principles in redesigning the electrical system. Three layers of improvement were incorporated: First layer, prevent cell overheat; Second layer, prevent cell to cell propagation in case of cell overheat; Third layer, prevent fire, in case of cell to cell propagation. The 250-seat jetliner, which costs about $212 million at list prices, had initial problems. It has had issues also with brakes, fuel lines, hydraulics, and other systems, but the misfortune hit mainly the battery system just for Japanese airlines and in January!

By considering an electrical abuse, generating a thermal abuse we can consider the case described in [47], which reports the fire of an PHEV while driving, which fortunately was stopped allowing the driver to escape. Many curious aspects are described in the accident report. For example, how the melting temperatures of a nickel sheet (1560 °C) have been reached. This aspect makes us understand what the risk of a thermal runaway is, but fortunately the fusion of the collector sheet has electrically separated the part in thermal runaway from the rest of the cells in parallel. It must also be said that the battery pack used on a vehicle was an aftermarket, not that of the PHEV manufacturer and that the phenomenon was triggered by an electric arc generated by an incorrect fastening of a bolt, since the washer had been placed in a wrong way…

The previous abuses manifested a malfunction leading to a thermal consequence. The temperature increases, until the first cell is destroyed, and subsequently the neighboring ones. In [40] three level describe the complete phenomenon: level I, the cell with internal short circuit shows self-extinguish features, there is slow self-discharge but no apparent heat generation, the temperature rise is so slow that cannot be appreciated; in level II, the characteristics of the internal short circuit become more clear, with a faster falling of voltage and faster rise of temperature; finally level III show an thermal runaway with unstoppable heat generation, due to the collapse of separator (SEI). Such approach can be observed in the aircraft accidents previously described and opportunely faced. Figure 11 reproduce the levels described in [40].

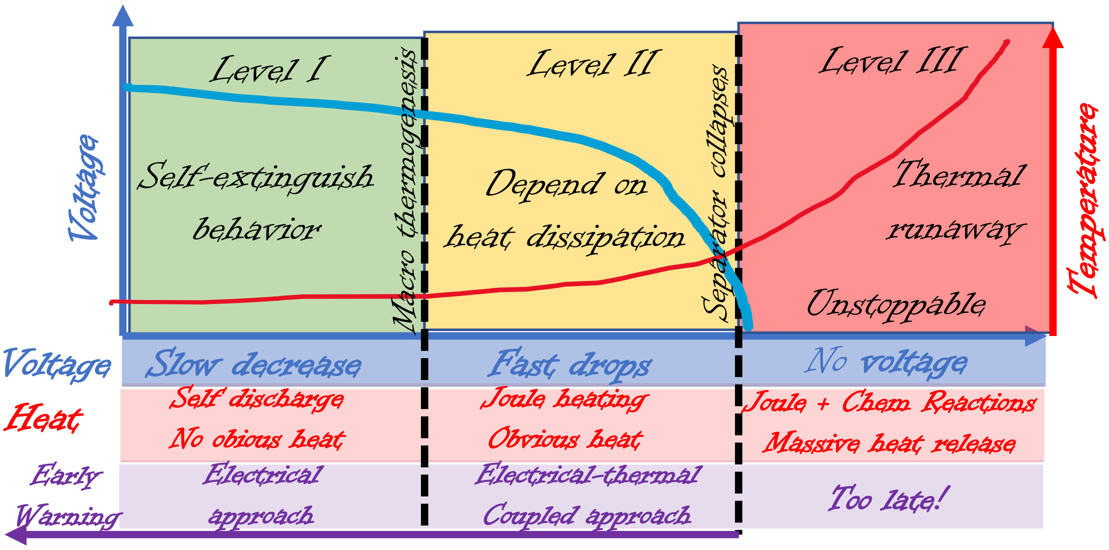

Figure 11 –Different levels of malfunctions: between level I and II macro genesis of heat appears, between level II and III there is the separator collapse, [40].

Auspiciously, the development of the spontaneous internal short circuits takes long time from Level I to Level III, so battery management system can interrupt before reaching level III, and the evacuation of the car, which requires 30 sec, after accident, can be done.

