

## Evaluation of Automobile Manufacturing Enterprise Competitiveness from Social Responsibility Perspective

### Ocena konkurencyjności branży samochodowej z perspektywy odpowiedzialności społecznej

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#### Abstract

The article proposed an index system based on social responsibility, including the main index of Employee dimension, Government dimension, Customer dimension, Business partner dimension, Ecological benefits dimension and the sub-index which comprised 18 indexes to evaluate the automotive manufacturers competitiveness. Based on the index system, an evaluation model integrates by extension theory and AHP and groups eigenvalue method (GEM) was introduced. Using established evaluation system and evaluation model, an empirical analysis is elaborately explained. The key result of the evaluated show that the index system and evaluation model built in this research not only can overcome the shortcomings of other methods requiring large data but also can clear the mechanisms and determinants of how CSR produces competitiveness, so it has a good applicability in automobile manufacturing enterprise competitiveness evaluation.

**Key words:** social responsibility, automotive manufacturers' competitiveness, extension theory, GEM

#### Streszczenie

Artykuł przedstawia system wskaźników oparty na społecznej odpowiedzialności, uwzględniający główne wskaźniki na poziomie zatrudnienia, rządu, konsumenta, partnera biznesowego, korzyści ekologicznych i zawierający 18 elementów pozwalających ocenić konkurencyjność branży samochodowej. Na systemie wskaźników oparto ocenę modeli integrujących teorię rozszerzenia, AHP i GEM. Korzystając z przyjętego systemu i modelu oceny przeprowadzono następnie badania empiryczne. Uzyskane rezultaty pokazują, że zastosowana metodologia pozwala nie tylko rozwiązać problemy wynikające z niedociągnięć innych metod wymagających dużych baz danych, ale także pozwala na lepsze zrozumienie mechanizmów i uwarunkowań odnoszących się do tego, w jaki sposób koncepcja społecznej odpowiedzialności biznesu wpływa na konkurencyjność, a poprzez to znakomicie nadaje się do zastosowania w ocenie konkurencyjności branży samochodowej.

**Słowa kluczowe:** odpowiedzialność społeczna, konkurencyjność branży samochodowej, teoria rozszerzenia, GEM

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## Introduction

As the pillar industry of the national economy, automobile manufacturing enterprises' competitiveness strength have more direct influence to the regional economic development and the country's overall competitiveness, therefore, it has become an important indicator to measure the regional economy and national economic development situation, and also become the key point to accelerate Chinese automobile industrial development and to enhance the national economy. In terms of the selection of automobile manufacturing enterprise competitiveness evaluation index and evaluation method, there have some scholars studied. For example, combined with the characteristics of automobile manufacturers, Yan (2004) divided the automobile manufacturing enterprise competitiveness evaluation index into four level indicators, including: *the scale and profitability* indicators, *technical factors* indicators, *market capacity* indicators, *organization and management capability and corporate culture* indicators, which composed by the 33 secondary indicators, Yan also use fuzzy comprehensive method made an empirical evaluation, according to the result, he point that, as an important indicator to measure the regional and national economic development situation, the automobile manufacturing enterprise competitiveness is an integrate result of market efficiency, innovation, management and environmental factors. Yu (2004) analyzed the status of Chinese automobile manufacturing enterprises, and proposed *labor costs* should be considered as Chinese automobile manufacturing enterprise core competitive advantage, he also advanced that, foster and enhance the automobile manufacturing enterprises' overall competitiveness, we should performed in several ways, like: enhanced self-development capacity, improve labor productivity, accelerate development of service industries, etc. Zhao and Leng (2006) using eight indicators: *the main business income, net profit, net assets, ROE, the main business profit margins, net operating cash flow per share, the main business revenue growth, net profit growth* and factor analysis method, make an evaluate to the competitiveness of Chinese A-share market auto manufacturing enterprises, conclude that the size factor, profitability and development factors, management factors are the three main factors which influence automobile enterprise competitiveness. Zhang and Zhu (2009) pointed out that the competitiveness of automobile manufacture enterprise amount to its independent innovation capability, and built an automobile manufacturing enterprise independent innovation ability index system including internal conditions, external environment, innovation input and innovation output four dimension, they also using expert scoring method to determine the index weight and build a comprehensive evaluation model based on evidence theory. Wang (2005) utilize rough set theory to analysis and

