Evaluating electric vehicles demand influence based on fuzzy extended AHP

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Received 1 June 2014, www.cmnt.lv

Abstract

Vehicle emission is a hot issue for a big city health environment developing, and electric vehicle is a shortcut way to reduce the vehicle emissions. How to enhance electric vehicle's demand in vehicle's market is a multi-criterion decision problem. The aim of this paper is to identify and discuss some of the important critical indicators for the decision problem. A totally fourteen indicators are selected for the electric vehicle's demand influence evaluation system from the aspects of vehicles' performance, service and personal preference three aspects. Fuzzy extended analytic hierarchy process (FEAHP) is proposed solving the problem because it has the advantages of simple, less time taking and capture the vagueness of human thinking. Finally, a case study and the results show the proposed model is feasibility and effective for the evaluation.

Keywords: Electric Vehicle, Demand Influence, Fuzzy Extend AHP

1 Introduction

Controlling vehicle exhaust emissions for controlling urban air pollution has become an important task of a city's sustainable development. In recent years, the vehicle ownership of China has been increased year by year. The "China Motor Vehicle Pollution Control Annual Report (2010)", issued by Ministry of Environmental Protection, pointed out that the harmful gas emissions from vehicle have been become a major source of air pollution in big cities. The vehicle gas emissions have seriously hampered a city's sustainable development, especially in a large population and traffic city like Beijing, Shanghai in China and so on.

Vehicle ownership remained a stable growth trend in last five years, according to Ministry of Public Security Traffic Management Bureau Statistics, at the end of Jun 2012, the national vehicle has reached 114 million, and there are 17 cities has been reached over one million cars in an annual, in which Beijing, Chengdu, Tianjin, Shenzhen, Shanghai five cities of vehicle ownership are more than two millions. Vehicle industry and its ancillary industries has brought great convenience and opportunity to China's economy, but at the same time, the big consumes fossil energy used by vehicle also caused serious air pollution problem, which brought worries of China's green economic growth. The International Energy Agency (IEA) released "World Energy Outlook 2009" descripted that the world's crude oil demand will average increase 1% every year, while China is 3.5%, which is much higher than the world average level of growth. Chinese scholars give a forecasting result in 2030, in which the energy consumption by vehicles in China will reach 250-300 million tons of oil equivalent, it will rise to around 40% proportion of the total oil consumption [1]. It brings a big energy problem to China's energy security. Currently, in order to the gas emissions of fuel vehicle is as a main sources of air pollution, it is also still making a lower quality life of the people living in big or medium-sized cities. Therefore, if China wants to control vehicle pollution of the air pollution, it is essential to reform the vehicle industry. The primary problem is slowing down the fuel vehicle demand increasing trend; it is a shortcut of using electric vehicle to instead the fuel vehicle.

How to improve the market competition ability of electric vehicle is a key problem of low carbon vehicle industry. Many researchers have been analysed the influence factors of the electric vehicle's market competition. Gordon Ewing studies the demand influence with three factors form a start time of vehicle running, end time of vehicle running and mileage charge, and gave the various factors affecting analysis[2]. Some scholars find that the high prices, poor battery performance, low consumer income levels, inadequate facilities construction are important factors affecting the demand for electric vehicles [3-4]. Other scholars analyse the factors of the electric vehicle's charging power demand and give a reasonable forecasting by the analysis result[5-6]. These studies achieved a certain success result of the influence factors on electric vehicles demand; however, most of these studies are qualitative analysis, only a few are quantitative analysis. Therefore, this paper wants to give a systematic quantitative analysis of electric vehicles demand by FEAHP method, and give an evaluation index system of electric vehicles demand. It will provide a reference to improve electric vehicles demand in the vehicles market.

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2 An evaluation index system of electric vehicles demand influence

From the above researches, the researchers divides the influence factors into consumer preferences, driving miles, acceleration performance and energy supply four aspects. In this paper, we divided the influence of electric vehicles to customers into three aspects, which are vehicles' performance, service and personal preference, and gave the factors of these aspects as follows.

