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GREY APPROACH FOR AUTOMOBILE DEALER EVALUATION BASED ON "INTERNET PLUS AUTOMOTIVE AFTERMARKET"

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Under the globalization background, automobile manufacturers are now exploring an effective management strategy to face the demands of uncertainty and violent market competition. To improve competitiveness, automobile manufacturers must choose competitive dealers. This paper aims to study a new evaluation approach by combining grey evaluation model with a multiple indexes evaluation system. The algorithm steps of the proposed method are summarized. And a Chinese case of automobile dealer selection is included for demonstrating the process of the approach. Results show that the approach is effective and helpful in choosing competitive dealers.

Keywords: Grey system theory, Grey decision-making, Automobile dealer evaluation, automotive aftermarket

1. INTRODUCTION

With the globalization and the rapid development of economy, vehicles become the people's indispensable riding instead of walking tool. Due to reform and the opening-up policy, China's economics have made great progress in the past four decades. At the same time, people's income has increased rapidly and they tend to ask more of their quality of life. Undoubtedly, to own a private car is a measurable index of a family's quality of life. Therefore, demand for different kinds of vehicles has improved greatly, which directly led to the successful sale for almost all automobile manufacturers.

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In addition, with approximately twenty percent of the world's total population, China provides automotive companies with a unique market with high growth opportunities. Since 2009, China overtook the US and became the largest automotive market in the world, with China accounting for nearly a quarter of the world's total automotive sales. As shown in Figure 1, total automotive sales in China from 2000 to 2015 increased more than 12 times. The amount hit new highs, reaching almost 24.6 million units in 2015. While the US record was nearly 17.5 million units at the same time. In order to meet the needs of China's buyers, almost all of the automobile manufacturers expanded their production capacity continuously and operated at full capacity. As shown in Figure 2, total automotive production in China from 2000 to 2015 has got almost the same trend and increasing rates of total automotive sales. In our opinion, this developing miracle does not spring up out of nowhere but relies on China's economic development. The per capita GDP in 2000 in China was a little less than 1000 US dollars while in 2015, the record reached more than 8000 US dollars. In other words, China's economic growth promoted the automobile consumption. Especially, consumers' desire is continuously stimulated by rising personal incomes, increasing affordability, low penetration rates, improving infrastructure and favorable government policies. However, increasing rates of both total automotive sales and total automotive productions dropped to under 10%. We consider the drop was caused partly by the decreasing growth rate in per capita GDP. But the most important reason was that consumers were not satisfied by getting a travel tool, but also paid more attention to services and the consumption experience.

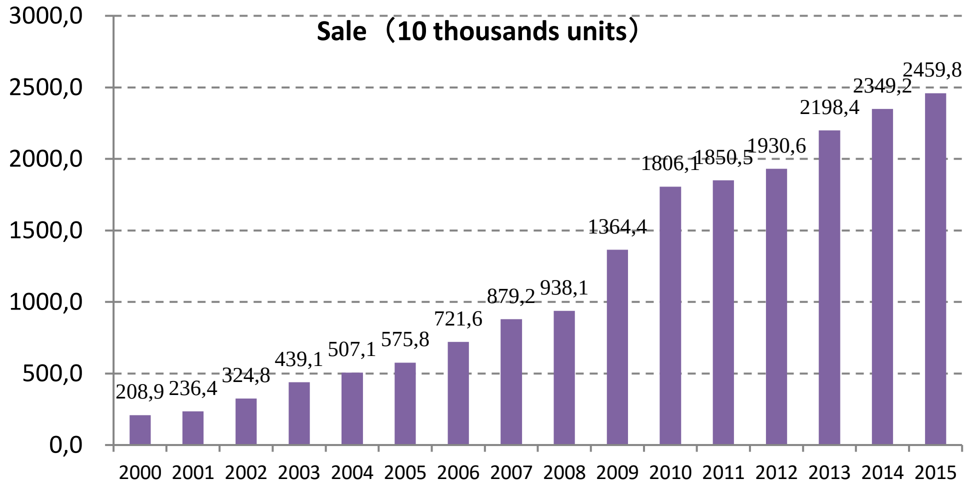

Figure 1. Total automotive sales in China 2000-2015 (sources: China Association of Automobile Manufacturers)

