Research Article

Deriving factors influencing consumers’ adoptions of electric vehicles

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ABSTRACT

In order to reduce the effects of global warming, governments of leading economies started to provide various incentives for supporting the adoption of new energy vehicles (EVs). Albeit important, limited scholars tried to investigate the influential factors. Thus, this study aims to derive the factors influencing the adoption of (EVs). This research will use the decision making trial and evaluation laboratory (DEMATEL) as a research method to predict the factors being related to consumer intentions and behaviors. Taiwanese experts of EVs will be invited for providing opinions. Based on the empirical results, the subsidies for new EVs and the number of charging piles play the most dominant roles. The results can serve as a basis for predicting consumer acceptance of new EVs in the future.

Keywords: Energy Consumption; Electric Vehicles (EVs); Fuel Economy; Decision Making Trial Evaluation Laboratory (DEMATEL)

1. INTRODUCTION

In response to the threat of climate change and air pollution to the health of the people, the promotion of electric vehicles to reduce vehicle greenhouse gas emissions has become one of the main responses adopted by many countries in the transportation sector in recent years. The phenomenon of climate change has attracted the attention of countries and international organizations all over the world for many years. Many countries in the world have successively announced or studied the target timetable for the ban on the sale of traditional fossil fuel vehicles. The timetable for the ban on the sale of traditional fuel vehicles by various countries is shown in Fig. 1.

![Fig. 1. Timetables announced by countries to ban the sale of fuel vehicles](image-url)
In order to reduce the effects of global warming, governments of leading economies started to provide various incentives for supporting the adoption of new energy vehicles (EVs). It’s very obvious that the development trend of electric vehicles depends on relevant government policies in the world. Taking Norway, Iceland, Sweden and other countries as examples, there are many ways to promote the development of electric vehicles, which can be divided into four major aspects: "policy norms", "financial and tax incentives", "publicity and education", and "green procurement". The policy aspect refers to guiding toward policy goals or taking due actions through authorization or clear rules of conduct, such as drafting strict fuel efficiency standards and compulsory regulations for zero-emission vehicles. Financial and tax incentives are about reducing taxation and rewarding people and promote the electric vehicle market. For example: purchase subsidies, tax incentives for electric vehicles, research subsidies for batteries or free public charging stations, lower tolls or parking fees, etc. "Publicity and education" and "green procurement" not only provide incentives to the public, but also encourage companies to combine the power of the government, the public, and enterprises to maintain the earth's ecology.

However, in contrast to Taiwan, in July 2018, the goal of a comprehensive ban on the sale of fuel vehicles in 2035 was originally set, but the Executive Yuan instructed to suspend the policy in 2019, which not only delayed the market transformation time, also showed the lack of an overall development policy for electric vehicles, and the government have no definite future market capture targets.

Compared with countries that actively promote electric vehicle policies such as Europe, the United States, and China, Taiwan is a slower one in developing the electric vehicle market. Taiwan's electric vehicles are still in the early stages of development, so Taiwan is the main area to be discussed in the study to predict the electric vehicle market, referring to the national energy policy and corporate attitudes.

Summarize factors related to consumers' intentions and behaviors to derive their dimensions and evaluation criteria, and then invite Taiwanese electric vehicle experts to provide opinions. This study will use the Decision Test and Evaluation Laboratory (DEMATEL) as the research method. Through this research method, the results can serve as a basis for predicting consumer acceptance of new EVs in the future.

2. LITERATURE REVIEW

Electric vehicles are the future industry trend. First, we will introduce the various types of electric vehicles, and then explain the policy differences between Taiwan and other countries (Europe, the United States, and China). Through the literature discussion of consumers' intentions and behaviors, we can get the possible reasons that affect consumers to buy electric vehicles and make some explanations for these reasons.

2.1. Electric Vehicle

EVs can run solely on electric propulsion or they can have an ICE working alongside it. Having only batteries as energy source constitutes the basic kind of EV, but there are kinds that can employ other energy source modes. These can be called hybrid EVs (HEVs). The
International Electrotechnical Commission’s Technical Committee 69 (Electric Road Vehicles) proposed that vehicles using two or more types of energy source, storage or converters can be called as an HEV as long as at least one of those provide electrical energy. This definition makes a lot of combinations possible for HEVs like ICE and battery, battery and flywheel, battery and capacitor, battery and fuel cell, etc. Therefore, the common population and specialists both started calling vehicles with an ICE and electric motor combination HEVs, battery and capacitor ones as ultra-capacitor-assisted EVs, and the ones with battery and fuel cell FCEVs (Fuad 2017). These terminologies have become widely accepted and according to this norm, EVs can be categorized as follows:

1. Battery Electric Vehicle (BEV)
2. Hybrid Electric Vehicle (HEV)
3. Plug-in Hybrid Electric Vehicle (PHEV)
4. Fuel Cell Electric Vehicle (FCEV)

EVs with only batteries to provide power to the drive train are known as BEVs. BEVs have to rely solely on the energy stored in their battery packs; therefore the range of such vehicles depends directly on the battery capacity. Typically they can cover 100 km–250 km on one charge, whereas the top-tier models can go a lot further, from 300 km to 500 km. These ranges depend on driving condition and style, vehicle configurations, road conditions, climate, battery type and age. Once depleted, charging the battery pack takes quite a lot of time compared to refueling a conventional ICE vehicle. It can take as long as 36 h completely replenish the batteries, there are far less time consuming ones as well, but none is comparable to the little time required to refill a fuel tank.