screening the automobile enterprise competitiveness evaluation index system, pointed out that when evaluate the current competitiveness of automobile manufacturing enterprise, the index which reflects the scale and efficiency, such as: sales revenue and net assets, are the key index. In addition, Cong (2008) analyzed the auto companies' internationally competitive advantages and disadvantages in Yangtze River Delta, proposed improving the international competitiveness of enterprises, they should implementation an *open, competitive, restructuring and overall cost leadership* strategy. Qiu (2008) thought to improve the competitiveness of automotive manufacturers, flat management is an efficient way. Fan (2009) argued that increasing the economic efficiency of enterprises is the wise choice to improve the competitiveness of automobile manufacturing companies at the present stage. Zhao and Cai (2006) analysis the automobile manufacturing enterprise competitiveness from two aspects: *scale competitiveness* and *brand competitiveness*. Kang and Wang (2006) uses seven indicators including market share, profit margins, etc. evaluated the international competitiveness of Chinese auto manufacturers.

From the above, we can know that, although the scholars have made great achievements in the study of automotive manufacturers' competitiveness evaluation indicators and evaluation methods, but the researches integrate the social responsibility into competitiveness is rare. Previous competitiveness evaluation factors selecting mostly involve economic interests dimensions and technical innovation level, less involved the interests of customers, ecological benefits and other social responsibility dimension which enterprises should undertaken. Porter and Kramer (2006) believes that companies should integrate socially responsible management to corporate strategy, thereby creating shared value of the business and society, which is an important factor affecting the company's future competitiveness. Visser (2010) also noted that the current social responsibility has entered a new era, social responsibility management would turn from professional to diversify, that is, from the experts responsible to company's management and even integrated into the company's core business. From the above, we also can know that, on the choice of competitiveness evaluation methods, scholars usually use factor analysis or comprehensive evaluation model based on evidence theory or rough set theory or ANP, all these methods often require large amounts of data to support and their calculation process is very complex, which would cause lots difficulties in some practical applications. In order to solve the above problems, this paper will design an index system from the perspective of social responsibility, and establish an evaluation model combine AHP, GEM and extension theory. This evaluation index system and evaluation model not only can solve the previous difficulties, it also can provides a new thinking way for the auto-

mobile manufacturing enterprise competitiveness evaluation in the background of sustainable development.

The rest of this paper is structured as follows. In Section 2, based on the theory of social responsibility, and according to the automobile manufacturing enterprise production process and output performance characteristics, five dimensions of automobile manufacturing enterprise competitiveness evaluation index system been proposed; In Section 3, put forward AHP-GEM-Extension comprehensive assessment model, which can overcome the inconsistency of Saaty matrix construct; In Section 4, based on the proposed evaluation system and model, an empirical analysis is elaborately explained; In Section 5, the finally section, conclusions and some managerial implications are drawn from the study.

## 2. Design competitiveness evaluation index based on social responsibility

Theory and practice of corporate social responsibility has experienced nearly a hundred years, the debate about the concept of social responsibility has never stopped (Li and Xiao, 2008; Drucker 1984) believes that social responsibility requires managers should be aware of company policies and behaviour and to consider their business activities' impact to social, considering whether certain behaviours can promote the public interest and beneficial to the advances of social basic beliefs and social stability, prosperity and harmony. Koontz (1998) proposed that corporate social responsibility mean manager should seriously considering the impact of company's movements on society. McWilliams and Siegel (2001) defined the corporate social responsibility as *some behaviour beyond business interests and beyond legal requirements, all these behaviour is to promote social development*. Chen and Mao (2006) thought that corporate which shoulder social responsibility should take maximize the value to society as the goal in the process of social value creation, they should overstep immediate benefits and think about not only get their own development, but also contribute to the development of society. Schwartz and Carroll (2008) also pointed out that social responsibility refers to, when an enterprise in the pursuit of economic performance and their own development, they not only committed to the creation of social net, but also should take the sustainable development of society and the environment into account and concerned about their own contribution to greenhouse gas emissions as well as local economic growth and so on. If view from the logic of institutional theory, the essence of corporate social responsibility is a kind of institutional arrangements that can affect the overall behaviour of enterprises and individuals to some extent, and thus have an impact on the value creation process and the results. This new institu-

tional arrangements will have an impact on the existing institutional system, companies will experience an organizational change during the long mutual integration process of social responsibility and business operations (Yuan et al., 2011). As the process of Chinese economic integration globalization speed up, the practice of corporate social responsibility has made a rapid development in the past decade. However, there is still a widespread misconception in corporate that socially responsible behaviours are opposed to daily operations activities, it belonging to the *attached behaviour* which beyond the scope of corporate responsibility will increasing the enterprises operating costs and weaken their competitiveness. This wrong perception leading enterprises produce a psychological conflict to fulfill their social responsibility and hampered social responsibility promote. Some companies even forced to make some response under the external pressure, but their actions are often restrictions on the oral and written, lacking of create real social value.