2.1 THE PERFORMANCE OF THE VEHICLE

The main factors of influence the vehicle's consumer is the performance of a vehicle. For electric vehicle, the main performance reflects in vehicle's battery, vehicle's motor technology and related facilities three factors. In these factors, the vehicle's battery and vehicle's motor technology are the two main factors restricting the development of pure electric vehicles sales. Customers, considered the electric vehicle's long time running and long distance operations, are mainly thinking the battery's performance; it is also a key problem for using electric vehicle. Besides, the electric charging price, the price of the electric vehicle, accelerating ability, the economic speed per hour, total running miles and battery charging convenience are all the consumers' considering factors.

2.2 SERVICE OF ELECTRIC VEHICLES

When consumer pick a vehicle, he is not only noticed the vehicle performance, but also pay more attention to the vehicle' service. Therefore, if electric vehicle wants to keep a higher market competition than fuel vehicle, it should enhance its service and strive to improve their market position in the minds of consumers from the service. For vehicles, the consumer is generally more concerned about the insurance service, the maintenance services and the convenient of the service.

2.3 PERSONAL PREFERENCE OF CONSUMER

Personal desire is a driven factor of a consumer who wants to buy a vehicle, the influence of the desire is always from inherent needs and external environment, and the desire can be seen as a result from the two aspects affecting. Due to the low carbon economic influence of the world, the external environment influence is mainly affected by government subsidies and the energy saving intends, especially the influence by relative and friends behaviour. Nowadays, with the internet high speed developing, the marketing in virtual communities such as forum, blog, chatting software has a very important influence for consumers, and the marketing strategy in internet is also the most important issue of the vehicle's company. In addition, some consumer awareness for the car brand will be extended to the purchase of electric vehicles willing of the consumer.

The evaluation index system of electric vehicles demand influence is shown in Table 1.

TABLE 1 Evaluation index system of electric vehicles demand influence

Object level	Criterion level(B)	Index level(C)
electric vehicles demand influence evaluation	The performance of the vehicle (B_1)	electric charging price
		Speed and accelerate
		total running miles and battery
		economic speed per hour
		electric vehicle's price
		charging convenience
	Service of electric vehicles (B_2)	insurance service
		the maintenance services
		the convenient of the service
	Personal preference of consumer (B_3)	government subsidies
		energy saving intend
		Related person influence for consumers
		public opinion's influence
		Vehicles' brand influence

3 FEAHP methods

How to determine the weights of each indicator of the index system is a key problem. AHP[7-8] is suitable for systematic multi-criterion decision making problems with complex hierarchy structure, and this method can deal with not only the quantitative factors but also the qualitative factors. It has the advantage of practicability, systemic and simplicity. However, it has been generally criticized because of the use of a discrete scale of one to nine which cannot handle the uncertainty and ambiguity present in deciding the priorities of different attributes, but the appearance of FEAHP[9-10] has provided a solution to this problem, because decision-makers usually find that it is more confident to give a fuzzy number than a precise number judgments. And the method has been applied successfully in many fields [11-15]. Triangular fuzzy numbers (TFN) are used in FEAHP, and a typical TFN is graphically depicted in Figure 1.

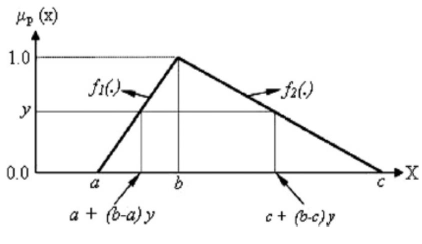

FIGURE 1 A triangular fuzzy number.

If *a*, *b* and *c*, respectively denote the smallest possible value, the most promising value and the largest possible value that describe a fuzzy event, then the TFN can be denoted as a triplet (*a*,*b*,*c*). Generally, $a \le b \le c$, and the relationship between x which can be any point between *a*, *b* and *c*, and its membership *y* conforms to

$$\begin{cases} x = a + (b-a)y & x \in [a,b] \\ x = c + (b-c)y & x \in [b,c] \\ 0 & otherwise \end{cases} \quad (1)$$

And the weight can be calculated by the four steps as follows: (where all the $M_{g_i}^{j}$ are TFNs whose parameters are a, b, and c).