Batteries are the key differentiator between the various EV manufacturers. The amount of energy stored in the battery determines the range of the EV, thought to be a major limitation on EV sales. Consumers tend to worry that an EV with a range of 80 to 250 miles on a single charge would be inconvenient for long trips due to the time it takes to recharge the battery. Manufacturers have spent millions to improve the availability and efficacy of EV chargers, and as a result the fastest ones today take no more than 15 minutes to recharge a vehicle.

It can be seen from this that what consumers are most worried about when buying electric vehicles is the "charging service." Consumers are particularly concerned about whether the battery performance of electric vehicles can support long-distance travel.

If it is to expand the area of electric vehicle charging stations or increase the number of charging piles, this concern can be eliminated. In addition, some consumers care about the charging speed of electric vehicles and the charging plan provided by the supplier.

2.2. Domestic and Foreign Electric Vehicle Development

It will present a brief consolidation and development of national policies electric vehicles. In terms of policies, in recent years, countries around the world have been polarized according to the degree of market development. Some countries have vigorously promoted electric vehicles a few years ago. Therefore, there have been preliminary results
in sales and penetration (such as the annual sales volume in China have achieved one million vehicles, and the electric vehicles market of Norwegian have accounted for 56% of new vehicles sold).

These countries have begun to gradually reduce subsidies to return market mechanisms, such as China, Norway, the United Kingdom, and the Netherlands. Some countries released relevant policies last year, such as Germany, Italy, and India.

From the observation of market sales in 2019, the European region has potential for development. In addition to the introduction of new policies by various countries, the EU requires that the average emissions of new passenger cars sold in Europe from 2020 be reduced from the previous 120g CO2/km to 95g CO2/km, As the world’s most stringent emission standards and regulations, is expected to also promote the maturity of the European electric vehicle market. In order to encourage consumers to purchase electric vehicles, governments of various countries have drafted many policies, including: France, Japan, the United States and China and regions. The specific policies mostly range from "reduction of various expenses", "reduction of taxes" and "subsidies for car purchase", etc.

The implementation of the three directions is expected to reduce the obstacles caused by the high purchase cost of electric vehicles.

Governments of various countries have also put forward stricter and stricter regulations for car suppliers. The most obvious is the Corporate Average Fuel Economy (CAFE). CAFE standards regulate how far our vehicles must travel on a liter of fuel. Vehicle manufacturers are required to have a sales-weighted average fuel economy that meets or exceeds these fuel economy targets, or pay a penalty that is a function of both their total sales and fuel economy shortfall. If the calculated average fuel economy is over the target value, the earned Credits may be accumulated for the calculation of the next 4 year’s average fuel economy values. However, if it is below the target value, the vehicles will be forbidden to sale by the government.

Taiwan’s Bureau of Energy planning the next phase of CAFE, implementation is expected in 2022. However, it can be seen from the following table 1 that Taiwan’s growth in electric vehicles is very slow.

**Table 1. Growth table of the proportion of new energy vehicles in Taiwan from 2017 to 2019**

<table>
<thead>
<tr>
<th>Years</th>
<th>New car sales in Taiwan</th>
<th>PHEV sales</th>
<th>BEV sales</th>
<th>Proportion of new energy vehicles</th>
</tr>
</thead>
<tbody>
<tr>
<td>2017</td>
<td>444,669</td>
<td>56</td>
<td>689</td>
<td>0.17%</td>
</tr>
<tr>
<td>2018</td>
<td>435,135</td>
<td>239</td>
<td>624</td>
<td>0.20%</td>
</tr>
<tr>
<td>2019</td>
<td>439,836</td>
<td>447</td>
<td>3,302</td>
<td>0.85%</td>
</tr>
</tbody>
</table>

Currently, Taiwan’s CAFE plan is based on China’s policies. However, the current development of Taiwan’s electric vehicle market is far from that of China. Looking at the development status of CAFE and energy vehicles in various countries in the table 2 below, Taiwan’s next phase of policies will not meet the standards.
Table 2. CAFE implementation year, standards and Proportion of new energy vehicles

<table>
<thead>
<tr>
<th>Country</th>
<th>European Union</th>
<th>United States</th>
<th>China</th>
<th>Taiwan</th>
</tr>
</thead>
<tbody>
<tr>
<td>Standard year</td>
<td>2020</td>
<td>2020</td>
<td>2020</td>
<td>2022</td>
</tr>
<tr>
<td>Standard (km/l) (95g CO2)</td>
<td>About 24.7</td>
<td>18.4</td>
<td>20</td>
<td>20.4</td>
</tr>
<tr>
<td>Proportion of new energy vehicles</td>
<td>3.6%</td>
<td>2%</td>
<td>4.6%</td>
<td>0.85%</td>
</tr>
</tbody>
</table>

At present, Taiwan's sales of new energy vehicles are far behind China, but the new CAFE standard is even higher than China's. The Taiwan government has not yet matured its regulations and policies and has regulated enterprises to sell electric vehicles with high standards, which will cause instability in the electric vehicle market.