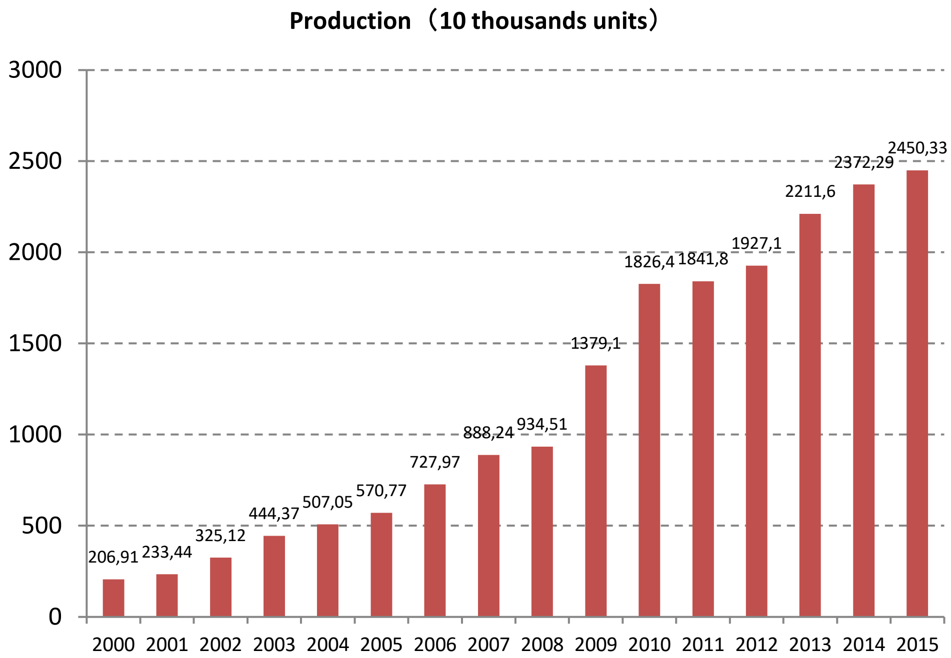

Figure 2. Total automotive production in China 2000-2015 (sources: China Association of Automobile Manufacturers)

Recently, to further satisfy consumers' demand, China's government paid more attention to the automotive aftermarket. Automotive aftermarket is the lower industry in the automotive industry chain, which clings to final customers and affects their consumption of a car. As a result, the automotive aftermarket, to a great extent, will definitely influence and penetrate into China's total car sales. In addition, the Internet industry in China has been growing fast and a great number of small and mid-size firms and several world-class corporations have emerged over the past ten years. Combining the Internet with marketing became a new option for manufacturers. Only a small percentage of manufacturers insisted on traditional marketing channels. While more and more manufacturers tried to combine traditional marketing channels with the Internet. Automobile manufacturers are no exception. Under the shock of the Internet plus environment and the automotive aftermarket, automobile manufacturers must choose competitive dealers so as to improve sales performance. This paper aims to study the grey evaluation approach to aid in choosing competitive dealers.

This paper is organized as follows: Section 1 is a general introduction and research background. Section 2 reviews the automotive aftermarket and a series of evaluation methods. In section 3, an index system for evaluating automobile dealers is constructed by considering the Internet plus environment and the automotive aftermarket. In section 4, a multi-attribute grey decision making model is constructed and the operation steps of the proposed model are given. Section 5 demonstrates a numerical case about automobile dealer selection with the proposed grey approach. Finally, Section 6 concludes the paper.

2. LITERATURE REVIEW

Aftermarket refers to activities associated with products and services after initial sale (Phelan, 2000). In the early stage, aftermarket is linked with remanufacturing, which is an industrial process whereby used products referred to as cores are restored to useful life (Sundin, 2004). The automotive aftermarket is in the same developing trend with other aftermarket businesses. Firstly, repair shops will have incentives to return the cores to dealers to get an upgrade and to provide low cost remanufactured product for customers. Now, more and more automotive manufacturers focus on providing value-added services rather than return components of a car. Subramoniam, Huisingh and Chinnam (2009, 2010) summarized remanufacturing in the automotive aftermarket. In general, automotive aftermarket is not only a special activity for competitive strategy of an auto dealer but also for the whole supply chain of automotive manufacture. "Supply chain management" SCM was firstly defined by Mentzer, Dewitt, Keebler et al. as "the systemic, strategic coordination of the traditional business functions and the tactics across these business functions within a particular company and across businesses within the supply chain, for the purposes of improving the long-term performance of the individual companies and the supply chain as a whole" (Mentzer, DeWitt, Keebler et al., 2002). Carter and Rogers further defined SCM as "the strategic, transparent integration and achievement of an organization’s social, environmental and economic goals in the systemic coordination of key inter-organizational business processes for improving the long-term economic performance of the individual company and its supply chains" (Carter, Rogers, 2008). Therefore, aftermarket development becomes an important part of the whole supply chain of automotive manufacture industry.

Faced with diversified customer’s demands and a changeable marketing environment, marketing competitions are gradually transformed from different companies into different supply chains (Mattsson, 2003; Johnson, 2006). In the supply chain management area, a great number of literature focused on dealer selection. Literatures were traditionally divided into operations management community that seeks intuitive understanding about the problem and decision process with different kinds of mathematical techniques, such as Analytic Hierarchy Process (AHP), Data Envelopment Analysis (DEA), Fuzzy Analysis (FA), Mathematical Programming (MP) and Grey System Model (GSM), etc. (De Boer, Labro, Morlacchi, 2001; Ghorabaee, Zavadskas, Amiri, 2016; Purohit, Choudhary, Shankar, 2016; Govindan, Sivakumar, 2016; Sang, Liu, 2016; Xie, Xin, 2014). As an important issue in supply chain management, dealer selection must be incorporated into supply chain management strategy (Sanayei, Mousavi, Abdi, 2008; Huang, Li, 2012; Omurca, 2013). Generally, the dealer selection problem could be structured as a typical multi-attribute decision making (*MADM*) problem, i.e. a series of indexes should be defined and their information should be aggregated in an evaluation process. *MADM* problem is a typical decision problem to select a most satisfied alternative from feasible alternatives set. A great number of literatures were concerning applying the *MADM* model to select dealers (Chen, Huang, 2007; Chan, Kumar, Tiwari, 2008; Tseng, Chiang, Lan, 2009; Wu, 2009; Keskin, Ilhan, Ozkan, 2010; Kilincci, Onal, 2011; Dowlatshahi, Karimi-Nasab, Bahrololum, 2015; Memon, Lee, Mari, 2015; Qin, Liu, 2016). Decision makers may not be able to express their evaluations in precise numbers, but they may be able to give some kinds of approximate form with their knowledge and perception. Therefore, uncertainty always lies in the dealer selection process. Fuzzy number, Interval number and Grey number are three most typical forms to express uncertainty. Fuzzy sets are utilized to define vague information (Zadeh, 1965; Zadeh, 1975), interval numbers are used to describe the boundary information (Moore, 1979) and grey numbers are employed to characterize information partially known with limited observation samples (Deng, 1982).