Recent years, China has gradually become the major exporter. Chinese exports are mainly concentrated in the developed countries of Europe and America which take the labor issue as a social responsibility and try to link it to the trade. Through *purchase power*, these countries require multinational industry bear social responsibility, like improve labor treatment of the processing plant (especially labor-intensive industries), protection of the environment, etc. Some NGO, which involve Greenpeace, environmental protection, social responsibility and human rights, appeal repeated and asked social responsibility should link with trade. Also some industries and global industry organizations and non-governmental organizations even developed their own codes, according to the International Labor Organization (ILO) statistics, such codes have been more than 400, including SA8000 which is the most influential and more familiar in China. Under this background, China's enterprises are in full swing social responsibility certification activities, especially automobile manufacturing enterprises, because they have a large share of exports. Unlike general business, automobile manufacturing social responsibility relate to various aspects of the ecological chain of the automotive industry, it has a multiple layers. First automobile manufacturing enterprises should undertake basic social responsibilities, such as output quality products and services, make themselves earnings and so on. Second, although the car can create wealth and bring about social progress and improving quality of public life, but it is a special commodity which would consume a lot of energy, material and other supplies, so it will become a culprit of pollute the environment and threaten the life, thus automobile manufacturing enterprises also should bear other deep-seated social responsibilities which can highlight the corporate's image, such as environmental

protection, rational use of resources, labor rights, legal compliance, maintenance of public relations, concerns vulnerable groups in society and promote social harmony development. At present, Chinese automobile manufacturing social responsibility situation is not optimistic, displaying more serious labor conflicts, environmental pollution and crisis of social confidence, all these become important factors that hinder the further development of automobile industry. The underlying reason mainly because of the integration of social responsibility and corporate culture, strategy and operational is not well. Therefore, this paper will build a social responsibility competitiveness evaluation index system from the perspective of integration of social responsibility and automobile manufacturing competitiveness strategy, and it will have very important significance to strengthen the competitive advantage of automotive manufacturers and promote it undertake social responsibility actively and efficiently.

Many scholars have studied the relationship between social responsibility and corporate performance (Liu and Song, 2010). However, the researches analysis the enterprises competitiveness from the perspective of social responsibility is not much, few related literature mostly around different stakeholders (Bi Nan, 2012) or different social responsibility issues (He and Lu, 2008) to discuss performance social responsibility will produce positive effect on the competitive advantage, among them, the more representative view are: corporate bear social responsibility to meet the expectations of stakeholders, thereby improving corporate reputation, thus contributing to the competitiveness of enterprises (Bi and Feng, 2011); and if corporate social responsibility can be integrated into its core strategy, it can bring a competitive advantage and social advantages (Michael and Klame, 2006). Unfortunately, these studies have failed to examine the profound changes bring by social responsibility from the angle of enterprises competitiveness create process. In terms of the essence of competition ability creation, competitiveness integration of social responsibility can be seen as a business model innovation (Visser, 2010). This business model innovation is realized by the integration of social responsibility: through integrate with the core values to promote all employees establish the correct value; integrate with mission and the sustainable development strategy to propos value proposition of pursue a comprehensive value maximization; integrate with the whole process of automobile manufacturing operations to realize the value integration of all aspects of the value chain; eventually, change the enterprises original behaviour and establish new enterprises behaviour comply with social expectations, curing them as an important part of corporate value system and become the most strong and advantage competitiveness. Therefore, the essence of the building of competitiveness based on social responsibility is the integration of the two institutional

system, and the institutionalization of corporate social responsibility is the ultimate goal of the entire integrate process (Maon et al., 2009). To successful institutionalize the concept and the requirements of social responsibility to automotive manufacturers competitive system and become an important part of its competitiveness, we needs to decomposition competitiveness strategy which blend of the social responsibility into a series of competitive performance management indicators.

