# Analysis of barriers to the massification use of private electric vehicles in urban passenger transport in Lima, Peru

## *Análisis de las barreras para la masificación del uso de vehículos eléctricos privados en el transporte urbano de pasajeros en Lima, Perú*

## *Análise das barreiras ao uso generalizado de veículos elétricos particulares no transporte urbano de passageiros em Lima, Peru*

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**Summary. -** The study aims to evaluate and understand the general perception of the interest groups involved in the adoption of electric vehicles on the barriers against their massification. Electric vehicles have benefits such as: making the vehicle fleet energy independent from fossil fuel, improving public health, reducing imports and environmental impact; however, the adoption rate of electric vehicles in many countries is relatively low and varies substantially between countries. developed and developing. In emerging markets, stakeholders must know which barriers are most significant to prevent their massification, consequently determine what policy actions could be applied to help the adoption of electric vehicles. The Social Impact Assessment (SIA) has become a key factor to determine the viability of projects, know the population's expectations about projects or programs, carry out a market study and help in decision making. In this study, we propose an approach for SIA using an integrated gray clustering and entropy weighting method (the IGCEW method), In Peru, four interest groups were identified and the three main barriers were evaluated. As a result, the weights of each barrier in the introduction of electric vehicles in an emerging market will be obtained.

***Keywords:*** Electric vehicles; barriers; Adoption of EV; Emerging markets.

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***Resumen. -*** *El estudio busca evaluar y comprender la percepción general de los grupos de interés involucrados en la adopción de vehículos eléctricos sobre las barreras que impiden su masificación. Los vehículos eléctricos ofrecen beneficios, la mejora de la salud pública, la reducción de las importaciones del petróleo y el impacto ambiental. Sin embargo, la tasa de adopción de vehículos eléctricos en muchos países es relativamente baja y varía considerablemente entre países desarrollados y en desarrollo. En los mercados emergentes, los actores clave deben conocer las barreras más significativas que impiden su masificación para determinar qué políticas podrían implementarse para impulsar su adopción. La Evaluación de Impacto Social (SIA) se ha convertido en un factor clave para determinar la viabilidad de los proyectos, conocer las expectativas de la población sobre proyectos o programas, realizar un estudio de mercado y contribuir a la toma de decisiones. En este estudio, proponemos un enfoque para la SIA utilizando un método integrado de agrupamiento gris y ponderación por entropía (método IGCEW). En Perú, se identificaron cuatro grupos de interés y se evaluaron las tres principales barreras. Como resultado, se obtendrá la ponderación de cada barrera en la introducción de vehículos eléctricos en un mercado emergente.*

***Palabras clave:*** *Vehículos Eléctricos; Barreras; Adopción de VE; Mercados emergentes.*

***Resumo**. -* *O estudo busca avaliar e compreender a percepção geral dos stakeholders envolvidos na adoção de veículos elétricos quanto às barreiras que impedem seu uso generalizado. Os veículos elétricos oferecem benefícios como independência da frota em relação aos combustíveis fósseis, melhoria da saúde pública e redução de importações e impacto ambiental. No entanto, a taxa de adoção de veículos elétricos em muitos países é relativamente baixa e varia consideravelmente entre países desenvolvidos e em desenvolvimento. Nos mercados emergentes, os principais participantes precisam entender as barreiras mais significativas à adoção generalizada e, consequentemente, determinar quais políticas podem ser implementadas para impulsionar a adoção. As Avaliações de Impacto Social (SIA) se tornaram fatores-chave para determinar a viabilidade de projetos, entender as expectativas do público em relação a projetos ou programas, conduzir pesquisas de mercado e contribuir para a tomada de decisões. Neste estudo, propomos uma abordagem para SIA usando um método integrado de agrupamento de cinzas e ponderação de entropia (método IGCEW). No Peru, quatro grupos de interesse foram identificados e as três principais barreiras foram avaliadas. O resultado será uma ponderação de cada barreira à introdução de veículos elétricos em um mercado emergente.*