Grey System Theory (*GST*) is considered as a multi-disciplinary theory dealing with a systems lack of information, and an important theoretical breakthrough of management science in China (Wang, Yan, Hollister, 2008). A grey number is the basic element of grey system in which the precise value could not be determined but the potential range of values can be defined. Considering different potential value sets, a grey number could be expressed as a discrete grey number, continuous grey number or mixed grey number. In particular, if the set of potential values is denoted as one continuous interval, it is called as interval grey number. Liu and Lin (2006) give out the basic definitions of grey numbers and their operations. Zhu and Keith further combined interval grey numbers in solving multiple stages grey target decision making problems (Zhu, Keith, 2012). Zhang, Wu and Olson applied grey numbers with grey relational method to solve multiple attribute decision making problems (Zhang, Wu, Olson, 2005). Zavadskas et al. (2009) effectively combined grey numbers with the *MADM* model (Zavadskas, Kaklauskas, Turskis, 2009). Similar methods have been applied in solving dealer selection problems (Xie, Xin, 2014; Li, Yamaguchi, Nagai, 2007; Davood, Mahour, 2012; Bai, Sarkis, Wei, 2012). Therefore, the application of the concepts and operations of interval grey numbers will be helpful to deal with the uncertain information in *MADM*.

Differences with dealer selection problems have frequently been focused on. There is much less literature focused on dealer selection or evaluation. Chen and Wu (2009) the Grey Correlation Theory to evaluate automotive dealer capability with a comprehensive multi-level evaluation system. Hsiao (2012) investigated how competencies lead to performance. However, a good dealer will improve sales performance obviously. Therefore, the question of how to choose a dealer from alternative dealers becomes more and more important for car manufacturers. Especially online and mobile service platforms become more important in the current car market. Therefore, the index system must be constructed for evaluating auto dealers' competences and Internet service capability indexes must be included.

3. INDEX SYSTEM FOR EVALUATING AUTO DEALERS' CAPABILITY

Before aggregating the values of evaluation indices, detailed information of indices about evaluating automotive dealers' service capability must be constructed. In this section, the index system is established by referring Company B's information, which is a famous automobile manufacturer in China. In addition, several experts' opinions are also considered. The framework of the index system for evaluating auto dealers' capability is shown as Figure 3.

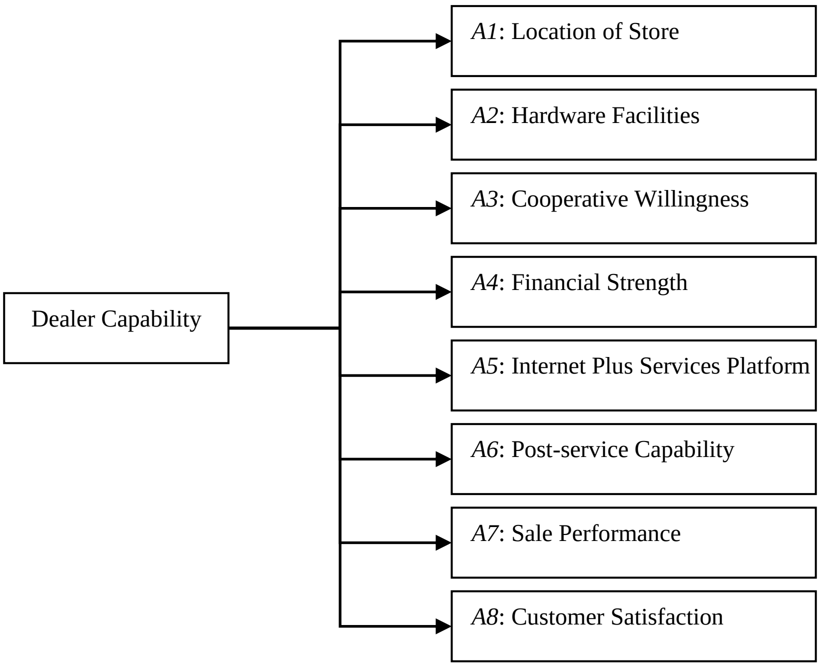

Figure 3. Index System of Automotive Dealer's Capability

Details about each particular index of automotive dealer's capability are further explained as follows:

(1) A1: Location of Store; Location of store is whether the proposed store location is in the center of auto center, city center or nearby street. This index is mainly used to measure potential customers and advertisement effect.

(2) A2: Hardware Facilities; Hardware mainly relates to various hardware standard automotive business and strength. Which consists of building conditions and devices. Whether buildings are owned or on lease, and building age. Buildings built or rebuilt and whether devices meet the standard requirements or not.

(3) A3: Cooperative Willingness; Cooperative willingness is to measure whether dealers are willing to cooperate with automobile manufacturers.

(4) A4: Financial Strength; Financial strength mainly examines the actual sales quantity of the car and operating condition.

(5) A5: Internet Plus Services Platform; Internet plus services platform is mainly about whether dealers set up the Internet platform so that customers could search for potential services.