On the measure of enterprises competitiveness, Scholars have a lot of different opinions and proposed many evaluation index system (Fan, 1997; Yang and Zhang, 1999; Zhang, 1999; Wang, 2002; Jin, 2005). Among them, the most influential, and widely accepted by the academic community is *Enterprise Competitiveness Evaluation Theory and Method* which proposed by Jin (2003) and published in *China Industrial Economy*. The purpose of this research was to study the competitiveness indicators which integrated social responsibility, therefore, the competitiveness evaluation index design mainly from the perspective of social responsibility assume. Corporate social responsibility is the corporate responsibility to the main stakeholders (Clarkson, 1995; Freeman, 1984; Frederick, 1994), this article will take RAOD model which proposed by Canadian economist Clarkson (Clarkson, 1995) as the basis, and in accordance with Chinese reality, divide the automobile manufacturing enterprises' social responsibility into five dimensions: social responsibility to employees, social responsibility to government, social responsibility to customers, social responsibility to business partners, and social responsibility to the natural environment. When setting indicators, we will also take these five dimensions as the basis for dividing index dimensions. (1) The dimension of social responsibility to employees. Corporate fulfilling their social responsibility to employees is essentially maintaining their social reputation and image; it will help to attract high-quality personnel. Talent personnel is the most important resource for the survival and development of enterprises, have adequate highly qualified personnel is an important factor in gaining and maintain a competitive advantage. Corporate responsibility to employees mainly reflected in the payment for employees, including the remuneration and expenditure was spent on staff training. In this paper, we will use *the revenue growth* (Friedman, 1970; Archie, 1994; Clarkson, 1995; Abigail, 2001; Garriga, 2004), *employees' profit levels* (Harrison, 1999; Garriga, 2004) and *employee retention rate* (Kelvin and Jarrett, 2002; Jocelyn, 2003) to describe. (2) The dimension of social responsibility to government. Enterprise is the executor and builders of government policies and regulations, legitimate business and tax law is the most basic responsibility of enterprise to government. Enterprises actively undertake the social responsibility to the government is beneficial to get

government approval and get more policies inclination, for example, in terms of land administration, taxation, loans, etc. all these preferential policies would conducive to business operations. In this paper, we will use *the proportion of taxation to revenue increase* (Luetkenhorst, 2004; Lois, 2005), *scale competitiveness* (McGuire, 1988; Porter and Kramer, 2002) and *market competitiveness* (Porter and Kramer, 2002; Schwartz, 2003). (3) The dimensions of social responsibility to customer. Customers are the recipients and users of the enterprise's products or services, enterprise's survival and development are all dependent on the customer's identity, the stronger customer's identity, the more they spending, and the more profit companies can get, therefore, the ultimate goal of the enterprise competition is to win customers. With the advancement of technology and the development of society, customers' attention to the consume products and services is not limited to its basic functions, but also concerned about the negative impact during use and disposal process. Simultaneously, more and more customers also concerned about whether their own consumption behaviour cause harm to the natural environment and so on. Based on this, this paper will use *expects of customer satisfaction* (Maignan, 2001; Michael, 2006), *customer growth rate* (Maignan, 2001; Michael, 2006), *the safety grade of automobile* (Yu, 2004; Cong, 2008) and *market share expected* (Yan, 2004; Michael, 2006). (4) The dimension of social responsibility to business partners. Enterprise business partner generally refers to the partner which business activities in close contact with, such as partners, suppliers, distributors, and other peer companies. Business Partners agreed that: a responsible business must have good social relations and the lower operational risks, so if trading with them, the potential risky is also less. Therefore, corporate fulfilling social responsibility to business partners is equivalent to convey the signal to the various stakeholders they have a good public reputation, and helpful to get all parties trust and support. In this paper, we will use *investment efficiency coefficient* (Alexander, 1978; Clarkson, 1995; Abigail, 2001), *the success rate of the contract* (Jeff, 1997; Abigail, 2001), *the manufacturing cost* (Harrison, 1999; Abigail, 2001) and *crisis management capabilities* (Barney, 1991; Harrison, 1999; Hillman, 2001; Hart, 2004; David, 2005). (5) The dimension of social responsibility to ecological benefits. the current economic development demand enterprise to fulfill its responsibilities to the natural environment or ecological benefits and made the energy saving to strategic height. Automobile manufacturing enterprise produces lots of wastes, like *three wastes* or *noise pollution* in production process, resources and energy consumption during using process, and abandoned Cars, all these activities excessive consumption of resources and energy and so serious violate the social development theme *Man and nature harmony*. In order to improve

Table 1. Automobile manufacturing enterprise competitiveness evaluation index system

