Research on Competitiveness of Automotive Product Innovation in China

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***Abstract*—In this paper, the author firstly constructed an evaluation index system of competitiveness of Chinese auto industry innovation, and determined the weights by the use of AHP method, and then uses fuzzy evaluation method to calculate and quantize the competitiveness of innovation. Finally, through comparing, it is come to conclusions that the competitiveness of Chinese auto industry innovation is within a range of fair and poor and the competitiveness of China's auto industry innovation is still at a low level.**

Keywords- AHP Fuzzy evaluation method; China; auto industry innovation; competitiveness

Level of innovation is the core of industrial competitiveness. The market rule "survival of the fittest" requires enterprises in the industrial cluster continue to adapt to market demand changes, timely detect market development trends, produce and develop better quality products to maintain market competition advantage. This paper attempts to do quantitative analysis on competitiveness of Chinese auto industry innovation by using AHP evaluation method.

I. EVALUATION INDEX SYSTEM OF COMPETITIVENESS OF CHINESE AUTO INDUSTRY INNOVATION

Competitiveness of automobile industry innovation is a comprehensive ability of cluster development, which is composed of factors in industrial competitiveness, interaction among the factors and the overall operation of industrial cluster.

To construct the automotive industry innovation competitiveness evaluation index system, we need to do systematical analysis on competitiveness of industrial innovation, including factors that consist of the industrial innovation system, in what way these factors formed; industry innovation environment analysis, characteristics and development trends of the environment. The complexity of industrial innovation determines that the evaluation of the competitiveness of industrial clusters must be multi-layered.

On the basis of current studies on evaluation index system of automotive industry innovation competitiveness, according to detailed analysis on influencing factors of automotive industry innovation competitiveness, a two indicators-evaluation system of competitiveness of automotive industry innovation is proposed in this paper, as is shown in Table1.

TABLE I. THE COMPETITIVENESS OF CHINA'S AUTO INDUSTRY INNOVATION EVALUATION SYSTEM

automotive industry innovation competitiveness system（C）	indexes		
	first-grade indexes	second-grade indexes	third-grade indexes
	Innovation Level（C_1）	R&D Funds (C_{11})	growth rate (C_{111})
			proportion of total sales (C_{112})
		R&D personnel (C_{12})	researchers reserve(C121)
			proportion of total employees (C_{122})
		patents (C_{13})	growth rate (C_{131})
			domestic and foreign patents ratio(C_{132})
	innovation foundation（C_2）	independent brand (C_{21})	input of brand building (C_{211})
			cluster brand (C_{212})
		hardware facilities (C_{22})	supporting facilities (C_{221})
			new technologies using ratio (C_{222})
		government behavior (C_{23})	government subsidies (C_{231})
			development plan (C_{232})
	industry opportunity（C_3）	market capacity (C_{31})	domestic demand (C_{311})
			consumption growth rate (C_{312})
		industrial status (C_{32})	GDP GDP per capita (C_{321})
			proportion of output value in China (C_{322})

II. DETERMINE THE WEIGHT OF INDEX SYSTEM BY AHP

AHP (Analytic Hierarchy Process, AHP) is a method to identify weight vector effectively, which is proposed by Saaty, an American professor of operations research, in 1970s.

In general, if a problem involves n factors, when the basis isn't very full, the share of each factor in the whole can only be judged by experts' experiences.

But as long as $n \geq 3$, any expert can be difficult to tell a group of precise data, however, if any two factors are taken from all the factors to do a comparison, the experts can

generally use qualitative language like "important", "slightly important ", " obviously important", " very important ", " extremely important " to explain the degree of importance between one of the factors and the other. Saaty proposed to quantify these qualitative language, and to introduce the function $f(x,y)$ to express scale of importance of factor x and y.

When a factor in above hierarchy is taken for comparison criteria, α_{11} can be used to express the relative importance of element i and j in a hierarchy. Generally, α_{11} take a positive integer of 1-9 and its reciprocal as scale, as in Table 2.

Such a matrix composed of α_{11} is called the comparative judgment matrix $\mathrm{A}=(\alpha_{ij})_{mn}$. In this paper, we do comparason between two indicators of the indicator system established in the former part according to expert questionnaires, and transform the results of the qualitative judgments into quantitative data according to the proportion scale of 1 to 9, to form the following pairs of judgment matrix:

$$\mathrm{A}=\begin{pmatrix} a_{11} & \cdots & a_{1n} \\ \vdots & \ddots & \vdots \\ a_{m1} & \cdots & a_{mn} \end{pmatrix}$$

TABLE II. SCALES AND THEIR MEANING

Value	explainations
1	i and j Equally important
3	i Somewhat important than j
5	i Obviously important than j
7	i Highly important than j
9	i Extremely important than j
2、4、6、8	Median
Reciprocal	If ratio of importance of i and j is α_{ij}, the ratio of importance of j and i is $\alpha_{ji}=1/\alpha_{ij}$

After judgment matrix A being constructed, calculate the largest eigenvalue $\lambda_{\max}$ of the matrix, and then use its corresponding characteristic equation:

$$\mathrm{A}\Omega=\lambda_{\max}\Omega \qquad (1)$$

Calculate the corresponding eigenvector Ω, then feature vector normalize Ω. This is the importance in weight of the factors in the same hierarchy relative to one factor in the former hierarchy. This process is called hierarchy single fanking.