2.3. CONSUMER INTENTIONS AND BEHAVIORS

Excluding policy and corporate factors, the most important thing is consumers' intention and behavior to purchase electric vehicles.

Consumers' purchase intentions or behavior is generally an attribute of human behavior. The description of consumers' behavior is generally a collection of actions intended to meet the consumption needs of individuals with different personalities. There are many theories of consumer behavior that include for example; the economic man approach, psychodynamic approach, rising income theory, behavioristic approach, and cognitive approach. The economic man approach suggests that consumers must be able to distinguish between choices accessible to them when purchasing foodstuffs.

Consumer behavior involves the study of individuals and the method they employ to choose, utilize, and set out products and services to fulfill their wants and the effect that these method have on the consumer and the society as a whole. Consumer behavior refers to all the thought, feelings and actions that an individual has or takes before or while buying any product, service or idea. Buyer behavior is the concept which answers what, why, how, when, and where an individual makes purchase. As a result, the outcome of buyer behavior is the buyer’s decision. The entire purchasing process involves giving a thought on what should be bought, which brand is good or suitable, from where or whom should the purchase be made, when to purchase, how much to spent, and how many time to buy and in what intervals. Consequently the end result of the buyer behavior is the customer’s final decision regarding the product choice, brand choice, dealer choice, purchase timing, purchase amount and purchase frequency. Consumer buying behavior “is a confluence of at least three streams of social science, i.e., individual psychology, social psychology and cultural anthropology” (Khaniwale 2015).

Consumer behavior is the study of the processes involved when individual or groups select, purchase, use, or dispose of the product, service, ideas or experiences to satisfy needs and desires. The expand view of consumer embrace much more than the study of why and what consumer buy, but also focuses on how marketer influence consumers and how consumers use the products and services (Kumar 2016).
For consumers who will buy a vehicle, they value the “vehicle performance” and the "maintenance service" provided by the supplier. For specific consumers, they are particularly concerned about the vehicle's "life and replacement."

2.4. **Research model**

Based on the above literature, this research divides the elements that affect "consumers' intentions and behaviors" into three categories: product value, supplier strategy, and government policy. Based on this, this article summarizes a total of 20 criteria in five dimensions, as shown in Fig. 2. We will use these criteria as factors to predict consumer intentions and behaviors. The following will illustrate the relationship between these dimensions and criteria.

![Fig. 2. Research model](image)

2.4.1. **Vehicle performance**

Vehicle performance is a factor that consumers care about when buying a vehicle. The high performance of an electric vehicle will increase the value of the product. Therefore, this article is divided into four criteria for the maneuverability of electric vehicles: "Gradeability" is the maximum slope an electric vehicle can travel. "Endurance" is the longest distance that an electric vehicle battery can travel once it’s fully charged. "Maximum speed" is the maximum speed that an electric vehicle can reach. "Battery performance" refers to the number of years the battery can be used when the normal power storage declines.
2.4.2 Charging Service

Charging service is an important factor that requires the integration of government policies and supplier strategies. If the charging service is stable and good, it will increase consumers' motivation to purchase and increase the value of the product. Therefore, this article is divided into four criteria for charging services: "Number of charging stations" refers to the number of electric vehicle battery charging stations (intensity and popularity in a single area). "The area of charging station" is the area where the electric vehicle charging station is installed (the convenience of each area and the degree of city coverage). "Charging speed" is the charging speed of electric vehicles (average speed of fast charging and slow charging). "Charging fee" is the charging plan provided by the supplier for the electric vehicles sold.

2.4.3 Maintenance service

The maintenance service of electric vehicles is different from traditional fuel vehicles. Guaranteed maintenance services can increase consumers' confidence in buying and increase the value of products. The supplier's strategy also occupies a very important position in the maintenance service, so this article is divided into four criteria for the maintenance service: "Regular maintenance" means that the supplier can provide regular maintenance services for the electric vehicles sold. "Product Warranty" is the supplier can provide product warranty services for the electric vehicles sold. "Parts replacement" means that the supplier can provide parts replacement service for the electric vehicles sold. "Maintenance fee" refers to the average annual warranty cost of the electric vehicle sold by the supplier after returning to the factory.

2.4.4 Car purchase cost

The cost of electric vehicles is the biggest obstacle to consumer consumption. Lowering the threshold for purchasing electric vehicles has become an issue for suppliers and the government. Therefore, this article is divided into four criteria for the cost of buying a car: "Product pricing" is the retail price at which consumers can buy electric vehicles in general sales channels. "Subsidy policy" refers to the promotional programs and price subsidy carried out by suppliers or government in order to increase the market size. "Tax relief" refers to the government's tax relief for electric vehicles such as license tax and fuel tax. "Insurance fee" is a compulsory liability insurance stipulated by government agencies in order to increase compensation for accident damage.