Guidelines layer	Indicators layer	Indicators data sources
Employees dimension C <sub>1</sub>	revenue growth C <sub>11</sub>	(new revenue - original income) / original income
	employee retention rate C <sub>12</sub>	number of employees at the end of the year / number of employees at the beginning of the year
	employees' profit levels C <sub>13</sub>	payments to employees and paid for employees in cash / main business income
Government dimension C <sub>2</sub>	the proportion of taxation to revenue increase C <sub>21</sub>	year tax / revenue increase
	scale competitiveness C <sub>22</sub>	using a 5-point score to obtain
	market competitiveness C <sub>23</sub>	using a 5-point score to obtain
Customer dimension C <sub>3</sub>	expects of customer satisfaction C <sub>31</sub>	using a 5-point score to obtain
	customer growth rate C <sub>32</sub>	number of new customers / number of original customers
	the safety grade of automobile C <sub>33</sub>	use weighted average of automobile production and test data volume by C-NCAP to describe.
	expects of market share C <sub>34</sub>	product sales / comparable domain sales
Business partners dimension C <sub>4</sub>	investment efficiency coefficient C <sub>41</sub>	revenue Increase / investment of previous period
	contract success rate C <sub>42</sub>	success rate = 1 - failure rate
	manufacturing cost C <sub>43</sub>	weighted average of Industry manufacturing costs
	crisis management capabilities C <sub>44</sub>	using a 5-point score to obtain
Ecological benefits dimension C <sub>5</sub>	atmosphere environment coordination C <sub>51</sub>	reduced emissions per ten thousand yuan output value/ original emissions per ten thousand yuan output value
	water environment coordination C <sub>52</sub>	reduced Wastewater emissions per ten thousand yuan output value/ original Wastewater emissions per ten thousand yuan output value
	expectations of energy consumption reduce rate C <sub>53</sub>	reduced energy consumption per ten thousand yuan output value/ original energy consumption per ten thousand yuan output value
	innovation capability C <sub>54</sub>	using a 5-point score to obtain

the natural environment, and to enhance the sustainable competitiveness, more and more automobile manufacturers began to pay attention to environmental responsibility and actively participate in the environmental related business among. This article will use *atmosphere environment coordination* (Deb, 2002; Bagnoli and Watts, 2003; David, 2005), *water environment coordination* (Bagnoli and Watts, 2003; Yan, 2004), *expectations of energy consumption reduce rate* (Wang, 2005; Fan, 2009), and *innovation capability* (Ranard and Forstater, 2002; Husted, 2006).

In summary, the automobile manufacturing enterprise competitiveness evaluation index system based on social responsibility was shown in Table 1.

### 3. Construction of Comprehensive Evaluation Model based on Extension theory

Extension theory is a new kind of knowledge system based on the concepts of matter-element and extension set. Its subject selection began in 1976, and its initiative paper was published in 1983. It was the stage for generating knowledge of extension theory from 1983 to 1992. By far, the primary frame of extension theory has been set up with the effort of many researchers. Matter-element theory and the theory of extension set are two theoretical pillars of extension theory. The combination of these two pillars with other science generates the respective knowledge, which is the soft part of extension theory. The biggest advantage of extension theory is it can makes it possible to develop the formalized description for activities of creative thinking, such as knowledge innovation, new products designing and strategy generating. With the combination of extension theory with management science, cybernetics, information science and computer science, extension engineering methods have been applied to some engineering fields such as economic engineering, management engineering, decision process and process control.

#### 3.1. Construct the same levy matter-element model

According matter element theory to build the n-dimensional same levy matter-element model of the automotive manufacturing enterprise competitiveness, the model is as follows:

$$R_i = (N_i \quad C \quad V_i) = \begin{bmatrix} N_i & c_1 & v_{1i} \\ & c_2 & v_{2i} \\ & \vdots & \vdots \\ & c_n & v_{ni} \end{bmatrix}, i = 1, 2, 3, \dots, n \quad (1)$$

Where:  $N_i$  representatives of the i-th automobile manufacturing enterprise competitiveness;  $C_1, C_2, \dots, C_n$  represents the main feature of the automotive manufacturing enterprise competitiveness (i.e. evaluation index), such as revenue growth, employee profit level, atmospheric environment coordination etc;  $V_{1i}, V_{2i}, \dots, V_{ni}$  represents the magnitude

of automobile manufacturing competitiveness  $N_i$  to the corresponding  $C_r$  ( $r = 1, 2, \dots, n$ ).

#### 3.2. Determine the classical field and section domain

According matter element theory to construct classical field and section domain model as follows:

$$R_0 = \begin{bmatrix} N & G_1 & G_2 & \dots & G_m \\ C_1 & \langle a_{11}, b_{11} \rangle & \langle a_{12}, b_{12} \rangle & \dots & \langle a_{1m}, b_{1m} \rangle \\ \vdots & \vdots & \vdots & \vdots & \vdots \\ C_n & \langle a_{n1}, b_{n1} \rangle & \langle a_{n2}, b_{n2} \rangle & \dots & \langle a_{nm}, b_{nm} \rangle \end{bmatrix} \quad (2)$$