(6) A6: Post-service Capability; Post-service capability is decided to be the key to the survival of a 4s store. It mainly examines the service response speed, the service report on time rate, internal cooperation satisfaction, customer service complaints.

(7) A7: Sale Performance; Sale performance mainly measures performance of all kinds of car sales in recent years.

(8) A8: Customer Satisfaction; Customer satisfaction is measured by questionnaire, which includes reliability, assurance, tangibles, empathy, responsiveness.

4. GREY BASED EVALUATION MODEL

In this section, a novel evaluation approach with a multiple attribute decision-making framework based on interval grey numbers is constructed. For the model, the most important thing is to compare rating results in interval grey number forms. In 2010, Xie and Liu constructed novel rules for comparing interval grey numbers (Xie, Liu, 2010). In their work, interval grey numbers were expressed by a rectangle area and the possibility degree between interval grey numbers was calculated with the area proportion between above the straight line $x = y$ and the whole rectangle. As shown in Figure 4, set $\otimes_1 = [\underline{a}_1, \overline{a}_1]$ and $\otimes_2 = [\underline{a}_2, \overline{a}_2]$ as two independent interval grey numbers. Comparing area of $\otimes_1$ and $\otimes_2$ is defined as rectangle area whose apexes are the points $\underline{a}_1, \underline{a}_2$), ($\underline{a}_1, \overline{a}_2$), ($\overline{a}_1, \underline{a}_2$) and ($\overline{a}_1, \overline{a}_2$). Define $f(x)$ as the probability density function of $\otimes_1$ and $f(y)$ as the probability density function of $\otimes_2$, then we can get the following equations apparently.

$$\int_{\underline{a}_1}^{\overline{a}_1} f(x)dx = 1 \quad (1)$$

$$\int_{\underline{a}_2}^{\overline{a}_2} f(y)dy = 1 \quad (2)$$

Marking the area above the straight line x = y as D_1 and the area below the straight line x = y as D_2, we can define probability $p(\otimes_1 \le \otimes_2)$ for $\otimes_1$ is less than $\otimes_2$ with the joint probability density function as shown in Equation (3).

$$p(\otimes_1 \le \otimes_2) = \frac{\iint_{D_2} f(x,y)dxdy}{\iint_{D_1+D_2} f(x,y)dxdy} \quad (3)$$

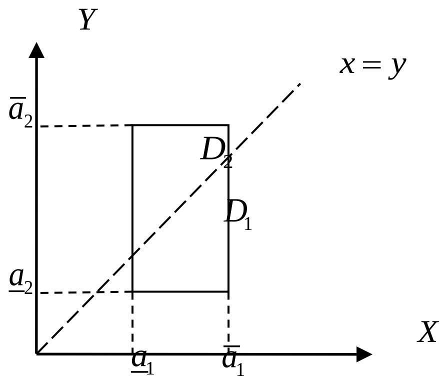

Figure 4. The sketch map comparing the interval grey numbers $\otimes_1$ and $\otimes_2$

In particular, if the probabilities of any two values in a value-covered set are equal, i.e. $f(x,y)=1$, then

$$P(\otimes_1 \le \otimes_2) = \frac{S_2}{S_1 + S_2} \quad (4)$$

where S_1 is the area of D_1 and S_2 is the area of D_2.

Considering the different values of $\underline{a}_1$, $\overline{a}_1$, $\underline{a}_2$ and $\overline{a}_2$, the possibility degree of $P(\otimes_1 \le \otimes_2)$ is detailed in Equation (5).

$$P(\otimes_1 \le \otimes_2) = \begin{cases} 0, & \underline{a}_1 > \bar{a}_2 \\ 1-(\bar{a}_1 - \underline{a}_2)^2 / [2(\bar{a}_1 - \underline{a}_1)(\bar{a}_2 - \underline{a}_2)], & \underline{a}_1 < \underline{a}_2 < \bar{a}_1 < \bar{a}_2 \\ (\bar{a}_2 - \underline{a}_1)^2 / [2(\bar{a}_1 - \underline{a}_1)(\bar{a}_2 - \underline{a}_2)], & \underline{a}_2 < \underline{a}_1 < \bar{a}_2 < \bar{a}_1 \\ (2\bar{a}_2 - \underline{a}_1 - \bar{a}_1)(\bar{a}_1 - \underline{a}_1) / [2(\bar{a}_1 - \underline{a}_1)(\bar{a}_2 - \underline{a}_2)], & \underline{a}_2 < \underline{a}_1 < \bar{a}_1 < \bar{a}_2 \\ (\bar{a}_2 + \underline{a}_2 - 2\underline{a}_1)(\bar{a}_2 - \underline{a}_2) / [2(\bar{a}_1 - \underline{a}_1)(\bar{a}_2 - \underline{a}_2)], & \underline{a}_1 < \underline{a}_2 < \bar{a}_2 < \bar{a}_1 \\ 1, & \underline{a}_2 > \bar{a}_1 \end{cases} \tag{5}$$

The method is very suitable for solving the group multi-attribute decision making (*G-MADM*) problem with uncertain information. The structure of *G-MADM* problem is shown in Table 1. There are k decision makers in the decision committee, assume that S = {S_1, S_2, …, S_m} is a discrete set of m potential dealer alternatives. A = {A_1, A_2, …, A_n}is a set of n attributes of each dealer.

$$\otimes_{ij}^{l} = [\underline{a}_{ij}^{l}, \bar{a}_{ij}^{l}] \, (i = 1, 2, \cdots, m; \; j = 1, 2, \cdots, n; l = 1, 2, \cdots, k) \tag{6}$$

is the l th decision maker's rating value about i th dealer for the j th attribute.