In order to avoid the occurrence of thermal runaway different safety strategies were adopted: modification of cathode materials, modification of anode materials, more stable electrolyte systems, employment of advanced separators. Some modern safety devices are [41]: Cell Vent or Tear-Away Tab allowing safe release of gas if excessive pressure arise inside cells; Shutdown Separator between anode and cathode preventing ionic conduction if cell internal temperature exceeds a certain limit; Current Interrupt Device (CID) protecting against over-current that breaks the internal electrical connection when internal pressure reaches a certain value; Positive Temperature Coefficient of expansion (PTC) disks, placed in the cell header limiting high currents; Current Limiting Fuses, used in place of PTC devices when a sustained discharge is not preferred; Diodes preventing a low SoC cell to be reverse polarized by series higher SoC cells during a massive discharge (bypass diode); Battery Management System (BMS) controlling electrical distribution with a battery pack and protecting against over- or under-voltage conditions as well as excessive current or temperature. The cost of an EV is for 48% due to the battery, but it must be considered that it is not the cost of the cells but of the battery protection system that has a heavy weight. Economy vehicles may not follow the three safety levels described above.

After a similar examination, from a psychological point of view, the user may be led to not consider EVs as safe means. In the interpretation of probability, the self-induced failure of the lithium ion battery occurs but at a very low level. Authors in [40] reports that the failure rate is approximately 1 over 10,000, less than the one of traditional vehicle (7.6 fire accidents per 10,000 vehicles), also explained in [39] since ICEVs, which dissipate a lot of power in heat, have greater possibilities for triggering short circuits in heat-ruined insulators. Authors in [41] estimate that if safety devices work well, a failure rates of lithium ion rechargeable battery cells less than 1 in 10 million or also 1 in 40 million cells. The probability of self-fire of an EV, without previous accident and with a modern safety system, and its following explosion, is close to the probability of dying from a local meteorite impact or having a car accident with a white shark, as suggested in [48], anticipating the Mayans prediction of end of the world, Figure 12.

Odds of dying from selected causes in a human lifetime			
Cause	Odds	Cause	Odds
Motor Vehicle Accident	1 in 90	Lightning strike	1 in 43,000
Suicide	1 in 120	Asteroid Impact Global	1 in 75,000
Homicide	1 in 185	Terrorism (non Middle East)	1 in 80,000
Falls	1 in 250	Tnumami	1 in 100,000
Terrorism (Middle East)	1 in 1000	Insect bite or sting	1 in 100,000
Fire or smoke	1 in 1,100	Earthquake	1 in 135,000
Electrocution	1 in 5,000	Asteroid Impact Regional	1 in 1,600,000
Drowning	1 in 9,000	Food Poisoning by Botulism	1 in 3,000,000
Flood	1 in 27,000	Shark Attack	1 in 8,000.000
Airplane Crash	1 in 30,000	EV explosion	1 in 10,000.000

Figure 12 – Fear of explosion: table of odds of dying from selected causes in a human lifetime. The provability of an electric vehicle's explosion is the same as being hit by a meteorite, as if the extinction of mankind could be accomplished by the EVs in a very strange Mayan prophecy.

6. Viking men paradox or gender attitudes

During the definition of the profile of the first adopters of EVs, some psychological and socio-economic aspects, were highlighted. Although a dualism has been found between an eco-friendly attitude and purchasing behavior, the transition from ICE to EV is often conditioned by general well-being (income, household size, ownership of more than one car), than education, gender or age, but some common recurrent perceptions were found. In the U.S. currently the number of men with EVs is twice that of women one [49]. This should be the reason for deepening the investigation on gender attitude.

Authors in [36], by discussing on the main attitudes to EVs in early years of twentieth century, stated that "*many women preferred to push an electric button than use of shifting gears or turning hand cranks to start*", identifying EVs as girlish, contraposed to ICEVs which required physical prowess (more a matter of cleanliness and hygiene, or quick reflexes, if the crank escaped, we suppose). Articles of popular magazine of these years, as cited in [50], asserted the same thesis: Phil A. Riley suggested that *EVs were perfectly suited to the needs of women, travelling shorter distances, near to home, needing an ever ready runabout for daily use, leaving extended travels and fast driving to the men in gas powered cars*; C. H. Claudy, also stated *EVs suited to women since the need of a circumscribed radius, appropriate for the accomplishment of domestic tasks and starting at the touch of a switch and not by turning crank*. Luckily such ways of thinking have been overcome, even with demonstrations by adventurers like Emily Post and Alice Huyler Ramsey, responsible for pioneering ventures.