Where:  $R_0$  is the same levy matter-element,  $R_1, R_2, \dots, R_m$  is the body of same levy matter-element;  $G_r$  represents the divided r-th evaluation categories;  $C_i$  represents the i-th index;  $V_{ir} = \langle a_{ir}, b_{ir} \rangle$  represents the  $N_r$  magnitude range under the stipulated of  $C_i$ , that is classical field of data obtained by the evaluation index of each category.

$$R_p = [P \quad C \quad V_p] = \begin{bmatrix} P & C_1 & V_{1p} = \langle a_{1p}, b_{1p} \rangle \\ & C_2 & V_{2p} = \langle a_{2p}, b_{2p} \rangle \\ & \vdots & \vdots \\ & C_n & V_{np} = \langle a_{np}, b_{np} \rangle \end{bmatrix} \quad (3)$$

Where:  $P$  represents all categories,  $V_{ip}$  on represents the magnitude range of  $P$  was taken from  $C_i$ , i.e., the section domain of  $P$  and  $V_{ir} < V_{ip}$  ( $i = 1, 2, \dots, n; r = 1, 2, \dots, m$ ).

#### 3.3. Determine the matter-element to be evaluated and the index weight coefficient

For the automobile manufacturing competitiveness ( $q$ ) which to be evaluated, we use the matter-element (formula (4)) to describe its scores for the evaluation index.

$$\begin{bmatrix} N & c_1 & v_1 \\ & c_2 & v_2 \\ & \vdots & \vdots \\ & c_n & v_n \end{bmatrix} \quad (4)$$

Formula (4) referred to the matter-element of automotive manufacturing enterprise competitiveness ( $q$ ) to be assessment;  $V_i$  is magnitude of  $q$  for evaluation index  $C_i$ , that is, the score of index. In the past, determine the weighting coefficients in extension evaluation method most used AHP, but there would exit inevitable human factors during pairwise comparison judgment process and the final results of the evaluation will have more subjective influence in. Therefore, this paper will mix in the groups eigenvalue method (GEM), according to GEM, determining the weight coefficient index  $C_i$  is  $a_i$ , and that the method can effectively overcome the inconsistency when use AHP build expert judgment matrix and can effectively overcome subjective factors interference.

#### 3.4 Calculate the correlation degree of each index

Establish the correlation function of the evaluation index on the grade  $r$ :

$$K_j(v_i) = \begin{cases} \frac{-p(v_i, V_{ij})}{|V_{ij}|} & v_i \in [a_{ij}, b_{ij}] \\ \frac{p(v_i, V_{ij})}{p(v_i, V_{ij}) - p(v_i, V_{ij})} & v_i \notin [a_{ij}, b_{ij}] \end{cases}$$

Among them:

$$|V_{ij}| = |b_{ij} - a_{ij}|$$

$$p(v_i, V_{ij}) = p(v_i, \langle a_{ij}, b_{ij} \rangle) = \left| v_i - \frac{a_{ij} + b_{ij}}{2} \right| - \frac{b_{ij} - a_{ij}}{2}$$

$$p(v_i, V_{ip}) = p(v_i, \langle a_i, b_i \rangle) = \left| v_i - \frac{a_i + b_i}{2} \right| - \frac{b_i - a_i}{2}$$

3.5. Calculate the comprehensive correlation of matter-element to be evaluated

According to the  $a_i$  (weighting coefficients of index  $C_i$ ) and  $K_r(V_i)$  (correlation degree of each index on rank  $r$ ), Calculate the comprehensive correlation of matter-element to be evaluated:

$$K_j(q) = \sum_{i=1}^n a_i K_j(v_i)$$

3.6. Rating

Compare the size of each grade comprehensive correlation degree to determine assessment results. The larger the correlation of rank  $r$ , the better compliance degree of the automotive manufacturing enterprise competitiveness ( $q$ ) with the rank set.

$$K_{j0}(q) = \max_{j \in \{1, 2, \dots, m\}} K_j(q)$$

Then, assessment  $q$  belonging to the rank  $r_0$ . Calculate level variable eigenvalues of the automotive manufacturing enterprise competitiveness ( $q$ ):

$$j = \frac{\sum_{j=1}^m j \bar{K}_j(q)}{\sum_{j=1}^m \bar{K}_j(q)}$$

Where:

$$\bar{K}_j(q) = \frac{K_j(q) - \min_j K_j(q)}{\max_j K_j(q) - \min_j K_j(q)}$$

Level variable eigenvalues reflects the degree of automotive manufacturing enterprise competitiveness level ( $r_0$ ) tend to another category.