2.4.5 Car life and replacement

Looking to the future, the lifespan and replacement of electric vehicles are issues that must be considered. It affects consumers' purchasing motivation, and also tests the strategies of suppliers and the government for the electric vehicle market. Therefore, this article is divided into four criteria for life and replacement: "Product service life" is the number of years an electric vehicle can be used most often under normal use. "Recycling residual value" refers to how much residual product value can be recovered from scrapped electric vehicles and battery recycling. "Secondary sales" refers to the circulation market of secondhand (middle age) electric vehicles and whether the product price drop is reasonable.
"Replacement cost" is whether the supplier is willing to provide the old trade-in service to accelerate product replacement and update.

The expert questionnaire will be designed based on the five dimensions summarized above and a total of 20 criteria, and Taiwan electric vehicle experts will be invited to provide opinions. This study will use Decision Testing and Evaluation Laboratory (DEMATEL) as a research method to predict factors related to consumer intentions and behaviors.

3. METHODOLOGY/MATERIALS

In Table 3, we code according to a total of 20 criteria in these five dimensions. The research method will use the Decision and Trial Evaluation Laboratory (DEMATEL). In the following, the concept of DEMATEL will be explained, and the factors related to consumer intentions and behaviors will be analyzed and predicted through these dimensions and criteria.

Table 3. Codename, dimensions and criteria of research methods

<table>
<thead>
<tr>
<th>Codename</th>
<th>Dimensions</th>
<th>Criteria explanation</th>
</tr>
</thead>
<tbody>
<tr>
<td>a</td>
<td>Vehicle performance</td>
<td>The maximum speed an electric vehicle can travel.</td>
</tr>
<tr>
<td>a1</td>
<td>Gradeability</td>
<td>The longest distance that an electric vehicle can travel once it’s fully charged.</td>
</tr>
<tr>
<td>a2</td>
<td>Endurance</td>
<td>The maximum speed that an electric vehicle can reach.</td>
</tr>
<tr>
<td>a3</td>
<td>Maximum speed</td>
<td>The number of years that the battery can be used when the normal power storage declines.</td>
</tr>
<tr>
<td>a4</td>
<td>Battery performance</td>
<td>The number of years that the battery can be used when the normal power storage declines.</td>
</tr>
<tr>
<td>b</td>
<td>Charging service</td>
<td>The number of electric vehicle battery charging stations (intensity and popularity in a single area).</td>
</tr>
<tr>
<td>b1</td>
<td>Number of charging stations</td>
<td>The area where the electric vehicle charging station is installed (the convenience of each area and the degree of city coverage).</td>
</tr>
<tr>
<td>b2</td>
<td>The area of charging station</td>
<td>Electric vehicle charging speed (average speed of fast charging and slow charging).</td>
</tr>
<tr>
<td>b3</td>
<td>Charging speed</td>
<td>The charging plan provided by the supplier for the electric vehicles sold.</td>
</tr>
<tr>
<td>b4</td>
<td>Charging fee</td>
<td>Maintenance service</td>
</tr>
<tr>
<td>c</td>
<td>Regular maintenance</td>
<td>Suppliers can provide regular maintenance services for electric vehicles sold.</td>
</tr>
<tr>
<td>c1</td>
<td>Product warranty</td>
<td>Suppliers can provide product warranty services for electric vehicles sold.</td>
</tr>
<tr>
<td>c2</td>
<td>Parts replacement</td>
<td>Suppliers can provide parts replacement services for electric vehicles sold.</td>
</tr>
<tr>
<td>c3</td>
<td>Maintenance fees</td>
<td>The supplier’s average annual warranty costs for the electric vehicles sold after returning to the factory.</td>
</tr>
<tr>
<td>c4</td>
<td>Car purchase cost</td>
<td>The retail price at which consumers can buy electric vehicles in general sales channels.</td>
</tr>
<tr>
<td>d</td>
<td>Product pricing</td>
<td>Promotional programs and price subsidies carried out by suppliers or governments in order to increase the size of the market.</td>
</tr>
<tr>
<td>d1</td>
<td>Subsidy policy</td>
<td>The government has reduced or exempted the license tax and fuel tax for electric vehicles.</td>
</tr>
<tr>
<td>d2</td>
<td>Tax relief</td>
<td>Compulsory liability insurance stipulated by government agencies in order to increase compensation for accident damage.</td>
</tr>
<tr>
<td>d3</td>
<td>Product life and replacement</td>
<td></td>
</tr>
<tr>
<td>d4</td>
<td>Car life and replacement</td>
<td></td>
</tr>
<tr>
<td>e</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
This research will use the decision making trial and evaluation laboratory (DEMATEL) as a research method to predict the factors being related to consumer intentions and behaviors.

DEMATEL is a method developed by the Banelle Memorial Institute of Geneva for the Science and Human Affairs Program between 1972 and 1976. It is used to solve complex and entangled problems. DEMATEL can improve the understanding of special problems, groups of entangled problems, and identified by hierarchical structure to provide practical solutions (Tzeng et al., 2007).