***Palavras-chave:*** *Veículos elétricos, Barreiras, Adoção de VE; Mercados emergentes.*

**1. Introduction. -** In Peru, particularly in Lima, there is a lack of urban planning and territorial organization. This is exacerbated by massive migration from rural provinces to the city. Thus, exponential population growth (people and cars) has resulted in severe problems with traffic, noise, pollution and health. This situation makes the transportation sector the most critical priority for the Peruvian government, just behind public safety. Peru's transportation sector represents 43% of the national energy demand. In addition, vehicles cause 40% of CO2eq emissions from all energy consumers [1], resulting in a 3% GHG annual emission growth rate. This puts Lima in the 22nd place of most polluted cities in the world. According to WHO, in Lima 15,000 people die annually due to respiratory and cardiac diseases caused or aggravated by environmental pollution [2], It can't be overemphasized that chaotic transportation and uncontrolled pollution negatively impact public health and quality of life, as well as public safety, security and business development, including tourism [3]. According to Peru's National Society of Mining, Petroleum and Energy (SNMPE), the trade balance of hydrocarbons for Peru is negative (more imports than exports) and this situation has caused a trade deficit of US$3,587 million in 2017 [4]. This shows Peru is highly dependent on imported oil, weakening its trade balance. This makes Peru a vulnerable country, economically and strategically.

So, it is imperative that the government of Peru urgently focus on developing and implementing viable and sustainable alternatives to the above-described set of intertwined and interdependent demographics transportation, pollution, health, and safety problems. Clearly, a more effective, efficient and environmentally sound transportation system must be implemented as part of a systemic approach. Transport electrification using renewable sources of energy will significantly reduce emissions, improve public health and enhance quality of life. This is a universal concern in urban areas of both developed and developing countries alike [5]. From the energy supply side, Peru's oil production is decreasing year after year. Considering it is a nonrenewable resource that is now harder to obtain locally and more expensive to buy internationally, transport electrification should be an obvious alternative. But, thus far, it is not in Peru. Note Peru has untapped potential in hydro, solar, wind, geothermal and cogeneration (combined heat and power). But oil and gas, addiction and dependency, are hard to quit.

Europe has the transport white paper as a roadmap towards a competitive and efficient transport system in the use of resources, with goals for 2050, the reduction of GHGs in the European Union of between 80 and 95% in 2050 compared to 1990 levels, in addition the use of conventionally fueled cars in urban transport should be reduced by 50% by 2030, and in cities completely eliminated by 2050 [6]. That is to say, in Europe it is already included in the design of energy and transportation policy [7], as well as in the main polluting countries such as China [8] and the United States. [9]. Peru also has a goal of reducing 40% of CO2 emissions by 2030. According to Peru's Ministry of the Environment (MINAM), this means that by 2030 total GHG emissions must not exceed 179 million tons of CO2eq.

To achieve this goal, and to have a more efficient, competitive, sustainable and less-vulnerable energy matrix, many countries are promoting EVs. Thus, Norway is a leading country with the highest per capital sales of EVs, with the aim of using only EVs from 2025 onwards [10]. Japan planned to increase EV and PHEV adoption rate by 15-20% in new cars by 2020 [11]. However, in an International Energy Agency (IEA) report, EV sales in 2020 were less than 1% of total sales. Germany announced a goal to supply 1 million EVs by 2020 [12], but the IEA reports that the country didn't reach half a million in sales in 2020. Therefore, many leading countries have tried ambitious adoption and deployment goals, but the actual adoption rate is much lower than expected. The percentage of EVs sold in the world during 2020 by country is shown in Figure 1.