TABLE 2 Fuzzy conversion scale

Linguistic scale	TFN scale	TFN reciprocal scale
Just equal	(1,1,1)	(1,1,1)
Equally important	(1/2,1,3/2)	(2/3,1,2)
Weakly important	(1,3/2,2)	(1/2,2/3,1)
Strongly more important	(3/2,2,5/2)	(2/5,1/2,2/3)
Very strongly more important	(2,5/2,3)	(1/3,2/5,1/2)
Absolutely more important	(5/2,3,7/2)	(2/7,1/3,2/5)

Step 1. The value of fuzzy synthetic extent with respect to the j th object is defined as:

$$S_i = \sum_{j=1}^{m} M_{g_i}^{j} \otimes \left[\sum_{i=1}^{n} \sum_{j=1}^{m} M_{g_i}^{j} \right]^{-1} \quad (2)$$

To obtain $\sum_{j=1}^{m} M_{g_i}^{j}$, perform the fuzzy addition operation of m extent analysis values for a particular matrix such that $\sum_{j=1}^{m} M_{g_i}^{j} = \left(\sum_{j=1}^{m} a_j, \sum_{j=1}^{m} b_j, \sum_{j=1}^{m} c_j \right)$, $j = 1,2,\ldots,m$ and to obtain $\left[\sum_{i=1}^{n} \sum_{j=1}^{m} M_{g_i}^{j} \right]^{-1}$, perform the fuzzy addition operation of $M_{g_i}^{j}$ (j=1,2,…,m)values such that

$$\left[\sum_{i=1}^{n} \sum_{j=1}^{m} M_{g_i}^{j} \right]^{-1} = \left(\frac{1}{\sum_{i=1}^{n} c_i}, \frac{1}{\sum_{i=1}^{n} b_i}, \frac{1}{\sum_{i=1}^{n} a_i} \right), \ i = 1,2,\ldots,n \quad (3)$$

Step 2.The degree of possibility of $M_2 \geq M_1$ is defined as:

$$V(M_2 \geq M_1) = hgt(M_1 \cap M_2) = \mu_{M_2}(d)$$
$$= \begin{cases} 1 & b_2 \geq b_1 \\ 0 & a_1 \geq c_2 \\ \dfrac{a_1 - c_2}{(b_2 - c_2) - (b_1 - a_1)} & otherwise \end{cases} \quad (4)$$

Where d is the ordinate of the highest intersection point d between μ_{M_2} and μ_{M_2}.

Step 3. The degree of possibility for a convex fuzzy number to be greater than k convex fuzzy numbers M_i (i=1,2,…,k) can be defined as follows:

$$V(M \geq M_1, M_2, \ldots, M_k) = \min V(M \geq M_i) \quad (5)$$

Step 4. Assume that $d'(A_i) = \sum V(M_i \geq M_k)$. Then the weight vector is given by $W' = (d'(A_1), d'(A_2), \ldots d'(A_n))^T$, where A_i $(i = 1,2,\ldots,n)$ are n elements. Then normalize the vector to get the normalized weight vectors which are $W = (d(A_1), d(A_2), \ldots d(A_n))^T$ where W is a non-fuzzy number.

4 Case study of electric vehicles demand influence evaluation base on fuzzy extended AHP

Based on indicator system above, related experts will be invited to give mark to what is intended to be appraised. These experts are either experts on low carbon economic management and electric vehicle's management. Therefore, the weight and indicator value they give will have certain credibility. According to the principle of FEAHP theory, the expert judgment matrix on all layers of indicators can be calculated as follows:

(1) Expert judgment matrix on the performance of the vehicle indicators is as follows

$$\begin{bmatrix} (1,1,1) & (1/2,1,3/2) & (1/3,2/5,1/2) & (1,3/2,2) & (2/5,1/2,2/3) & (1/2,2/3,1) \\ (2/3,1,2) & (1,1,1) & (1,3/2,2) & (3/2,2,5/2) & (1/2,1,3/2) & (1/2,1,3/2) \\ (2,5/2,3) & (1/2,2/3,1) & (1,1,1) & (1,3/2,2) & (1/2,1,3/2) & (3/2,2,5/2) \\ (1/2,2/3,1) & (2/5,1/2,2/3) & (1/2,2/3,1) & (1,1,1) & (1/2,1,3/2) & (1/2,1,3/2) \\ (3/2,2,5/2) & (2/5,1/2,2/3) & (2/3,1,2) & (2/3,1,2) & (1,1,1) & (3/2,2,5/2) \\ (1,3/2,2) & (2/3,1,2) & (2/5,1/2,2/3) & (2/3,1,2) & (2/5,1/2,2/3) & (1,1,1) \end{bmatrix}$$