The biggest feature of DEMATEL is to explain the interrelationships between facets or clusters, and obtain effective. The core principles between the representative elements/facets. In addition, DEMATEL has also been successfully applied in many situations, such as marketing strategies, control systems, security issues, global managers and group decision-making capabilities development (Hori & Shimizu, 1999; Chiu et al., 2006; Liou et al., 2007; Wu & Lee, 2007; Wu et al., 2009).

3.1. Operation Steps

Step 1: Define the degree size.

The size of the design evaluation scale is used to indicate the degree of influence of the facet. The semantic value and its operational definitions are divided into 1, 2, 3, 4, 5 which represent different degrees of influence, namely "no influence (1)", "low influence (2)", and "moderate influence" (3), "High influence (4)", "Extremely high influence (5)".

Step 2: Establish a direct relationship matrix.

This matrix is filled out by questionnaire experts (evaluators), and the experts judge the degree of influence of the two dimensions. And fill in the value defined in step 1 in the corresponding position to generate a direct relationship table. Then integrate the results answered by the experts to produce a direct relationship matrix A, such as formula (1), where n represents the number of indicators, a[ij] represents the degree to which facet i affects facet j, and divides the diagonal The value of the part is set to 0.

$$A = \begin{bmatrix} a_{11} & \cdots & a_{1j} & \cdots & a_{1n} \\ \vdots & \ddots & \vdots & \ddots & \vdots \\ a_{i1} & \cdots & a_{ij} & \cdots & a_{in} \\ \vdots & \ddots & \vdots & \ddots & \vdots \\ a_{n1} & \cdots & a_{nj} & \cdots & a_{nn} \end{bmatrix}$$
Step 3: Standardize the direct relationship matrix.

Standardize according to the direct relationship matrix A obtained in step 2 to obtain a standardized relationship moment matrix X. The standardization method is as formula (2), (3):

\[
S = \min \left[ \frac{1}{\max_i \sum_j |a_{ij}|^2}, \frac{1}{\max_j \sum_i |a_{ij}|^2} \right] \quad (2)
\]

\[
X = S \times A \quad (3)
\]

Step 4: Establish a total relationship matrix.

Let T be the total relationship matrix, \( \lim_{n \to \infty} (X)^k = [0]_{n \times n} \), the formula is expressed as (4):

\[
T = \sum_{k=1}^{\infty} X^k = X(I - X)^{-1} \quad (4)
\]

Among them, \( T = [t_{ij}]_{n \times n}, i,j = 1,2,\ldots,n \); I is the unit matrix with a diagonal value of 1.

In addition to adding up each column and each row of the total relationship matrix T, we can get the value of D and R are shown in formulas (5) and (6). The D value represents the extent to which the facet directly or indirectly affects other facets, and the R value represents the extent to which the facet is directly or indirectly affected by other facets.

\[
D = (D_i)_{1 \times n} = [\sum_{j=1}^{n} t_{ij}]_{1 \times n} \quad (5)
\]

\[
R = (R_j)_{1 \times n} = [\sum_{i=1}^{n} t_{ij}]^T_{n \times 1} \quad (6)
\]

Then calculate \((D_i + R_j)\) and \((D_i - R_j)\) according to formulas (5) and (6), where \((D_i + R_j)\) is called Prominence, representing the strength of the relationship between the facets, \((D_i - R_j)\) is called the degree of cause (relation), representing the strength of the facet’s influence or being affected, if \((D_i - R_j)\) is a positive value, it means the facet’s bias Resulting; when \((D_i - R_j)\) is negative, it means that the facet is biased to be affected.

Step 5: Establish a threshold and draw a cause and effect diagram

According to the T matrix obtained by the formula (4) in step 4, the threshold value \( \alpha \) is established (\( \alpha \) is an expert decision). If the value in the T matrix is less than \( \alpha \), it will be replaced with 0, otherwise if it is greater than \( \alpha \), it will be retained. This can eliminate the influence of the small facets in the T matrix, and obtain a simpler facet causality structure diagram (Ou Yang et al., 2008), as shown in Fig. 3. Among them, t11, t21, t32, and t33 are not greater than the preset \( \alpha \) value, so Replace with 0.
4. RESULTS AND FINDINGS

In this section, the factors for predicting consumer intentions and behaviors will be summarized and confirmed by experts. Using the DEMATEL method will be used to construct the causal network.

4.1. CALCULATION RESULTS

Then, the factors being suitable for predicting consumer intentions and behaviors can be derived.

The average influence of \( i \) criterion on \( j \), and \( n \) denotes number of criteria, here \( n = 20 \) and \( n \times n \) matrix.