Based on hierarchy single fanking, uniformity inspection on the matrix must be done. Whether the consistency ratio $C.R.\le 0.1$ is established can be used to do the test. If $C.R.\le 0.1$, inconsistency of the matrix can be acceptable.

$$C.R.=\frac{C.I.}{R.I.},\quad C.I.=\frac{\lambda_{\max}-n}{n-1} \qquad (2)$$

TABLE III. AVERAGE RANDOM CONSISTENCY INDEX

N	1	2	3	4	5	6	7	8	9
R.I.	0	0	0.58	0.9	1.12	1.24	1.32	1.41	1.45

Finally, do hierarchy general ranking and uniformity inspection. Hierarchy general ranking is to calculate the scale of relative importance of all elements in the same hierarchy to the top. This process is carried out from the highest hierarchy to the lowest layer by layer. Formula for calculating the general ranking weight is as follows:

$$\alpha^{k-1}=(\alpha_1^{k-1},\alpha_2^{k-1},\cdots\alpha_m^{k-1}) \qquad (3)$$

α^{k-1} is a combined weight vector of element m on the k-1th hierarchy relative to total target.

Then on the kth hierarchy, $\alpha^k=B^kB^{k-1}\cdots B^3\alpha^2$, $B^k=(b_1^k,b_2^k,\cdots b_m^k)$,

$$B_i^k=[b_i^k(1),b_i^k(2),\cdots b_i^k(n)]^T,$$

$b_i^k(i)$ is scale of relative importance of element i on the kth hierarchy.

A ranking weight formula is:

$$\alpha^k=B^kB^{k-1}\cdots B^3\alpha^2, 3\le k\le h \qquad (4)$$

α^2 is ranking weight vector for factors on the second hierarchy, h is the number of hierarchy.

Evaluation index system weights of China's auto industry innovation competitiveness are calculated in Table4.

TABLE IV. CHINA'S AUTO INDUSTRY INNOVATION COMPETITIVENESS EVALUATION INDEX SYSTEM WEIGHTS TABLE

	indexes					
	first-grade indexes	Weight	second-grade indexes	Weight	third-grade indexes	Weight
C	C_1	0.552	C_{11}	0.618	C_{111}	0.759
					C_{112}	0.241
			C_{12}	0.227	C_{121}	0.317
					C_{122}	0.683
			C_{13}	0.155	C_{131}	0.736
					C_{132}	0.264
	C_2	0.217	C_{21}	0.401	C_{211}	0.573
					C_{212}	0.427
			C_{22}	0.172	C_{221}	0.405
					C_{222}	0.595
			C_{23}	0.427	C_{231}	0.791
					C_{232}	0.209
	C_3	0.231	C_{31}	0.506	C_{311}	0.573
					C_{312}	0.427
			C_{32}	0.113	C_{321}	0.142
					C_{322}	0.158

III. FUZZY EVALUATION OF COMPETITIVENESS OF CHINESE AUTO INDUSTRY INNOVATION

A. Establishment of the Fuzzy Set

a) Define set of indicators on criteria hierarchy as $C=(c_1,c_2,c_3)$, the corresponding weight set as $\Omega=(\omega_1,\omega_2,\omega_3)$, in which $\omega_k=(1,2,3)$ expresse the proportion of indicator c_k in C and normalized, and $\sum_{k=1}^{3}\omega_k=1$. Secondary index set as $C_k=(c_{k1,}c_{k2}\cdots c_{kn})$, the corresponding weight set as $\Omega_k=(\omega_{k1},\omega_{k2},\cdots\omega_{kn})$, in which ω_{kn} means the proportion of c_{kn} in C_K.

b) Define set of indicators on project hierarchy as $C_{ky}=(c_{ky1},c_{ky2},\cdots c_{kyn})$, the corresponding weight set as $\Omega_{ky}=(\omega_{ky1},\omega_{ky2},\cdots\omega_{kyn})$, in which ω_{kyn} means the proportion of c_{kyn} in C_{ky}.

c) Define evaluation sets as $V=(v_1,v_2,\cdots v_m)$, in which $v_t(t=1,2,\cdots m)$ expressed high to low levels of reviews. In this paper, five scoring system is adopted. Take $m=5$, that is, $V=$(excellent, good, fair, poor, bad).