And the calculation's processes are shown as follows.

$$S_1 = (3.73, 5.07, 6.67) \otimes (1/53.83, 1/39.07, 1/28.67) = (0.07, 0.13, 0.23)$$
$$S_2 = (5.17, 7.50, 10.50) \otimes (1/53.83, 1/39.07, 1/28.67) = (0.10, 0.19, 0.37)$$
$$S_3 = (5.17, 7.50, 10.50) \otimes (1/53.83, 1/39.07, 1/28.67) = (0.10, 0.19, 0.37)$$
$$S_4 = (3.40, 4.83, 6.67) \otimes (1/53.83, 1/39.07, 1/28.67) = (0.06, 0.12, 0.23)$$
$$S_5 = (5.73, 7.50, 10.67) \otimes (1/53.83, 1/39.07, 1/28.67) = (0.11, 0.19, 0.37)$$
$$S_6 = (4.13, 5.50, 8.33) \otimes (1/53.83, 1/39.07, 1/28.67) = (0.08, 0.14, 0.29)$$

According to the basic principle of FEAHP and through the comparison of $(S_1, S_2, S_3, S_4, S_5, S_6)$,we can get $d'(S_1) = \min V(S_1 \geq S_2, S_3, S_4, S_5, S_6) = 0.55$; $d'(S_2) = 0.89$; $d'(S_3) = 1$; $d'(S_4) = 0.53$; $d'(S_5) = 0.89$; $d'(S_6) = 0.68$

According to $d'(S)$, we can get the weight, vector $W' = (0.55, 0.89, 1, 0.53, 0.89, 0.63)^T$,which can be standardized into $W_{c1-c6} = (0.12, 0.20, 0.22, 0.12, 0.20, 0.15)^T$.

According to the above calculation, we can get the following results: $W_{c7-c9} = (0.33, 0.37, 0.30)^T$,

$W_{c10-c14} = (0.19, 0.21, 0.25, 0.20, 0.15)^T$,

$W_B = (0.49, 0.20, 0.31)^T$, and combining all of the weight, we can get the final weights of all the indicators.

Because most indicators are qualitative, and they are difficult to be quantified, which left the evaluation a hard problem to overcome. In this paper, the related theory concerning fuzzy appraisal sets have been quantified: first qualitative indicators was clearly defined, then according to the indicator definition and actual situation the appraisal sets was divided into 5 ranks (very good, good, ordinary, poorer, very poor) with a corresponding 5-rank score set (5, 4, 3, 2, 1).

Combining with the above idea on the appraisal and the appraisal results experts give, we survey several people who wish to buy a vehicle recently, combined with traditional fuel vehicles, they give their feeling scores of the indicators, and we use average value as the indicator value. And the evaluation results are shown as Table 3.

TABLE 3 ase study results

Person ID	Evaluation results	Personal willing
001	2.53	Either electric vehicle or fuel vehicle
002	2.42	Prefer fuel vehicle
003	4.19	Prefer electric vehicle
004	2.64	Either electric vehicle or fuel vehicle
005	1.57	Prefer fuel vehicle
006	1.15	Prefer fuel vehicle
007	1.51	Prefer fuel vehicle

From the table 3 we can see that four persons are clearly choosing a fuel vehicle, only 1 person selected electric vehicle, the most reason for which is that the surveyed person doubt the electric vehicle's performance, and the preferred electric vehicle person is an environmentalist. From practice, it can be seen that the electric vehicle should enhance its technology and performance, it is also shown evaluation indicator system and evaluation model are basically reasonable, and that they can play a part in guiding customers to pick a vehicle from a fuel vehicle and an electric vehicle.

5 Conclusions

In this study, a fuzzy extended AHP (FEAHP) approach has been presented to evaluate electric vehicles demand influence. A three levels hierarchy index system are also presented, which is evaluating from vehicles' performance, service and personal preference, and the total 14 sub-indicators have been decided.

AHP is the most appropriate method for a hierarchy evaluation problem. However, since the FEAHP model is proved to be simple, less time taking, capture the vagueness of human thinking and having less computational expense than artificial evaluation problems, this study uses FEAHP method to solving the evaluation problem. The results obtained in the example reflect the situation of electric vehicle demand in vehicle market.

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