The normalized direct influence matrix \( N \):

\[
\begin{array}{cccccccccccccccccccccc}
 & a1 & a2 & a3 & a4 & b1 & b2 & b3 & b4 & c1 & c2 & c3 & c4 & d1 & d2 & d3 & d4 & e1 & e2 & e3 & e4 \\
a1 & 0.01 & 0.05 & 0.03 & 0.07 & 0.03 & 0.07 & 0.03 & 0.01 & 0.03 & 0.03 & 0.01 & 0.03 & 0.07 & 0.01 & 0.01 & 0.03 & 0.03 & 0.05 & 0.05 & 0.01 \\
 & 9 & 6 & 7 & 4 & 7 & 4 & 7 & 9 & 7 & 7 & 9 & 7 & 4 & 9 & 9 & 7 & 7 & 6 & 6 & 9 \\
a2 & 0.07 & 0.01 & 0.05 & 0.07 & 0.07 & 0.05 & 0.03 & 0.03 & 0.05 & 0.01 & 0.03 & 0.07 & 0.03 & 0.01 & 0.03 & 0.05 & 0.05 & 0.05 & 0.01 \\
 & 4 & 9 & 6 & 4 & 4 & 6 & 7 & 7 & 6 & 9 & 7 & 4 & 7 & 9 & 7 & 6 & 6 & 6 & 6 & 9 \\
a3 & 0.09 & 0.05 & 0.01 & 0.07 & 0.01 & 0.01 & 0.03 & 0.01 & 0.07 & 0.03 & 0.03 & 0.05 & 0.07 & 0.01 & 0.01 & 0.03 & 0.01 & 0.05 & 0.05 & 0.01 \\
 & 3 & 6 & 9 & 4 & 9 & 9 & 7 & 9 & 4 & 7 & 7 & 6 & 4 & 9 & 9 & 7 & 9 & 6 & 6 & 9 \\
a4 & 0.03 & 0.09 & 0.05 & 0.01 & 0.03 & 0.01 & 0.09 & 0.07 & 0.05 & 0.03 & 0.05 & 0.07 & 0.03 & 0.01 & 0.01 & 0.05 & 0.07 & 0.07 & 0.01 \\
 & 7 & 3 & 6 & 9 & 7 & 9 & 3 & 4 & 6 & 6 & 7 & 6 & 4 & 7 & 9 & 9 & 6 & 4 & 4 & 9 \\
b1 & 0.01 & 0.03 & 0.01 & 0.07 & 0.01 & 0.07 & 0.05 & 0.07 & 0.01 & 0.01 & 0.01 & 0.05 & 0.05 & 0.01 & 0.03 & 0.07 & 0.05 & 0.09 & 0.01 \\
 & 9 & 7 & 9 & 4 & 9 & 4 & 6 & 4 & 9 & 9 & 9 & 9 & 6 & 6 & 9 & 7 & 4 & 6 & 3 & 9 \\
b2 & 0.01 & 0.01 & 0.01 & 0.05 & 0.01 & 0.05 & 0.05 & 0.01 & 0.01 & 0.01 & 0.03 & 0.05 & 0.03 & 0.01 & 0.03 & 0.03 & 0.07 & 0.09 & 0.03 \\
 & 9 & 9 & 9 & 9 & 9 & 9 & 6 & 9 & 6 & 6 & 9 & 9 & 7 & 9 & 7 & 9 & 7 & 4 & 3 & 7 \\
b3 & 0.01 & 0.05 & 0.01 & 0.09 & 0.03 & 0.03 & 0.01 & 0.05 & 0.03 & 0.01 & 0.01 & 0.03 & 0.01 & 0.01 & 0.03 & 0.01 & 0.01 & 0.01 & 0.01 & 0.01 \\
 & 9 & 6 & 9 & 3 & 7 & 7 & 9 & 6 & 7 & 9 & 9 & 7 & 9 & 9 & 7 & 9 & 9 & 7 & 9 & 9
\end{array}
\]
The normalized direct influence matrix \( T \):

\[
\begin{array}{cccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccc
This study being derived from the concept of the DEMATEL, can be applied to construct the structure of a decision problem and derive weights being associated with the criteria based on the total relationship matrix being derived by DEMATEL.

From Table 4, it can be found that each high-impact criterion is related to the battery, such as: battery efficiency, endurance, Maximum speed, or number of charging stations.