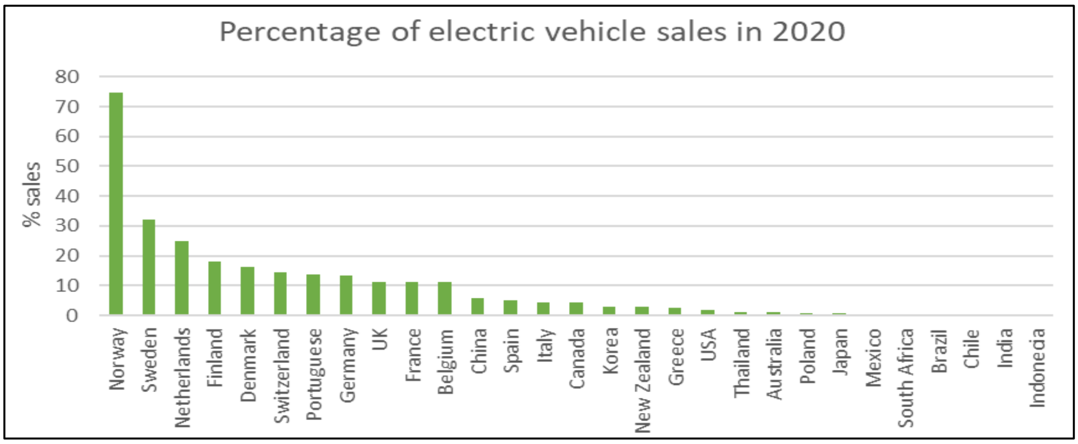


*Figure I. 2020 EV Sales in the World [12].*

Nevertheless, sales of EVs are slowly increasing everywhere. Consequently, we must insist on better ways to increase adoption and penetration of EVs using public, private and non-government means. Figure 1 clearly shows a big gap between EV adoption in developed versus developing countries. Therefore, in emerging markets, greater efforts should be made to achieve a higher penetration rate of electric vehicles. A market study is needed, because a crucial factor that determines the success or failure of a new technology is user acceptance [13].

Despite the many EV benefits, technological change and sustainable energy conversion are very slow, particularly in developing countries. To accelerate widespread EV adoption, several obstacles must first be overcome. An important barrier is the natural resistance to change of consumers with respect to new technologies, that may be considered foreign or unproven [14]. Thus, seriously considering such attitude is key in first understanding the barrier and eventually in overcoming it. Acceptance by a specific user is hard to predict, and attitudes toward EVs vary greatly between real and potential users [15] for BEV, it is particularly important to acknowledge that entrenched perceptions are affected by historical concerns (often no longer valid) with respect to low performance, poor functionality and safety [16].

It has been shown that it is important to deeply analyze attitudes and perceptions, with respect to widespread adoption [14]. Thus, social impact evaluation, such as SIA, applied to stakeholders at the outset of projects, by integrating technical, social and behavioral perspectives, has been proposed to achieve effective transport decarbonization [17]. Some of the main challenges for adoption include battery technology (capacity/ range/weight), battery cost, and charge infrastructure. However, intrinsic consumer acceptance is important, since many personal and subjective considerations make up ultimate decision criteria [14]. This work focuses on studying the main and most visible barriers to EV adoption, such as cost, range, and charging time. We will quantify with weights each of such barriers as perceived in the Lima, Peru, automotive market. This article contributes in determining what barrier is the most influential and provides a deeper understanding on how EV stake holders make adoption decisions. Such new knowledge should be useful to both public and private organizations.

**2. State of the art. -**Widespread adoption of EVs has had resistance in countries and cities. Some barriers are more important than others. Barriers often vary by location, market, type of vehicle, vehicle application, culture, economics, geography and energy resources. According to Berkeley et al., 2018, in Europe resistance to adoption is characterized by 12 barriers made of two main groups: “economic uncertainty” and “socio- technical factors.” Economic uncertainty is associated with age and geography, while the socio-technical issues are related to gender [18]. EV sales in 32 European countries identified country economic standing and fuel price [19].

In the Nordic region, common barriers are EV range, price and charge infrastructure in spite of technological progress. It has been shown that many barriers are highly interrelated and, in general, connected to consumer knowledge and experience [20]. In Sweden, new barriers were identified: the number of charge stations and charging preferences [21]. In the UK, the main barrier reported by consumers is EV range [22]. In Ireland, another set of barriers includes lack of sustained promotion and consumer awareness, thus EVs represent only 0.7% of new vehicles in the 2017 market, a much lower share than those in neighbor countries [23]. In the Netherlands, Amsterdam especially, in 2016, selecting an EV may be impeded by its purchase price and EV residual value uncertainty [24]. In Germany, the defining barriers for private buyers are EV price and range, according to survey data [25] There, high battery cost and immature technology cause only a few BEV and HEV to be considered cost effective without subsidies, when compared to ICEVs [26].