Table 1. Structure of the *G-MADM* problem

Dealer	**Decision maker *1***				**Decision maker *2***				$\cdots$	**Decision maker *k***			
	A_1	A_2	$\cdots$	A_n	A_1	A_2	$\cdots$	A_n	$\cdots$	A_1	A_2	$\cdots$	A_n
S_1	$\otimes_{11}^1$	$\otimes_{12}^1$	$\cdots$	$\otimes_{1n}^1$	$\otimes_{11}^2$	$\otimes_{12}^2$	$\cdots$	$\otimes_{1n}^2$	$\cdots$	$\otimes_{11}^k$	$\otimes_{12}^k$	$\cdots$	$\otimes_{1n}^k$
S_2	$\otimes_{21}^1$	$\otimes_{22}^1$	$\cdots$	$\otimes_{2n}^1$	$\otimes_{21}^2$	$\otimes_{22}^2$	$\cdots$	$\otimes_{2n}^2$	$\cdots$	$\otimes_{21}^k$	$\otimes_{22}^k$	$\cdots$	$\otimes_{2n}^k$
$\cdots$	$\cdots$	$\cdots$	$\cdots$	$\cdots$	$\cdots$	$\cdots$	$\cdots$	$\cdots$	$\cdots$	$\cdots$	$\cdots$	$\cdots$	$\cdots$
S_m	$\otimes_{m1}^1$	$\otimes_{m2}^1$	$\cdots$	$\otimes_{mn}^1$	$\otimes_{m1}^2$	$\otimes_{m2}^2$	$\cdots$	$\otimes_{mn}^2$	$\cdots$	$\otimes_{m1}^k$	$\otimes_{m2}^k$	$\cdots$	$\otimes_{mn}^k$

Table 2. The scale of attribute ratings $\otimes$

Scale	$\otimes$
Very low (VL)	[0, 3]
Low (L)	[3, 5]
Fair (F)	[5, 7]
High (H)	[7, 9]
Very high (VH)	[9, 10]

The attributes are assumed independent from each other. In this paper, considering the uncertain information in the dealer selection process, the ratings of dealers are viewed as linguistic variables which are expressed as interval grey numbers. The attribute ratings are scaled in 1-10 scale as shown in Table 2. The procedures of *G-MADM* method are summarized as follows:

Step 1: Define the grey rating value matrix of each Decision Maker (*DM*); Adopt a linguistic variable for attribute in Table 2 to define rating value about the i th dealer for the j th attribute and form the l th decision maker's grey rating value matrix as

$$D_l = \begin{bmatrix} \otimes_{11}^l & \otimes_{12}^l & \cdots & \otimes_{1n}^l \\ \otimes_{21}^l & \otimes_{22}^l & \cdots & \otimes_{2n}^l \\ \vdots & \vdots & \ddots & \vdots \\ \otimes_{m1}^l & \otimes_{m2}^l & \cdots & \otimes_{mn}^l \end{bmatrix} \tag{7}$$

where $\otimes_{ij}^l$ is shown as Eq. (6).

Step 2: Rating information aggregation of k *DM*s. Aggregating the synthesized rating value which can be calculated as

$$\otimes_{ij} = \frac{1}{k}(\otimes_{ij}^1 + \otimes_{ij}^2 + \cdots + \otimes_{ij}^k) = [\underline{a}_{ij}, \overline{a}_{ij}](i = 1,2,\cdots,m; j = 1,2,\cdots,n) \tag{8}$$

where

$$\underline{a}_{ij} = \frac{1}{k}\sum_{l=1}^{k}\underline{a}_{ij}^l \tag{9}$$

$$\overline{a}_{ij} = \frac{1}{k}\sum_{l=1}^{k}\overline{a}_{ij}^l \tag{10}$$

In order to simplify the decision process, the weight of each *DM* is viewed as equal in the decision-making committee. If the DMs' weights are not equal, the synthesized rating value of each element could be aggregated by different DMs' rating value and their corresponding weights.

Step 3: Establish the synthesized grey decision matrix as

$$D = \begin{bmatrix} \otimes_{11} & \otimes_{12} & \cdots & \otimes_{1n} \\ \otimes_{21} & \otimes_{22} & \cdots & \otimes_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ \otimes_{m1} & \otimes_{m2} & \cdots & \otimes_{mn} \end{bmatrix} \tag{11}$$

where $\otimes_{ij} = [\underline{a}_{ij}, \overline{a}_{ij}]$ is shown as Eq. (8).

Step 4: Normalize the grey decision matrix D as

$$D^* = \begin{bmatrix} \otimes_{11}^* & \otimes_{12}^* & \cdots & \otimes_{1n}^* \\ \otimes_{21}^* & \otimes_{22}^* & \cdots & \otimes_{2n}^* \\ \vdots & \vdots & \ddots & \vdots \\ \otimes_{m1}^* & \otimes_{m2}^* & \cdots & \otimes_{mn}^* \end{bmatrix} \tag{12}$$

where for a benefit attribute, $\otimes_{ij}^* = [\underline{b}_{ij}^*, \bar{b}_{ij}^*]$ is the generated from

$$\otimes_{ij}^* = [\frac{\underline{a}_{ij}}{a_j^{\max}}, \frac{\bar{a}_{ij}}{a_j^{\max}}] \tag{13}$$

$$a_j^{\max} = \max_{1 \le i \le m} \left\{ \bar{a}_{ij} \right\} \tag{14}$$

For a cost attribute, $\otimes_{ij}^* = [\underline{b}_{ij}^*, \bar{b}_{ij}^*]$ is the generated from

$$\otimes_{ij}^* = [\frac{a_j^{\min}}{\bar{a}_{ij}}, \frac{a_j^{\min}}{\underline{a}_{ij}}] \tag{15}$$

$$a_j^{\min} = \min_{1 \le i \le m} \left\{ \underline{a}_{ij} \right\} \tag{16}$$

This normalization is to transfer the ranges of interval grey rating number into $[0,1]$.