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Di</th>
<th>Rj</th>
<th>Di + Rj</th>
<th>Di - Rj</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gradeability(a1)</td>
<td>2.997391</td>
<td>2.107392</td>
<td>5.104782</td>
<td>0.889999</td>
</tr>
<tr>
<td>Endurance(a2)</td>
<td>3.521012</td>
<td>2.290972</td>
<td>5.811984</td>
<td>1.23004</td>
</tr>
<tr>
<td>Maximum speed(a3)</td>
<td>3.11119</td>
<td>1.904641</td>
<td>5.015831</td>
<td>1.206549</td>
</tr>
<tr>
<td>Battery performance(a4)</td>
<td>3.675227</td>
<td>2.969223</td>
<td>6.644455</td>
<td>0.706005</td>
</tr>
<tr>
<td>Number of charging stations(b1)</td>
<td>3.198811</td>
<td>2.472913</td>
<td>5.677125</td>
<td>0.725898</td>
</tr>
<tr>
<td>The area of charging station(b2)</td>
<td>2.708983</td>
<td>2.579444</td>
<td>5.288427</td>
<td>0.12954</td>
</tr>
<tr>
<td>Charging speed(b3)</td>
<td>2.346885</td>
<td>2.639593</td>
<td>4.986478</td>
<td>-0.29271</td>
</tr>
<tr>
<td>Charging fee(b4)</td>
<td>2.485197</td>
<td>2.538204</td>
<td>5.023401</td>
<td>-0.05301</td>
</tr>
<tr>
<td>Regular maintenance(c1)</td>
<td>2.467127</td>
<td>2.279009</td>
<td>4.746136</td>
<td>0.18819</td>
</tr>
<tr>
<td>Product warranty(c2)</td>
<td>1.615558</td>
<td>2.730512</td>
<td>4.34607</td>
<td>-1.1495</td>
</tr>
<tr>
<td>Parts replacement(c3)</td>
<td>2.467771</td>
<td>2.115622</td>
<td>4.583392</td>
<td>0.352149</td>
</tr>
<tr>
<td>Maintenance fees(c4)</td>
<td>1.904989</td>
<td>2.958872</td>
<td>4.863861</td>
<td>-1.05388</td>
</tr>
<tr>
<td>Product pricing(d1)</td>
<td>3.265023</td>
<td>3.596741</td>
<td>6.861763</td>
<td>-0.33712</td>
</tr>
<tr>
<td>Subsidy policy(d2)</td>
<td>2.363509</td>
<td>2.681923</td>
<td>5.045432</td>
<td>-0.31841</td>
</tr>
<tr>
<td>Tax relief(d3)</td>
<td>2.223651</td>
<td>2.016483</td>
<td>4.240134</td>
<td>0.207169</td>
</tr>
<tr>
<td>insurance fee(d4)</td>
<td>1.898375</td>
<td>1.90323</td>
<td>3.801605</td>
<td>-0.00486</td>
</tr>
<tr>
<td>Product service life(e1)</td>
<td>2.714437</td>
<td>3.288376</td>
<td>6.002813</td>
<td>-0.57394</td>
</tr>
<tr>
<td>--------------------------</td>
<td>----------</td>
<td>----------</td>
<td>----------</td>
<td>-----------</td>
</tr>
<tr>
<td>Recycling residual value(e2)</td>
<td>1.972923</td>
<td>3.561523</td>
<td>5.534446</td>
<td>-1.5886</td>
</tr>
<tr>
<td>Secondary sales(e3)</td>
<td>3.501036</td>
<td>3.991377</td>
<td>7.492413</td>
<td>-0.49034</td>
</tr>
<tr>
<td>Replacement cost(e4)</td>
<td>2.224978</td>
<td>2.038023</td>
<td>4.263001</td>
<td>0.186955</td>
</tr>
</tbody>
</table>

Then observe the relationship between the dimensions, and get the calculated matrix N and matrix T.

\[
N =
\begin{bmatrix}
a & b & c & d & e \\
0.067 & 0.200 & 0.133 & 0.267 & 0.200 \\
0.267 & 0.067 & 0.133 & 0.267 & 0.200 \\
0.200 & 0.133 & 0.067 & 0.200 & 0.267 \\
0.267 & 0.200 & 0.200 & 0.067 & 0.267 \\
0.200 & 0.200 & 0.133 & 0.200 & 0.067 \\
\end{bmatrix}
\]

\[
T =
\begin{bmatrix}
a & b & c & d & e \\
1.718 & 1.558 & 1.275 & 1.885 & 1.819 \\
1.995 & 1.532 & 1.350 & 1.995 & 1.926 \\
1.803 & 1.481 & 1.190 & 1.803 & 1.844 \\
2.080 & 1.721 & 1.462 & 1.913 & 2.065 \\
1.713 & 1.457 & 1.189 & 1.713 & 1.580 \\
\end{bmatrix}
\]

According to Table 5, the (Di - Rj) value of the Maintenance service and Charging service (Di - Rj) has the highest positive value. We can get more explanation in the following influence degree diagram.

**Table 5. Di + Rj and Di - Rj versus each dimension.**

<table>
<thead>
<tr>
<th>Dimensions</th>
<th>Di</th>
<th>Rj</th>
<th>Di + Rj</th>
<th>Di - Rj</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vehicle performance (a)</td>
<td>8.254229</td>
<td>9.309394</td>
<td>17.56362</td>
<td>-1.05517</td>
</tr>
<tr>
<td>Charging service (b)</td>
<td>8.798595</td>
<td>7.749172</td>
<td>16.54777</td>
<td>1.049424</td>
</tr>
<tr>
<td>Maintenance service (c)</td>
<td>8.120843</td>
<td>6.465218</td>
<td>14.58606</td>
<td>1.655625</td>
</tr>
<tr>
<td>Car purchase cost (d)</td>
<td>9.241597</td>
<td>9.309394</td>
<td>18.55099</td>
<td>-0.0678</td>
</tr>
<tr>
<td>Car life and replacement (e)</td>
<td>7.651782</td>
<td>9.233868</td>
<td>16.88565</td>
<td>-1.58209</td>
</tr>
</tbody>
</table>