But what are the actual gender perceptions towards electric vehicles? Different articles highlight that environmental issues and climate changes are more important for the female than male [9,10,16, 49,51].

In [52] Author reports that women are more sensible to environmental issues and more willingness to reduce their auto use than men do for sustainability reasons. Men are more sensible to power and performance, but also to cycle "unsafe" places to signify confidence and bravery [51].

Authors in [53] suggest that "*males have a higher preference to purchase EVs than females do*" and "*males tend to be much more interested in the latest technological items than females*". This vision depends on many aspects, since as shown in [9,10] the most interested in the adoption of EVs analysis were women.

A common stereotype is about men do never ask information for directions, "*men find it hard to ask for help because it is a submissive gesture*", [50]. In [54] is reported that German engineers, who designed navigators for BMW, insisted that the computer has a male voice. The engineers reasoned that "*men don't want women giving them directions*".

Savacool performed a very interesting analysis facing the gender identity in a five-national survey [51]. Answers to the questions were curious. In order to define the desire of younger drivers, one respondent replied "*Most boys want to drive big, fancy cars, or trucks, for going into the country*" (the desire to reach the frontier, in range anxiety paragraph). "*Nobody wants small car, especially those seeking to be macho Viking men*". A female participant commented that thinking about her parents, her dad wanted a "*huge-back station wagon*", her mom had a little car, to go to work and stuff. Her father has no need to long range journey with family and a pack of dogs, he has no farm to manage, but for him men need a big car. Savacool in [16] returned on the Viking men myth. Again here we report the opinions collected by works of Savacool. "*In a traditional bourgeois family, the man drives the big car and the woman, working half time, has a small car. Now it is shifting around. The man has the small car to arrive at work place every day, the EVs, the woman, by taking kids to football practice and to school and so on, needs a bigger car for that*". So, the myth of shieldmaiden can arrive!

However, if we consider the spread of EVs, it is necessary to make a note. In [49] it was stated that in Maryland there is a big gender gap in EV ownership, but it is possible that most households registered their EVs under male householders. A smart vision has been provided by a female energy expert in Finland [50], stating that although her husband bought the dishwasher and the washing machine, she was the one dealing with daily energy so using them.

In order to better address the issue, and to investigate beneath the surface, it is advisable to consider a Norwegian study, a country in which there was a transition from early adopters to early majority [55]. In this article, the survey is based on an interview with electric vehicle owners, and is aimed at defining gender attitudes. Different factors attract EV users in Norway besides environmentalism and economy. It stated that EVs appear as a symbolic hybrid, with both feminine and masculine connotations. It was found that there was an inclination between both men and women to emphasize that men drive more often and for longer distances.

Gender	Symbolic Practical Cognitive
Male	Fascination for German cars
Female	No such specific interest in cars
Male	Made the math, comparing gasoline, hybrids and Evs
Female	Consider cost in insurance, annual road fees, gas and tolls
Female	Studied the Tesla in car magazines and taken it for a test drive
Female	Not involved
female	Energy efficient and economic driving
Female	Range was prioritised over comfort, while winter coats can be employed to keep bodies warm and batteries long-lasting
Male	Technical 'motor-related' interest
Female	Green lifestyle
Male	Evs has a better control of the vehicle, enhancing manoeuvrability
Male	How fast the car goes from 0 to something in 4 seconds
Female	Transport me comfortably from A to B
Female	EVs has different limits, it is faster
Male	I'm noticing that she uses way more electricity than me, but that's most likely because I've driven it more
Female	He is a bit more used to it
Female	Evs primarily consider the environment
common	The second car has traditionally been 'the wife car' in Norway