In the UK and Germany, stakeholders report that technology bugs continue to plague EVs' commercial viability. Other barriers are fragmented infrastructure, lack of standards and regulations, and new technology skepticism among consumers [27]. In Switzerland and Finland, a key barrier to widespread adoption is BEV battery capacity, which is the main cause of range anxiety [28]. In Italy, the main barrier is high prices of EVs as compared with conventional cars. In Norway, financial incentives triggered a lower TCO for EVs. In the Netherlands, France and the UK, EV TCO is close to those of ICEVs. In other countries, EV TCOs continue to be higher than conventional cars [29]. Similarly, a study by Palmer shows that in the UK and the US (California and Texas), TOC of every type of electric vehicles (BEV, EVH, and PHEV) is relatively higher than the TOC of ICEV. But the gap has been reduced since the introduction of more EVs in 2015. The gap changed less in the UK, due primarily to the lack of EV subsidies [30]. In France, high cost, lack of charge infrastructure and low promotion are considered the most influential barriers [31]. In Latvia, absence of charge infrastructure and high initial cost are the two defining factors for EV adoption [32]. In the US, early in the process, existing barriers included perceived EV uncertainty and limited range, followed by overall cost [14].

In Asia, a report from Singapore shows that even though EV ownership cost is similar to ICEV's, remaining barriers to adoption are battery technology (range), charge infrastructure, public perception and other related cost factors [33]. In China (Tianjin) public perception barriers to BEV were surveyed, showing that high battery cost topped the barrier list [34]. Other Chinese authors said that in smaller cities with lower income, smaller population and infrastructure limitations, the consumers are more sensitive to purchase price, purchase subsidies and charge station coverage, in contrast to larger cities with more EVs [35]. A different report (He, Zhan, & Hu, 2018) shows that personal norms and consumer personality have a positive influence in proclivity to EV purchasing; specifically, consumers' innovation attitude and environmental concerns were influential. However, environmental concerns are tempered with high external EV cost, including actual purchase cost and perceived complexity [36].

In South America, barriers to implementing a fleet of EV taxis in the city of Cuenca, Ecuador, are broken down as follows: 50% are technological barriers, including range, charge time, charge infrastructure, and certified service personnel; then 25% is vehicle performance; and the remaining 25% is costs (vehicle, battery) and limited potential user knowledge [37]. In Argentina the first barrier is purchase price, next is battery range, third is the lack of public charge infrastructure, and finally the absence of tax incentives [38].

Summarizing this section about barriers, it is clear that a high initial cost continues to be the most important barrier, since it directly affects the total cost of ownership (TCO). Next, lack of better financing mechanisms, lack of charge infrastructure, and range limitation, real or perceived, are often mentioned. There is always some social skepticism and lack of knowledge from most new potential EV consumers [39].

**2.1 Objective of the study. -** Thus far, the social impact of barriers to EV adoption has been chiefly carried out through qualitative means, resulting in rather subjective interpretations. Consequently, the objective of this work is to apply a quantitative method that should provide more objectivity to the policy- making and decision- making processes, by using the Integrated Grey Clustering and Entropy Weight (IGCEW) method. This research focuses solely on the private light automotive market of Lima, Peru

## 3. Methodology. -

**3.1 Evaluation method. -** This section provides a description of the Integrated Grey Clustering and Entropy Weight Method. Both methods are combined in one (IGCEW) to assess the social impact of each barrier listed in Table 1, as a quantitative market research tool.

| Criteria | Barriers | Description |
|---|---|---|
| C1 | Autonomy | How many km can you drive before discharging. |
| C2 | High Price | Expensive compared to a conventional vehicle |
| C3 | Recharge time | Charging time is longer in electric vehicles |

*Table I. Main Barriers*

Social Impact Assessment (SIA) is a method to evaluate project viability where social preferences are key inputs. The key strategy of SIA is to understand peoples' preferences and concerns and also be able to address such preferences and concerns, thus minimizing potential social conflicts, while concurrently influencing both private decision making and public policy making. Similarly, understanding stakeholder drivers is a key success driver in any social project or program that involves significant change [40]. In general, other studies about EV preferences with public participation are based on qualitative methods [41]. To achieve more objectivity in analysis and decision making, this work attempts a more quantitative approach. The grey clustering method is based on the theory of grey systems, originally developed by Deng (1982) [42]. Grey systems is a theory that deals with small samples and limited information [43]. The Grey Clustering approach considers the uncertainty and classifies observed objects in grey classes [43]. Such a methodology has contributed to classifying air quality [44], energy quality [45], and drought risk [46], among others.