Step 5: Define the ideal dealer attribute sequence. For m possible dealer set $S = \left\{ S_1, S_2, \cdots, S_m \right\}$, ideal dealer attribute sequence $S^{\max} = \left\{ \otimes_1^{\max}, \otimes_2^{\max}, \cdots, \otimes_n^{\max} \right\}$, where

$$\otimes_j^{\max} = [\max_{1 \le i \le m} \underline{b}_{ij}^*, \max_{1 \le i \le m} \bar{b}_{ij}^*] \tag{17}$$

so we can get ideal dealer attribute sequence as

$$S^{\max} = \left\{ [\max_{1 \le i \le m} \underline{b}_{i1}^*, \max_{1 \le i \le m} \bar{b}_{i1}^*], [\max_{1 \le i \le m} \underline{b}_{i2}^*, \max_{1 \le i \le m} \bar{b}_{i2}^*], \cdots, [\max_{1 \le i \le m} \underline{b}_{in}^*, \max_{1 \le i \le m} \bar{b}_{in}^*] \right\} \tag{18}$$

Step 6: Calculate possibility degree between a particular alternative and its corresponding ideal attribute value as $P(\otimes_{ij}^* \le \otimes_j^{\max})$ with the Equation (5). And we can get a possibility degree matrix as

$$P=\begin{bmatrix} P(\otimes_{11}^{*}\le\otimes_{1}^{\max}) & P(\otimes_{12}^{*}\le\otimes_{2}^{\max}) & \cdots & P(\otimes_{1n}^{*}\le\otimes_{n}^{\max}) \\ P(\otimes_{21}^{*}\le\otimes_{1}^{\max}) & P(\otimes_{22}^{*}\le\otimes_{2}^{\max}) & \cdots & P(\otimes_{2n}^{*}\le\otimes_{n}^{\max}) \\ \vdots & \vdots & \ddots & \vdots \\ P(\otimes_{m1}^{*}\le\otimes_{1}^{\max}) & P(\otimes_{m2}^{*}\le\otimes_{2}^{\max}) & \cdots & P(\otimes_{mn}^{*}\le\otimes_{n}^{\max}) \end{bmatrix} \tag{19}$$

Step 7: Weight information aggregation of k *DM*s. Aggregate the attributes' weights of k decision makers and we can get synthesized weight for j th attribute as

$$w_j=\frac{1}{k}(w_j^1+w_j^2+\cdots+w_j^k)\ (j=1,2,\cdots,n) \tag{20}$$

where w_j^k is the weight for j th attribute of k decision maker.

Step 8: Calculate the synthesized possibility degree between compared dealer alternatives set S = {S_1, S_2,…,S_m} and ideal dealer S^{max} as

$$P(S_i\le S^{\max})=\sum_{j=1}^{n}P(\otimes_{ij}^{*}\le\otimes_{j}^{\max})w_j \tag{21}$$

Step 9: Rank the order of dealer alternatives and make a decision. When $P(S_i \le S^{max})$ is smaller, the ranking order of S_i is better. Similarly, when $P(S_i \le S^{max})$ is larger, the ranking order of S_i is worse. According to the ranking order of all dealers, the best dealer could be selected among a potential dealer set.

5. CASE STUDY AND ANALYSIS

Given seven dealers S = {S_1, S_2,…,S_7} are included in dealers set against eight attributes A = {A_1, A_2,…,A_8}, i.e. location of store, hardware facilities, cooperative willingness, financial strength , internet plus services platform , post-service capability, sale performance and customer satisfaction. Obviously all A_i are benefit attributes, i.e. the greater value could get the better result. The decision committee is composed of four decision makers (*DM*). The calculation steps are as follows:

Step 1: Define the grey rating value matrix of each decision maker (*DM*). According to Eq. (7), the results of each decision maker's rating values are shown in Table 3 (according to the experts grading).

Table 3. Original rating values for dealers

S_i	DM_1								DM_2								DM_3							
	A_1	A_2	A_3	A_4	A_5	A_6	A_7	A_8	A_1	A_2	A_3	A_4	A_5	A_6	A_7	A_8	A_1	A_2	A_3	A_4	A_5	A_6	A_7	A_8
S_1	VL	H	H	F	H	L	H	VH	L	H	F	VH	F	H	VH	H	L	H	L	F	F	VL	H	F
S_2	F	VH	L	F	L	VL	VH	L	F	L	H	L	L	H	L	VH	H	L	F	VL	VL	H	VH	L
S_3	VH	H	L	H	H	H	H	H	H	F	H	VH	H	VH	H	H	H	F	H	VH	H	H	H	F
S_4	H	H	F	H	H	VH	H	L	F	F	H	H	H	VH	H	VH	H	F	F	H	H	F	F	L
S_5	F	VH	H	VH	VH	F	H	VH	H	H	VH	VH	F	H	L	VH	H	H	H	H	H	VH	H	VH
S_6	L	L	VH	F	F	L	VH	L	F	VH	F	F	VL	L	H	H	L	VH	F	H	L	H	L	H
S_7	H	H	F	L	H	VH	H	H	VH	F	L	F	H	VH	H	F	H	L	L	H	VH	L	VL	L