common	Dad drives the big, nice, new diesel car while mom drives ´the little old one
common	Smaller car hasn't appealed to men
Female	Men are concerned with the more mechanical aspects of cars
Female	Women focus on comfortable and easy manoeuvring
Male	EV evolution is like going from a Nintendo Entertainment System to a PlayStation 3
Male	New type of driver: electric motorist
Male	Tesla appealed more to men because it symbolised power, speed and status
Female	Environmental profile of the Tesla suited for women
Female	People here really like their big Jeeps and the idea of freedom that they represent, also to go to the bakery
Male	The most common EV in the Nordic Region is a Tesla ... It is a beautiful car, cool to have
Female	satisfaction of "Viking" identity to drive big, fancy cars, or trucks, for going into the country. There are all these small cars but nobody buys them, especially those seeking to be macho "Viking men"
Female	More mechanics are men, that's a very male-dominated branch, men are the decision-makers around the house, and most car salespersons are men
Female	When I think about my parents, it was always my dad who wanted a huge-ass station-wagon and it was my mom who got a little car because she also needed to go to work and stuff
Male	Men find it more difficult to switch to cleaner or small cars, and women can switch easier
Male	My girlfriend for example likes a small car that she can park easily and is easy to go around the city
Male	Who likes big cars that make a lot of noise, go really fast and are super nice and comfy? Men. Who is environmentally-friendly and likes small cars? Then you're girly and more feminine.
Male	EVs are effeminate and environmental
Male	A woman's car is be red, safe, and kind of small and it drives around the city. It will be children friendly and stuff like that, and usually with room for a dog
Male	Men want something driving fast and something with flames or naked women, and driving through a mountain area
Male	EV owners see these characteristics such economic issue, range and public recharge as less important than those interested participants who do not own an EV
Female	stronger preferences than male on specific attributes like range, battery life, public charging and charging time
Male	If you want to go with a blonde you want a car with acceleration. And electric cars they have very good acceleration
Male	If you use a Buddy, you immediately look eighty years old
Male	In a traditional bourgeois household, let's say the man is driving the big car, the woman maybe works half time and has the small car. Now it's shifting around. The man has the small car to get to work every day, the battery car, the woman is driving the kids to practice and to school and football and so on and needs a bigger car for that
Female	the one at home who's actually dealing with the daily energy system is probably the woman. My husband bought the dishwasher and the washing machine, but I'm actually the one using it.
Female	My father wanted a huge-ass station wagon, even if he did not need to long range journey with family and a pack of dogs
Male	The sad part about electrical car is that it doesn't make any noise, and the noise is the sexiest part of the car
Female	It's a real housewives' car. You can put all the groceries in the back, and your handbag between the seats in front. If you haven't bought the stupid centre console you can do that, at least. That's what women have wanted. A place to put their bag.

Figure 13 –Report of different opinions between female and male gender about vehicles and more in detail EVs. Couples have been highlighted in order to show the different way of think. Opinions have been separated in symbolic (sand), practical (green) and cognitive (blue) issues [55 and 51]

7. Autonomous Silver vehicles

The world has never seen so many people over seventy, called the baby boomers. This is called "Graying of Society", and is an actual megatrend human society is facing or about to face [56]. As people grow older, they have a tendency to use more public transport as an alternative of driving their vehicles. As reported in [57], the United Nations estimate that the older populace of the world will increase from 962 million in 2017 to 2.1 billion in 2050, reaching 3.1 billion in 2100. A similar population growth is never accompanied by an equivalent development of transport systems, both for economic problems, but also for logistic ones, since the cities are exploding but also imploding. A radial expansion is accompanied by a development in height. In the early morning there is a convergence from the periphery towards the city center, while in the afternoon rush hours there is a departure from the city towards the periphery, creating a so-called donut effect. In such a situation it is possible that traffic jams, extending for kilometers and taking hours to pass, may arise.

Not conditioned by work problems, there are the elderly, however, have generally considered vulnerable road users [58]. Different are the barriers preventing elderly to drive their vehicles, in [57] are grouped as: health, environmental, economic and social factors. Health factors include physical, psychological and cognitive issues. Physical issue includes limits in ability to walk, cycle, drive, see and use also public transport services. Psychology of ageing hinders to drive since there is the fear to be stuck in a traffic jam or involved in traffic crash. Cognitive limits regard the difficulty to use technology or interpret maps. Environmental factors are related to new road design, with large or high-speed intersections, intimidating elderly to drive them. Economic factors hinder to use taxis for their tariff rate. Social factor is related to the difficulty to leave the familiar place, for example the refuse to discard old little grocery shop to great shopping mall.