Shannon's entropy concept is applied to measure differences among various criteria and is used in decision making [47]. Thus, the weight-entropy method is based on the theory originally developed by Claude E. Shannon [48]. Such a theory has contributed to resolve or clarify diverse issues, such as transport (shared taxi) [49], environmental [50], risk assessment (hazardous materials transportation and handling) [51], social conflicts [43], decision making [52], and others.

**3.2 Grey clustering method based on central triangular whitening function. -** In this article we use the grey clustering method, based on a central triangular whitening function (CTWF), applied to stakeholder groups as SIA observation objects.

The CTWF function for GREY CLUSTERING

$$f_j^k(x_{ij}) = \begin{cases} 0, & x \notin [\lambda_{k-1}, \lambda_{k+1}] \\ \frac{x-\lambda_{k-1}}{\lambda_k-\lambda_{k-1}}, & x \in [\lambda_{k-1}, \lambda_k] \\ \frac{\lambda_{k+1}-x}{\lambda_{k+1}-\lambda_k}, & x \in [\lambda_k, \lambda_{k+1}] \end{cases} \quad (1)$$

Where $f_j^k(x_{ij})$ is the CTWF of the $k$-th gray class of the $j$-th criterion,

**Case study:**

Our applying IGCEW for SIA was aimed at identifying the most critical barriers to EV widespread adoption in Peru, by observing the attitudes and behaviors of key stakeholders in Lima, Peru.

**Stakeholder groups:**

- EV Owners (G1). People who have purchased or leased an EV or more.
- Future EV Buyers (G2). People who want to buy an EV and said so.
- EV suppliers and importers (G3). We focused on salespeople who understand consumers' preferences and decision-making process.
- Specialists (G4). These are experts and professionals who are well informed about EVs.

| Center points of extended gray classes | | | | | | |
|---|---|---|---|---|---|---|
| $\lambda_0$ | $\lambda_1$ | $\lambda_2$ | $\lambda_3$ | $\lambda_4$ | $\lambda_5$ | $\lambda_6$ |
| 0 | 10 | 30 | 50 | 70 | 90 | 100 |

*Table II. Type Extended gray classes in case study*

| | Very Negative | Negative | Normal | Positive | Very Positive |
|---|---|---|---|---|---|
| $C_1$ | $0 \le x_{11} \le 20$ | $20 \le x_{21} \le 40$ | $40 \le x_{31} \le 60$ | $60 \le x_{41} \le 80$ | $80 \le x_{51} \le 100$ |
| $C_2$ | $0 \le x_{12} \le 20$ | $20 \le x_{22} \le 40$ | $40 \le x_{32} \le 60$ | $60 \le x_{42} \le 80$ | $80 \le x_{52} \le 100$ |
| $C_3$ | $0 \le x_{13} \le 20$ | $20 \le x_{23} \le 40$ | $40 \le x_{33} \le 60$ | $60 \le x_{43} \le 80$ | $80 \le x_{53} \le 100$ |

*Table III. Grey Classes for Each Criterion CJ, J=1,2,3*

Shannon showed that a function that satisfies the characteristics for measuring entropy or degree of disorder can be:

$$H_{shannon} = -k \sum_i^n p_i * \log(p_i) \quad (2)$$

Where: $0 \le p_i \le 1$; for $\sum_i^n p_i = 1$

Step 2: The entropy $H_j$ of each criterion $C_j$ is calculated using Eq. (3)

The normalization matrix, entropy

$$H_j = -k \sum_{i=1}^m p_{ij} * \ln(p_{ij}) \quad (3)$$

Step 3. The degree of divergence $div_j$, is calculated

$$div_j = 1 - H_j \quad (4)$$

Step 4. The degree of convergence $cov_j$, is calculated (it is the contribution of the research)

$$cov_j = 1/div_j \quad (5)$$

Step 5. Normalization of each criterion (barrier or policy) $w_j$ is calculated by the equation

$$w_j = \frac{cov_j}{\sum_{i=1}^m cov_j} \quad (6)$$

Step 6. The Weight of the criterion (barrier or policy) $w_j$ is calculated by equation (7)

$$z_{ij} = \sum_{K=1}^S f_i^k(x_{ij}) \bullet \alpha_k \quad (7)$$

Step 7. For our purpose of prioritizing the policies, equation (10) is obtained, obtaining the Weight of the criterion (barrier or policy) $w_j^*$

$$w_j^* = w_j . z_j \quad (8)$$

**4. Results. -** Table IV is the X matrix, from stakeholder groups survey output data. Tables V through XIII summarize the results of applying the underlying grey clustering methodology to the data obtained from the survey. Next, we determine the convergence for the data listed in Table XIII.