### 4.2. Influence Degree Diagram

At first, the influence of each criterion on others can be derived based on expert’s opinions. Initial 20 × 20 influence relation matrix D 20 × 20 can be constructed accordingly (refer to Fig. 4). Then, it will explain the findings of each association graph one by one.
Description of Fig. 5. For the comparison of the degree of influence between the dimensions, we can see that "vehicle performance", "car purchase cost" and "car life and replacement" are the affected factors, and "maintenance service" and "charging service" are the main influencing factors. As the electric car is not yet universal, consumer electric vehicles for maintenance content was unknown, that "maintenance service" impact factor values high. In addition, "charging service" is the most important service measure for electric vehicles. It is worth noting that "car purchase cost" can also be regarded as one of the factors that affect consumers' purchases.
Description of Fig. 6. It can be seen that in vehicle performance, the “endurance” of electric vehicles is the most important, and “battery efficiency” affects all the criteria. In addition, “battery performance” is affected by all criteria. This shows that consumers have concerns about battery and battery life.

![Vehicle performance graph](image)

**Fig. 6.** The causal relationship network for vehicle performance.

Description of Fig. 7. The “number of charging stations” is very important in charging service. It affects all the criteria among which it interacts with the “area of the charging station”. It can be shown that consumers are worried that they cannot find a place to charge electric vehicles, or that there are not enough charging stations to charge them instantly. The charging speed and the charging fee interact with each other, which means that consumers may be willing to choose a higher fee in order to fully charge faster.

![Charging service graph](image)

**Fig. 7.** The causal relationship network for charging service.

Description of Fig. 8. Regarding maintenance services, it is obvious that "regular maintenance" and "parts replacement" will indeed affect "maintenance costs." For "product warranty", it is mainly for the replacement of parts. The criteria in this dimension are consistent with the facts.
Description of Fig. 9. Obviously, in terms of car purchase costs, "product pricing" affects all the criteria, but it is very special that "product pricing" is not the most important. It is known from the relationship diagram that "tax relief" is the most important criteria that experts think that it needs to be paid attention to.

Description of Fig. 10. "Replacement cost" is very important in this dimension and affects all the criteria with "Secondary sales". This means that consumers are very concerned about money-related content in the process of replacing cars.
In the subsection, it can be found from the above research that consumers focus on whether the driving ability of electric vehicles is stable, including: endurance, battery efficiency, number of charging stations, and the area of charging station. Consumers attach great importance to tax reduction and exemption when it comes to product spending. Consumers are also very concerned about the after-sales service and replacement costs of electric vehicles.

5. CONCLUSION

In a comprehensive conclusion, through these dimensions, we know the main factors that affect "consumers' intentions and behaviors", and give suggestions on "product value", "supplier strategy", and "government policy" based on the results, as shown in the following table 6:

Table 6. Suggestion for research models

<table>
<thead>
<tr>
<th>Dimensions</th>
<th>Product Value</th>
<th>Supplier Strategy</th>
<th>Government Policy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vehicle performance</td>
<td>Emphasize the endurance and battery efficiency of electric vehicles to ensure that consumers can drive smoothly during the journey.</td>
<td>Suppliers should cooperate with the government to set up more charging stations in more areas and increase the number of charging piles. The government also grants construction subsidies.</td>
<td></td>
</tr>
<tr>
<td>Charging service</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Maintenance service</td>
<td>In addition to improving the proper rate of vehicles, consumers need to be more confident in regular maintenance.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Car purchase cost</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Car life and replacement</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Based on the empirical results, the subsidies and tax relief for new EVs, and the number of charging piles play the most dominant roles. The results can serve as a basis for predicting consumer acceptance of new EVs in the future.

5.1. SUGGESTIONS

Even in terms of legislative and financial support, the Taiwanese EV market is gaining momentum. However, Taiwan still faces similar problems as it did 10 years prior in regards to a non-existant charging infrastructure and consumer distrust.

It's suggested that the government should more actively solve the disadvantages of electric vehicles in the early stages of development, and carry out short, medium and long-term planning and related supporting facilities, such as the deployment density of public and private charging stations, operating modes and safety regulations.

The government should also encourage the installation of electric vehicle power supply equipment in buildings and provide incentives and safety regulations for this. Suppliers
must also cooperate with the government to strengthen the stability of the image of electric vehicles in the market. At the same time, suppliers need to have clearer specifications and service content in after-sales service.

Given the same price of electric vehicle, many Taiwanese still choose the convenience and familiarity of gasoline-powered vehicles. In order to significantly raise the adoption rate of electric vehicles, the government may have to implement disincentives to leverage the strength of their EV policies. Improved battery technology, electric vehicle pilot programs and battery replacement are all positive steps. At the same time, since the impact of electric vehicles on the environment depends on the carbon intensity of the source of electricity, the government also needs to carefully consider how to supply energy to its growing electric vehicle infrastructure in a sustainable manner.

5.2. RESEARCH LIMITATIONS AND PROSPECTS

The results of this research are only obtained through pre-testing by experts. For in-depth research, it is recommended to add DNP method to increase the value of research. Use more literature review or analysis methods to make the research model more robust and credible. For countries that have just started to develop the electric vehicle market, this study can have considerable research value. It’s the first step of the model to predict the electric vehicle market.

References