One possible solution to the previous barriers is supported by the creation of silver self-driving vehicles, discussed in a survey describing the elderly opinion for different scenarios presented to senior citizens in the province of Utrecht in Netherlands [59]. Four scenarios were studied: 1) automated public transport with fixed schedules and routes, which employs high occupancy vehicles (50 or more person) with fixed stops (similar to a bus system, but with no driver); 2) automated on demand public transport, with low occupancy (6-14 persons); 3) fleet-based automated shared vehicles, which offers carsharing for the family or ride sharing with strangers travelling similar origins and destinations; 4) privately owned automated vehicles, the own driverless vehicle. The survey highlighted different results: a) most of the participants showed a strong preference for on-demand scenarios (2, 3 and 4); b) the shared solutions made it possible to socialize when not traveling with family and friends; c) the participants expressed concern that a high cost could limit frequent use to reach family and friends; d) a complete lack of confidence in the automated driving system was highlighted.

Similar survey was presented in [57] concerning futuristic scenarios allowing the high costly autonomous transportation establishing a dualism between autonomous vehicles (AVs) and roads (also intended as traffic management). Scenario 1: Private AV (PAV) a costly vehicle own by the family, its sharing depends on willingness of the family; as usual roads host unused vehicles limiting transport; a possible decline of public transport, aged will prefer own AV. This scenario is quite a transportation of the hegemonic present in a more technological future. Scenario 2: Unconstrained shared fleet, private ride-sourcing compagnies offering taxi market; the roads become also a market for the companies, some roads are accessible to a given company, others are not, and also a dispute between local authorities that sees private companies as a competitor for the use and regulation of their roads. However, a similar scenario presents economic risks for the use of the service for the elderly. Scenario 3: new demand management, in which PAV and shared AV (SAV) of corporatized companies cohabit; government regulates the access of roads and PAV should become SAV in helping for congestion of roads; the government itself protects the elderly by regulating access to the service. Scenario 4 Public Mobility as a Service (MaaS) , a radical public management in which AVs are regulated to exist only within a government-managed public service with a dynamic ride sharing system, which offers tailored services for older people. Different aspects arise from the reading of these hypothetical scenarios. Except for the first scenario, there will be a revolution in transport systems with an increasingly reduced freedom to move where you want. The use of some roads instead of others could also affect the movement from A to B, a passage from C and D can also change the habits and purchasing attitudes of users.

Roadside structures, communication systems, safety and security issues and business models to implement such solutions are fully explained in [56]. While it seems that public transport such as trains may decline, given the services tailored to the elderly, this cannot be said for their technology. The movement of autonomous vehicles is not possible without the contribution of the most advanced technologies, especially telecommunications. To solve the problem of the limited capacity of existing roads, the absence of side parking spaces is assumed, but this is not enough, it is necessary to increase the travel speed of the roads themselves. What may seem like an ambitious goal can be achieved by inheriting the concept of wagons and moving blocks from trains. The journey of a vehicle from point A to point B can be divided into sub-routes, for which it is possible to find affinities with other vehicles. Assemblies of vehicles with similar destinations (identical in the sub-sections) are constituted as wagons of a train, can be consider about fifteen vehicles, which march compactly like a platoon. Different platoons are addressed in the use of roads with the technology of moving blocks of trains, for which there is always the prediction of the behavior of the previous and subsequent blocks, to reduce the possibility of impact to zero. Different levels of communication are therefore required. The first peer to peer, at the same level, between vehicles to ensure the formation of the platoon. The next level is given by the dialogue between platoons and roads, so that each platoon does not run into any red traffic lights, therefore communication is also assumed with the roadside. Finally, a hierarchically superior system establishes how to aggregate the platoons according to the needs of each vehicle.

Although autonomous driving systems are widespread on some vehicles, a distinction must be made between levels of autonomy from zero (no interlocking) to fully autonomous level 5 (no steering wheel!). Level one is represented by the possibility of correcting maneuvers in dangerous situations (wheel spin, skidding, crossing the middle of the road); level 2 instead sees the vehicle granted the possibility to perform a maneuver (parking); in level 3 the vehicle is given the opportunity to drive long distances by overtaking and crossing intersections, but the driver must always be ready to take command of the situation.

In level 4 the vehicle can proceed without the driver being in the driving position, in level 5 there will be no driving position either.

In the previous declinations it is not mentioned, but increasingly the responsibility of the guide passes from the user to the autonomous system, with progressive assumption of burdens and costs.