| | $C_1$ | $C_2$ | $C_3$ |
|---|---|---|---|
| $G_1$ | 52.14 | 65.00 | 67.65 |
| $G_2$ | 54.00 | 74.00 | 69.00 |
| $G_3$ | 47.33 | 73.53 | 66.47 |
| $G_4$ | 72.50 | 75.00 | 72.50 |

*Table IV. Matrix X, Results from Survey to Stakeholder Groups Gi and Criteria Cj*

| | $C_1$ | $C_2$ | $C_3$ |
|---|---|---|---|
| f11 | 0.0000 | 0.0000 | 0.0000 |
| f21 | 0.0000 | 0.0000 | 0.0000 |
| f31 | 0.8930 | 0.2500 | 0.1175 |
| f41 | 0.1070 | 0.7500 | 0.8825 |
| f51 | 0.0000 | 0.0000 | 0.0000 |

*Table V. CTWF Values for Group 1 Grey Clustering*

| | $C_1$ | $C_2$ | $C_3$ |
|---|---|---|---|
| f12 | 0.0000 | 0.0000 | 0.0000 |
| f22 | 0.0000 | 0.0000 | 0.0000 |
| f32 | 0.8000 | 0.0000 | 0.0500 |
| f42 | 0.2000 | 0.8000 | 0.9500 |
| f52 | 0.0000 | 0.2000 | 0.0000 |

*Table VI. CTWF Values for Group 2 Grey Clustering.*

| | $C_1$ | $C_2$ | $C_3$ |
|---|---|---|---|
| f13 | 0.0000 | 0.0000 | 0.0000 |
| f23 | 0.1335 | 0.0000 | 0.0000 |
| f33 | 0.8665 | 0.0000 | 0.1765 |
| f43 | 0.0000 | 0.8235 | 0.8235 |
| f53 | 0.0000 | 0.1765 | 0.0000 |

*Table VII. CTWF Values for Group 3 Grey Clustering*

| | $C_1$ | $C_2$ | $C_3$ |
|---|---|---|---|
| f14 | 0.0000 | 0.0000 | 0.0000 |
| f24 | 0.0000 | 0.0000 | 0.0000 |
| f34 | 0.0000 | 0.0000 | 0.0000 |
| f44 | 0.8750 | 0.7500 | 0.8750 |
| f54 | 0.1250 | 0.2500 | 0.1250 |

*Table VIII. CTWF Values for Group 4 Grey Clustering*

| Social impact class | Interval | $\alpha_k$ |
|---|---|---|
| Very negative | [20,30] | 20 |
| Negative | [30,50] | 40 |
| Normal | [50,70] | 60 |
| Positive | [70,90] | 80 |
| Very positive | [90,100] | 100 |

*Table IX. social impact evaluation for groups G1, G2 and G3.*

| | $C_1$ | $C_2$ | $C_3$ |
|---|---|---|---|
| $G_1$ | 62.14 | 75.00 | 77.65 |
| $G_2$ | 64.00 | 84.00 | 79.00 |
| $G_3$ | 57.33 | 83.53 | 76.47 |
| $G_4$ | 82.50 | 85.00 | 82.50 |

*Table X. Impact Matrix for Each Combination of Criterion and Stakeholder Group*

| | $C_1$ | $C_2$ | $C_3$ |
|---|---|---|---|
| $G_1$ | 0.23363 | 0.22899 | 0.24602 |
| $G_2$ | 0.24063 | 0.25646 | 0.25030 |
| $G_3$ | 0.21555 | 0.25503 | 0.24228 |
| $G_4$ | 0.310185 | 0.25952 | 0.26139 |

*Table XI. Normalized social impact matrix*

| | $C_1$ | $C_2$ | $C_3$ |
|---|---|---|---|
| $H_j$ | 807.1473 | 1041.0942 | 994.6186 |
| $Div_j$ | 0.71608 | 0.63379 | 0.65013 |
| $W_j$ | 0.3580 | 0.3169 | 0.3251 |