Step 2: According to the scale value in Table 2 and Eq. (8), we can aggregate DMs synthesized rating value for each attribute. For example, to the first attribute of the second dealer, we can get the rating information as "F", "F" and "H" evaluated by DM_1-DM_3. According to Eq. (8) and rating value in Table 2, $i = 2$, $j = 1$, and $k = 3$, we get

$$\otimes_{21} = \frac{1}{3}(\otimes_{21}^{1} + \otimes_{21}^{2} + \otimes_{21}^{3}) = \frac{1}{3}\{[5,7]+[5,7]+[7,9]\} = [5.67, 7.67] .$$

Step 3: According to Eq. (11) we can obtain the synthesized grey decision matrix of dealers as shown in Table 4. That is to say, with different $i = 1, 2, \ldots, 7$, $j = 1, 2, \ldots, 8$, and $i = 1, 2, 3$, we can get a rating value in each element and synthesizing all of the elements we get the synthesized grey decision matrix as shown in Table 4.

Table 4. Synthesized grey rating value matrix

S_i	A_1	A_2	A_3	A_4	A_5	A_6	A_7	A_8
S_1	[2.00, 4.33]	[7.00, 9.00]	[5.00, 7.00]	[6.33, 8.00]	[5.67, 7.67]	[3.33,5.67]	[7.67,9.33]	[7.00,8.67]
S_2	[5.67, 7.67]	[5.00, 6.67]	[6.33, 7.67]	[8.33, 9.67]	[2.00, 4.33]	[4.67,7.00]	[7.00,8.33]	[5.00,6.67]
S_3	[7.67, 9.33]	[4.00, 6.00]	[7.00, 9.00]	[8.50, 9.75]	[7.00, 9.00]	[7.67,9.33]	[7.00,9.00]	[6.33,8.33]
S_4	[6.33, 8.33]	[5.67, 7.67]	[5.67, 7.67]	[7.00, 9.00]	[7.00, 9.00]	[7.67,9.00]	[6.33,8.33]	[5.00,6.67]
S_5	[6.33, 8.33]	[7.67, 9.33]	[6.33, 8.33]	[8.33, 9.67]	[7.00, 8.67]	[7.00, 8.67]	[5.67, 7.67]	[9.00,10.0]
S_6	[3.67,5.67]	[7.00, 8.33]	[6.33, 8.00]	[5.67, 7.67]	[2.67,5.00]	[4.33,6.33]	[6.33,8.00]	[5.67,7.67]
S_7	[7.67,9.33]	[5.00, 7.00]	[3.67,5.67]	[5.00, 7.00]	[7.00, 9.00]	[7.00, 8.33]	[4.67, 7.00]	[5.00,7.00]

Step 4: According to Eq. (12) - Eq. (16) we can obtain the normalized grey decision matrix of dealers as shown in Table 5. For example, the first attribute A_1 is a benefit attribute, we need to calculate normalized rating value with Eq. (15) and Eq. (16). According to Eq. (16), we get $a_j^{\max} = \max_{1 \le i \le m} \{\bar{a}_{ij}\} = 9.33$ then we can calculate $\otimes_{11}^{*} = [0.214, 0.464]$. Similarly we can get normalized rating value in each element and normalized grey decision matrix as shown in Table 5.

Table 5. Normalized grey decision matrix

Si	***A1***	***A2***	***A3***	***A4***	***A5***	***A6***	***A7***	***A8***
S_1	[0.214,0.464]	[0.750,0.965]	[0.556,0.778]	[0.649,0.821]	[0.630,0.852]	[0.357,0.608]	[0.822,1.000]	[0.700,0.867]
S_2	[0.608,0.822]	[0.536,0.715]	[0.703,0.852]	[0.854,0.992]	[0.222,0.481]	[0.501.0.750]	[0.750,0.893]	[0.500,0.667]
S_3	[0.822,1.000]	[0.429,0.643]	[0.778,1.000]	[0.872,1.000]	[0.778,1.000]	[0.822,1.000]	[0.750,0.965]	[0.633,0.833]
S_4	[0.679,0.893]	[0.608,0.822]	[0.630,0.852]	[0.718,0.923]	[0.778,1.000]	[0.822,0.965]	[0.679,0.893]	[0.500,0.667]
S_5	[0.679,0.893]	[0.822,1.000]	[0.703,0.926]	[0.861,0.992]	[0.778,0.963]	[0.750,0.929]	[0.608,0.822]	[0.900,1.000]
S_6	[0.393,0.608]	[0.750,0.893]	[0.703,0.889]	[0.582,0.787]	[0.297,0.556]	[0.464,0.679]	[0.679,0.858]	[0.567,0.767]
S_7	[0.822,1.000]	[0.536,0.750]	[0.408,0.630]	[0.513,0.718]	[0.778,1.000]	[0.750,0.893]	[0.501,0.778]	[0.500,0.700]

Step 5: According to Table 5, Eq. (17) and Eq. (18), we can get an ideal dealer a ttribute sequence as

$$S^{\max} = \begin{Bmatrix} [0.822,1.000],[0.822,1.000],[0.778,1.000],[0.872,1.000], \\ [0.778,1.000],[0.822,1.000],[0.822,1.000],[0.900,1.000] \end{Bmatrix}$$

Step 6: Calculate the possibility degree between a particular alternative and its corresponding ideal attribute value as $P(\otimes_{ij}^{*} \le \otimes_j^{\max})$ with Equation (5). And we can get a possibility degree matrix as in Table 6.