For the realization of such a system, the technology is ready, there is a lack of infrastructures whose financing is unattainable for the single municipalities. Autonomous driving must interact in a vehicle-platoon-roads system, therefore a pervasive telecommunications system is necessary, which no car manufacturer can afford, perhaps we will assist some excellent vehicle with its own system, as in the case of Apple which creates both software than hardware, but in other cases we will see vehicles with third-party software, as in the case of phone systems that mount Android platform. These scenarios also require new business models, since the change will be so radical as to revolutionize insurance systems, but also regulatory systems as vehicles with obsolete software or without autonomous driving will no longer be able to circulate. But they also risk limiting the use of first aid and orthopedic departments as accidents will be truly reduced.

It was therefore found that regardless of future scenarios, there is a population target suitable for accepting the automation of vehicles. Contrary to what one may mistakenly think, that the elderly are less likely to change, the propensity to keep their habits and comforts will push them to accept self-driving vehicles, especially for the release of any responsibility. The autonomous vehicles of the future could be called silver vehicles, due to the strong propensity to use them by the elderly.

Baby boomers in order to avoid traumatizing experience of driving in traffic jams, will plebiscite safer and autonomous transportation. But which is attitude of baby boomers' grandchildren?

In [56] is reported that for the younger generation holding a new tablet or phone is more valuable than cruising and driving a Porsche 911 at 20 km/h in city streets, so the baby boomers' grandchildren will embrace the shared modern EV better than their grandparents.

8. Marriage or cohabitation?

Several scientific studies agree that to overcome the initial doubt of performance of EVs, the direct experience on the road is useful [9, 10, 60-66]. Electric vehicle is often seen with an evolution of a golf-kart, but an experience can demonstrate how much fun it is to drive and that it doesn't perform less than ICEV [62]. Common perceptions on EVs faced in the studies are: the limited range, difficulties on charging (lack in charging network), difficulties on refueling at home, "how they see me" (perception of others), driving fun, convenience.

Facing the range issue, interesting study is presented in [63], drivers were forced into critical range situation and learned from them. Range anxiety is studied dividing into range competences, range appraisal, primal appraisal is more a challenge, second one is more a threat, and finally range stress when initial challenge feelings are surpassed by threat feelings. Two trials were performed, first when there is a SoC to end the trip, second without covering range. Both tests reported good adaption effects. The study presented in [64] reported unsatisfactory experiences for the range, for which careful planning was required for journeys with distances greater than 30 km. A very different experience is reported in [65]. After one year of lease drivers stated that they have more promising feelings of EVs and higher buying intentions. Reporting some impressions, someone said “I appreciate experience of driving with one-pedal, without using mechanical brake”; in other case the rhetoric of reaction was confirmed as s driver said “Most people wouldn’t have the patience to drive EVs since of all the brain power was used to plan the trips”, like a refusal to do homework!

The initial difficulties in using the refueling stations were surpassed, it is much cleaner to use a connector than a gasoline gun. The perception on how to improve the charging stations is addressed in [27], a comparison on where to place the charging stations is made between BEV users and interested not users, both categories agree that fast charging stations must serve gas stations, and being in connection points for long journeys; opinions differ on Educational institutes, the BEV users do not believe that they are necessary there, compared to the not owners. Again, do BEV users not believe in higher education as found in the previous paragraphs? At least there is confirmation that to believe more in fast stations near educational institutes there are the female BEV users (71% useful, against 55% useful for male BEV users). For a gender survey the difference between users is reported, for "Willingness to vacate the parking lot" male users show 47% of agreement while female 36%, and for "Charging stations should be well-lit" male show 63% of agreement while female users show 83% of agreement.

The topic of refueling at home was faced in [64] and enthusiastic opinions were found, the most significant EV benefits was the convenience of home recharging, reducing average travelling cost.

Positive reputation is a direct issue faced in [9, 10, 61]. In order deeper to analyze the reasons for owning a BEV, overcoming the need to move from point A to point B, called the functional aspect, there is also the symbolic aspect. Owners are proud to differentiate them from others, show their lifestyle and show the environmentally friendly feelings, but also innovators of new technologies [10].

Finally, the most surprising aspect of the trial experience for everyone was the driving. The stereotype of golf karting has been dissipated, doubts about acceleration have been dispelled, indeed acceleration has been one of the most appreciated aspects. Even the possibility of regenerative braking, as well as from an economic point of view, has shown an aspect of pleasant control of the vehicle [65].