*Table XII. Determination of Divergence of weights for each barrier or Criterion. Values for $H_j$, $div_j$ and $W_j$ for each Criterion C-j used in the Case Study*

| | $C_1$ | $C_2$ | $C_3$ |
|---|---|---|---|
| $1/div_j$ | 1.3965 | 1.5778 | 1.5381 |
| $Cov_j$ | 0.3095 | 0.3496 | 0.3408 |
| Alfa | 66.4925 | 81.882 | 78.905 |
| $W_j^*$ | 20.578 | 28.631 | 26.896 |

*Table XIII. Determination of Convergence Values and Weights for each Criterion*

**5. Discussion of results. -**

**5.1 Analysis of Convergent Criteria. -** EV introduction to a new market or country encompasses a cultural, energy and technological transition. Barriers to adoption are ever present and need to be eliminated or lower to achieve a successful introduction and eventual widespread adoption.

**Limited Range. -** The range from an EV battery depends on several variables, including battery capacity, drive train efficiency, vehicle aerodynamics, driving habits, loads (carrying and hauling), road quality, geography, etc. This factor is often a defining one for many potential buyers [39]. Such concern has been consistently observed in the US [14], Switzerland and Finland [28]. In Ecuador, range is considered the main barrier [37], as well as in Singapore [33], Germany [25], and the UK [22].

**High Price. -** The gap between an EV's initial cost and a conventional ICEV's varies between the cost US $6,000 to $8,000 of comparable vehicles. In 32 European countries, the purchasing cost was identified as the main economic barrier [19]. This was shown in France [31], Latvia [32], and the Netherlands [24]. Also, initial cost was the main barrier in China [34] and Argentina [38]. A high initial cost impacts "Overall Cost of Ownership" or TCO, which also depends on the financing options and financial cost available [39]. Countries, regions or cities with lower purchasing power, less population and infrastructure limitations, have consumers that are even more sensitive to the purchasing price of any vehicle, electric or conventional [35].

**Charge Time. -** Charging (or filling up) a conventional or ICE car is quick and simple. But depending on several factors, charging EVs takes longer, and many users are not willing to wait so long for a full battery charge. This is often a key concern, given the lack of availability of rapid-charging stations. Most users do not want to interrupt and delay their road or city trips with excessive charging times [22], [25], [53]. In addition, charging time relates to range anxiety (smaller batteries can be charged quicker but have shorter EV range). Both factors are serious obstacles for adoption [28]. Thus quicker, more powerful (kW) and more expensive chargers are needed or expected for EVs with larger batteries (more kWh). Such expectations are manifest in Sweden [21], France [31], Singapore [33], Latvia [32], Colombia [54] and Argentina [38]. Technical barriers such as "lack of charge infrastructure," and "real vs. perceived range limitations" are present in most countries. In addition, there is "social skepticism" due to lack of awareness and knowledge by consumers [39]. In Latvia, a larger number of charge stations and free charging policy are appreciated by users [55], while in Switzerland and Finland, consumers demand ease (speed) of charging [28]. In general, commercial users have a higher preference for rapid charging systems, than private users [56].

**Barrier ranking. -** Social Impact Assessment (SIA) of barriers to adoption was carried out by using qualitative and quantitative approaches. The impact of barriers was measured through weights w for each barrier and criterion. Table XIV lists the ranking of each barrier/criterion pair with the corresponding weight wj*.

| Wj* | Criteria | barriers |
|---|---|---|
| 28.631 | C2 | High price |
| 26.896 | C3 | Recharge time |
| 20.578 | C1 | Autonomy range |

*Table XIV. Ranking of barriers/criteria using weights Wj**

**6. Conclusions. -** We have first identified and then qualitatively evaluated the barriers that impede EV's widespread adoption in Lima, Peru. Next, we have ranked and prioritized such barriers to help define more effective government and business policies that support a transition to EVs. By applying the IGCEW method, we have been able to make sense of qualitative information provided by four (4) stakeholder groups. We found that the first barrier is purchase price (initial cost), next is charging availability (ease of charging), and finally EV/battery range. A higher purchase price is even more important in lower-income towns, while range expectation depends on the intended EV use (urban vs. road). And commercial users give a higher priority to quick charging than private users. What we have learned in this work should help both Peruvian government and automotive businesses develop a more effective and coordinated strategy towards EV introduction, a smoother transition from ICE vehicles and eventual widespread adoption of EVs.

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