4. Empirical Analysis

Now using the extension comprehensive evaluation model been built above to evaluate Shanghai five automotive manufacturing enterprise's competitiveness ( $q_1, q_2, q_3, q_4, q_5$ ), the specific evaluate process is as follow:

4.1. Questionnaire reliability and validity of Measure Design questionnaire according competitiveness evaluation index and distribute it in parts of the au-

tomotive manufacturing enterprise, productivity centers, high-tech industry management department and some universities in Shanghai. 200 questionnaires were distributed, 147 were recovered, excluding seven invalid questionnaires, the effective response rate was 70%. Using SPSS software estimate the obtained data' reliability and validity: the reliability coefficients of scoring matrix which constructed with the data obtained were over 0.75, reaching the required level of reliability; the correlation coefficient between the variables were greater than 0.5; the association of each factor score with the total score were also greater than 0.5, and larger than the correlation coefficient between the various factors. All these indicating that the questionnaire had good level of content validity and construct validity in the survey.

4.2. Evaluation Process

Taking all considerations, select 20 experts from parts of the automotive manufacturing enterprise, productivity centers, high-tech industry management department and some universities in Shanghai who familiar with circular economy, green manufacturing, social responsibility and establishment an experts panel. According to their own cognitive and questionnaire results, expert panel conducted an evaluation to the five automotive manufacturing enterprise competitiveness. First, expert scoring *Indicators layer* indicators, then multiplying their own weight which belongs to the *Guidelines layer* indicators (weight obtained from GEM method), at last, calculate the value of *Guidelines layer* indicators through adding all the value of corresponding *Indicators layer* indicators which been weighted. After expert score, the evaluation scores of five automobile manufacturing competitiveness indexes were shown in Table 2.

Table 2. Project evaluation score

Competitiveness	C <sub>1</sub>	C <sub>2</sub>	C <sub>3</sub>	C <sub>4</sub>	C <sub>5</sub>
q <sub>1</sub>	84	72	74	69	80
q <sub>2</sub>	69	80	79	71	74
q <sub>3</sub>	90	81	89	84	87
q <sub>4</sub>	75	71	80	81	78
q <sub>5</sub>	71	72	67	73	67

Using GEM determined the five *Guidelines layer* indicators' weighting coefficients, shown in Table 3.

Table 3. Evaluation of weight values

evaluation index	C <sub>1</sub>	C <sub>2</sub>	C <sub>3</sub>	C <sub>4</sub>	C <sub>5</sub>
weights	0.24	0.17	0.17	0.19	0.23

In this empirical analysis, the classic domain of each index is:

Table 4 Correlation of each index about participating industry on the level of r

$K_n(v_i)$	$Q_i$	$V_1$	$V_2$	$V_3$	$V_4$	$V_5$
$K_1(v_i)$	$q_1$	-0.220 1	-0.339 1	-0.233 5	-0.432 2	-0.440 1
	$q_2$	-0.232 4	-0.224 0	-0.225 3	-0.215 8	-0.322 1
	$q_3$	-0.152 3	-0.324 1	-0.101 2	-0.115 2	-0.324 4
	$q_4$	-0.542 3	-0.234 9	-0.231 5	-0.635 4	-0.222 4
	$q_5$	-0.452 2	-0.234 0	-0.651 2	-0.113 5	-0.234 0
$K_2(v_i)$	$q_1$	-0.052 3	-0.042 1	-0.435 5	-0.352 1	-0.214 5
	$q_2$	-0.236 1	-0.234 4	-0.231 1	-0.152 3	-0.324 5
	$q_3$	-0.322 7	-0.069 8	-0.319 5	-0.235 4	-0.674 4
	$q_4$	-0.255 9	-0.221 3	-0.231 5	-0.223 4	-0.674 4
	$q_5$	-0.472 9	-0.539 9	-0.189 2	-0.215 9	-0.044 3
$K_3(v_i)$	$q_1$	-0.542 68	-0.334 2	-0.123 6	-0.435 1	-0.224 5
	$q_2$	-0.342 5	-0.213 0	-0.451 2	-0.166 3	-0.324 5
	$q_3$	-0.223 5	-0.434 2	-0.215 4	-0.165 8	-0.549 1
	$q_4$	-0.237 5	-0.649 0	-0.215 3	-0.645 3	-0.327 4
	$q_5$	-0.543 1	-0.322 7	-0.265 5	-0.424 1	-0.342 2
$K_4(v_i)$	$q_1$	-0.235 4	-0.234 5	-0.235 7	-0.095 1	-0.447 9
	$q_2$	-0.434 1	-0.214 5	-0.335 4	-0.325 5	-0.421 3
	$q_3$	-0.087 1	-0.042 2	-0.319 8	-0.235 5	-0.321 5
	$q_4$	-0.135 2	-0.321 4	-0.652 3	-0.164 2	-0.224 4
	$q_5$	-0.323 5	-0.365 4	-0.123 5	-0.343 3	-0.324 5

$$R_{v_t} = \begin{bmatrix} N_t & C_1 & X_{t1} \\ & C_2 & X_{t2} \\ & C_3 & X_{t3} \\ & C_4 & X_{t4} \end{bmatrix} \quad t=1,2,3,4$$