Table 6. Possibility degree matrix

Si	***A1***	***A2***	***A3***	***A4***	***A5***	***A6***	***A7***	***A8***
S_1	1	0.732	1	1	0.944	1	0.500	1
S_2	1	1	0.917	0.592	1	1	0.901	1
S_3	0.500	1	0.500	0.500	0.500	0.500	0.733	1
S_4	0.934	1	0.944	0.950	0.500	0.598	0.934	1
S_5	0.93	0.500	0.779	0.571	0.583	0.820	1	0.005
S_6	1	0.901	0.851	1	1	1	0.980	1
S_7	0.500	1	1	1	0.500	0.901	1	1

Step 7: According to Eq. (20) and Table 7 (weights of 3 decision makers), aggregating the attributes' weights of 3 decision makers we can get the weight matrix as Eq. (22).

Table 7. Weights matrix of 3 decision makers

DMi	***A1***	***A2***	***A3***	***A4***	***A5***	***A6***	***A7***	***A8***
DM1	0.2	0.15	0.15	0.05	0.15	0.1	0.12	0.18
DM2	0.3	0.1	0.18	0.06	0.18	0.06	0.07	0.05
DM3	0.25	0.16	0.1	0.09	0.1	0.1	0.1	0.1

$$w = [0.250, 0.137, 0.143, 0.067, 0.143, 0.087, 0.097, 0.110] \tag{22}$$

Step 8: According to Eq. (21) and Table 8, calculating the synthesized possibility degree between compared dealer alternatives set S = {S_1, S_2, …, S_m} and ideal dealer S^{max}, the results of the grey possibility degree are shown as:

$$P(S_1 \le S^{\max}) = 0.941,\ P(S_2 \le S^{\max}) = 0.985,\ P(S_3 \le S^{\max}) = 0.680,$$
$$P(S_4 \le S^{\max}) = 0.893,\ P(S_5 \le S^{\max}) = 0.703,\ P(S_6 \le S^{\max}) = 0.897,$$
$$P(S_7 \le S^{\max}) = 0.829$$

Step 9: According to Step 8, the result of ranking order is shown as follows:

$$S_3 \succ S_5 \succ S_7 \succ S_4 \succ S_6 \succ S_1 \succ S_2$$

So the dealer S_3 is the best choice in the dealer set. Next alternative is S_5 and then S_7, S_4, S_6, S_1. S_2 is the worst choice. According to Steps 1-9, we clearly know that the proposed model can be used for dealer selection.

6. CONCLUSIONS

With the quick development of economy, rapidly increasing incomes and everlasting consumption, vehicles became widespread and automobiles changed a lot. People are not satisfied with a replacement of a walking tool, and pay more attention to consumption feelings and services' quality. Therefore flexible Internet platforms and value-added aftermarket services must be considered by an automobile manufacturer so as to improve sales performance. That is to say, automobile manufacturers should pay attention to not only the vehicle production itself, but also to the whole supply chain's service quality. The selection of competitive dealers becomes the most important task in improving service quality. It is easy for manufacturers to give out a potential grey status rather than a precise value of a particular index for evaluation of the service capability of a dealer. This paper adopt linguistics to measure the uncertainty information of a particular index. By transforming the linguistic scale of rating dealer selection attributes into interval grey numbers, a novel grey multi-attribute decision making method was developed and the procedure of the proposed method is given. An index system for evaluating an automobile dealer's capability under the instigation of Internet platform and the automotive aftermarket is developed. Finally, a numerical case about automotive dealers' selection is used to test the effectiveness of the proposed model. Results show that the method is useful for aggregating decision makers' information and can effectively select the potential dealers.

To sum up, the main contributions of this paper were to apply grey numbers to multi-attribute decision making models and to help manufacturers choose potential dealers considering the Internet platform and the automotive aftermarket. Further studies should focus on further improving value-added aftermarket services and constructing novel MADM models to aggregate attributes effectively.

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PODEJŚCIE SZARYCH SYSTEMÓW DO OCENY DILERA SAMOCHODÓW NA PODSTAWIE "INTERNET PLUS AUTOMOTIVE AFTERMARKET"

Streszczenie

W świetle globalizacji, producenci pojazdów sprawdzają skuteczną strategię zarządzania adekwatną do niepewności popytu i brutalnej konkurencji na rynku. Aby zwiększyć konkurencyjność, producenci pojazdów są zmuszeni wybierać konkurencyjnych dealerów. Niniejszy artykuł ma na celu omówienie nowego podejścia do oceny przez połączenie szarych systemów systemem oceny wieloindeksowej. Zaprezentowano kolejne kroki algorytmu zaproponowanej metody. Na potrzeby przedstawienia procesu nowego podejścia wykorzystano przypadek wyboru dealerów samochodowych w Chinach. Wyniki pokazują, że podejście jest skuteczne i pomocne w wyborze konkurencyjnych dealerów.

Keywords: teoria szarego system, szare podejmowanie decyzji, ocean dilera samochodowego, rynek wtórny samochodów