B. Determine the evaluation matrix

Firstly, do fuzzy evaluation to the third-grade index set C_{ky} on project hierarchy that makes up of each secondary indicators C. Because of ambiguity of C_{ky}, specific data can not be obtained. To get the extent that C_{ky} is subordinate to the tth review V_t by experts scores, that is, ratio of project hierarchy third index set C_{ky} access to review V_t.It is in the form of single-factor evaluation and fuzzy evaluation matrix $R_{ky}=(r_{kyij})_{n\times5}$ is constructed.

$$R_{ky}=\begin{pmatrix} r_{ky11} & \cdots & r_{ky15} \\ \vdots & \ddots & \vdots \\ r_{kyn1} & \cdots & r_{kyn5} \end{pmatrix}$$

C. Comprehensive Evaluation

a) The first hierarchy evaluation. Do fuzzy operation to the third-grade index set C_{ky} on each project hierarchy to get membership vector B_{ky} that the third index set C_{ky} on project hierarchy to the reviews set V.

$$B_{ky}=\Omega_{ky}\times R_{ky}$$

b) The second hierarchy evaluation. To get fuzzy evaluation matrix from operations of the first hierarchy comprehensive evaluation:

$$R_k=\begin{pmatrix} r_{k11} & \cdots & r_{k15} \\ \vdots & \ddots & \vdots \\ r_{kn1} & \cdots & r_{kn5} \end{pmatrix}$$

Do fuzzy matrix calculation to R_k according to fuzzy evaluation model again, that is, do the second hierarchy comprehensive evaluation operations to get membership vector B_k ($B_k=\Omega_k\times R_k$)that the second index hierarchy C_k to the reviews set V.

c) The third hierarchy evaluation. To get fuzzy evaluation matrix from operations of the second hierarchy comprehensive evaluation:

$$R=\begin{pmatrix} B_1 \\ B_2 \\ \vdots \\ Bn \end{pmatrix}=\begin{pmatrix} b_{11} & \cdots & b_{15} \\ b_{21} & \cdots & b_{25} \\ \vdots & \cdots & \vdots \\ b_{n1} & \cdots & b_{n5} \end{pmatrix}$$

Do fuzzy matrix calculation to R according to Fuzzy evaluation model again, that is, do the third hierarchy comprehensive evaluation operations to get membership vector B that the target hierarchy index C to the reviews set V. $B=\Omega\times R=(b_1,b_2,b_3,b_4,b_5)$.

When $\sum_{t=1}^{5} b_t \neq 1$, normalized, that is, set:

$$\hat{b} = b_t / \sum_{t=1}^{5} b_t$$

Then $B = (\hat{b}_1, \hat{b}_2, \hat{b}_3, \hat{b}_4, \hat{b}_5)$

d) Fuzzy comprehensive evaluation model on target hierarchy:

$$B = \Omega \times R = \Omega \times \begin{pmatrix} B_1 \\ B_2 \\ \vdots \\ B_n \end{pmatrix} = \Omega \times \begin{pmatrix} b_{11} & \cdots & b_{15} \\ b_{21} & \cdots & b_{25} \\ \vdots & \cdots & \vdots \\ b_{n1} & \cdots & b_{n5} \end{pmatrix}$$

Let be score set $\mathrm{A} = (\alpha_1, \alpha_2, \alpha_3, \alpha_4, \alpha_5)^T$, then the competitiveness score formula of calculation of China's auto industry innovation is:

$$P = B \times \mathrm{A}$$

Expert investigation method is adopted in this paper. To invite a number of experts to do judgments according to actual situation of competitiveness of Chinese auto industry's innovation, the control score set V = (excellent, good, fair, poor, bad) and the weighted score coefficient matrix F = (9,7 , 5,3,1). Fuzzy evaluation results are shown in Table5

TABLE V. Fuzzy evaluation results

Target	Comprehensive evaluation	indexes			
		first-grade indexes	evaluation	second-grade indexes	evaluation
C	3.957	C_1	2.571	C_{11}	3.012
				C_{12}	4.174
				C_{13}	1.153
		C_2	2.243	C_{21}	2.401
				C_{22}	1.772
				C_{23}	4.165
		C_3	5.318	C_{31}	7.139
				C_{32}	3.302

IV. CONCLUSIONS

According to score set V and the weighted score coefficient matrix, when $P \geq 9$, the competitiveness of industrial innovation is good, when $7 \leq P \leq 9$, that is within a range of excellent and good, when $5 \leq P \leq 7$, that is within a range of good and fair, when $3 \leq P \leq 5$, that is within a range of fair and poor, when $1 \leq P \leq 3$, that is within a range of poor and bad, when $P \leq 1$, that is bad.

The comprehensive evaluation score of competitiveness of China's auto industry innovation is $P = 3.957$. From the foregoing, $3 \leq 3.957 \leq 5$, therefore, the competitiveness of Chinese auto industry innovation is within a range of fair and poor. It is concluded that the competitiveness of China's auto industry innovation is still at a low level.

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