We can therefore conclude that in having to take an important step like that of changing own vehicle for a BEV, the initial insecurity can be dispelled with an adequate test, such as living together before marriage. The partner has always met expectations, although some complained about the need to do their homework to evaluate the routes, afflicted by range anxiety, particular appreciation was shown by overcoming the noise barrier [64, 65], less than 3% declared the acoustics as a barrier after EV experience [60]. Smart people avoid not requiring mental commitment and noisy partner and prefer intelligent and quiet partners.

Figure 14 – Marriage after cohabitation… [64] refers that a 59.2% of the variability of the willingness to purchase an EV after the trial was found.

9. Conclusions

The review was addressed by reporting data present in technical literature and presenting the most curious aspects that fall within the spheres of our daily life. The main psychological attitudes, influencing the transition from conventional ICEV to BEV were presented, and such points of view can be referred to the inertia to abandon the opinions of a hegemonic present, to embrace a future vision. A first goal was to consider what are the reactions of users towards this new product. Some studies were considered to describe the characteristics of early adopters. The survey was not able to define common characteristics, if not the medium-high position from the point of view of economic income. This aspect is also due to the fact that in the embryonic stage EVs cost more than ICEs, and are not very popular as a second hand. Very curious is the description of the users, in some cases people over 50, in others young people worried by how others perceive their way of being green. It was also possible to see a country like Norway where the early adopters reached the first majority. Norway's success has been compared to the lack of leadership in diffusion of EVs of Sweden, a nation accustomed to innovation. This pointed out which policies to avoid, as the employment of underground charging stations. Speaking of charging stations, the problem of the dualism of the egg and the chicken has been addressed, who should be born first? Situations were shown in which the first early adopters users performed in disadvantageous circumstances such as low number of charging stations and high city extensions, but also introduced a metric on the use of charging stations, showing differences between countries, basing on the vehicle recharging coefficient index VRI, also compared with the presence of stations along the highways, to solve the fear of being stuck in a blizzard with unloaded EV. Such fear falls into the broader range anxiety. This anxiety has been discussed and an attempt has also been made to evaluate it numerically, demonstrating that although similar situations can occur in a few days a year, it is still one of the main obstacles to the spread of EVs, precisely because of the theory of the reaction to innovation. Among the false conditions for the adoption of EVs there is the fear that they give rise to unstoppable fires and that all EVs are therefore dangerous. The most famous cases of malfunction present in the technical literature have been cited, showing the paradoxical situations in which such accidents have occurred, from the replacement of the original battery pack with one that is not even well screwed for which the melting temperatures of a nickel sheet (1560 °C) have been reached, to the presence of very destructive tests for the EVs, in which not even the driver would survive, until the unfortunate chain of malfunctions for the planes of Japanese companies in January. Protocols for dealing with cell failures have been recalled, which prevent the phenomenon of thermal runaway with electrical approaches and then combined with thermal ones, which bring the provability of an accident to that of being hit by a meteorite.

The main attitudes towards EVs were recalled, the perception they have of them in northern European countries, between the opposition between Buddy (city car) and Tesla. If from one point of view the EVs were initially considered as girlish or for octogenarians, referring to small vehicles, from the point of view of the category of users falling within the modern Viking men, the advent of Tesla vehicles could connect the world male and female: for enthusiastic males the Tesla is a concentrate of technologies that advances from a Nintendo entertainment system to a PlayStation 3, for enthusiastic women it is a refined place to put the handbag. The advent of autonomous EVs was also taken care of. In this case, the comparison between generations was discussed, older users will prefer silver vehicles, self-driving EVs, but also their grandchildren, for whom it is more important to have a latest generation mobile phone than to drive a Porsche 911 in the city.

Finally, user testimonials have been reported, which are always positive. Small flaws are due to the difficulty of doing homework (calculating charging stops in the journeys) but also the absence of noise has been criticized, by some considered the sexiest part of the vehicle (referring to the ICEVs), but also the part with this survey began, showing the competition between car manufacturers. The driving experience was one of the most surprising aspects. The stereotype of golf karting has been dissipated, indeed for a user a new category of drivers can be defined: electric motorist!

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