Where:  $N_t$  represents the evaluation grade of automotive industry competitiveness, when  $t = 1,2,3,4$ ,  $N_t$  were 1 {excellent}, 2 {good}, 3 {medium}, 4 {poor}.  $X_{t1}, X_{t2}, X_{t3}, X_{t4}$  represents the specified magnitude range of  $N_t$  on the corresponding feature. When  $t = 1,2,3,4$ , its magnitude range are as follows:  $\langle 90,100 \rangle, \langle 75, 89 \rangle, \langle 60, 74 \rangle, \langle 0, 59 \rangle$ . In this case, the section domain is:

$$R_p = \begin{bmatrix} P & C & V_p \end{bmatrix} = \begin{bmatrix} P & C_1 & \langle 0,100 \rangle \\ & C_2 & \langle 0,100 \rangle \\ & C_3 & \langle 0,100 \rangle \\ & C_4 & \langle 0,100 \rangle \end{bmatrix}$$

According to the correlation function of each index to the rank which established above, using Matlab calculate the correlation of each index about participating industry on the level of  $r$ , the result was shown in Table 4.

Calculated the competitiveness of the selected five automotive industries according to the comprehensive correlation function and index weights in Table 3, evaluation results was shown in Table 5. From the evaluation results, we can know that: one automotive manufacturing industry belong to grades 1, three automotive manufacturing industries belong to grades 2, one automotive manufacturing industry belong to grades 3. That  $q_3$  automotive industry evaluation results as excellent,  $q_5$  automobile manufacturing evaluation results for the medium, and the rest of the automotive industry evaluation results are good. Depending on the level of automotive industry value variable characteristics  $r_*$  (the smaller the value, the higher the representative characteristic level), the

goodness order of automotive manufacturing industry competitiveness is  $q_3 > q_4 > q_2 > q_1 > q_5$ . So among the five automotive manufacturing industries, there are two automotive manufacturing industries ( $q_3, q_4$ ) have relatively excellent competitiveness. And the evaluation result obtained by this method is the same with the results of final argument by productivity centers of Shanghai. These verified the index system and evaluation model built in this research is practicality.

Table 5. Evaluation results

$q_n$	$N_1$	$N_2$	$N_3$	$N_4$	$r_0$	$r_*$
$q_1$	-0.346	0.235	-0.133	0.319	2	2.21
$q_2$	-0.365	0.322	0.112	-0.214	2	2.09
$q_3$	-0.085	-0.244	-0.323	-0.123	1	1.83
$q_4$	-0.234	0.123	-0.434	-0.231	2	2.03
$q_5$	-0.315	-0.214	-0.132	-0.175	3	2.61

### 5. Conclusion

In recent years, some scholars have begun to focus on the relationship between social responsibility and competitiveness of enterprises and through the study found that social responsibility can improve their overall competitiveness. However, the vast majority of the related researches are limited to qualitative research, quantitative research is very little, empirical researches integrate with corporate social responsibility and corporate competitiveness is rarer. In this research, by drawing theory and method which been proposed by other scholars to assess the competitiveness of the automotive manufacturing industry, combining the basic theory of social responsibility, according to the characteristics of the automotive industry production process and output performance, we construct a automotive industry competitiveness evaluation index system with five dimensions and



build a AHP-GEM-Extension comprehensive evaluation model which can overcome the inconsistency of Saaty matrix first, then through questionnaires and interviews with experts, we made an empirical analysis to evaluate automotive manufacturing industry competitiveness. The empirical analysis result proved the index system and evaluation model built is practicality.

Select automotive manufacturing industry competitiveness integrates social responsibility as a research topic, theoretically, it can clear the connotation of automotive manufacturing industry competitiveness at the present stage and it also can clear the mechanisms and determinants of how social responsibility produces competitiveness. In practice, the study of through strengthen automotive manufacturing industries' social responsibility in order to improved its competitiveness and sustainable development can remind all enterprises manager attach great importance and correct treatment to the social responsibility, and call their attention to change their consciousness, strengthen their social responsibility management and practice, and strive to achieve harmonious of economic, social and the environment.

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