Evaluating Human Resource Competitiveness Based on an Improved TOPSIS Method: The Case of Automotive Industry

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Abstract - **Human resource plays an essential role in the sustainable development of modern industry, especially the talent-intensive industries. Evaluating the human resource competitiveness is the basis for quantifying industrial competitiveness and shaping development strategies. In this study, an improved Technique for Order Preferences by Similarity to an Ideal Solution (TOPSIS) method is developed to evaluate the national human resource competitiveness by using the case of automotive industry. The new approach averts information loss effectively by combining subjective and objective weights, which reflect both the experience of experts and information of the data. Empirical results show that the proposed method is a viable, systematic approach in solving the problem. It is found that the factors of R&D expenditure, granted patents and published papers are the major factors determining national human resource competitiveness.**

Keywords - **Automotive industry, human resource competitiveness, comprehensive evaluation, improved TOPSIS method, combined weights**

I. INTRODUCTION

The automotive industry is a labor-intensive, capital-intensive and technology-intensive industry with the feature of long industrial chain, strong correlation relationship and highly degree of dependence on the related personnel [1, 2]. Human resource is an important resource for automotive industry, the source of development and independent innovation for automotive enterprises [3]. With attention to human resource is closely related to the understanding of innovation, which is the foundation of sustainable development, the essence of the core competitiveness. Human resource is the main body of implementing innovation but also is one of the most kernel elements of realization innovation. Human resource management as an instrument designed to enhance the labor extraction process and thus improve automotive industry performance.

In order to win in today's competitive environment, many organizations have recognized benchmarking as being of strategic important in the drive for better performance and commitment to achieve a competitive advantage [4, 5]. Many studies have investigated the method about human resource performance evaluation [6, 7].As early as 1879, German psychologist Wilhelm Wundt established the world's first psychological laboratory, namely the research on individual differences is the prototype of talent evaluation. To the 1930s, with the rapid development of industrial society, human resources management in the rise of behavioral science theory, evaluation was often associated with a variety of factors. In recent years, with the advent of economy, technological and cultural and the arrival of knowledge-based economy, many countries pay more attention to every aspect of talent, thus human resource management and talent evaluation has made a considerable progress.

Multiple Criteria Decision Making (MCDM) refers to finding the best opinion from all of the feasible alternatives in the presence of multiple, usually conflicting, decision criteria. Priority-based, outranking, distance-based and mixed methods could be considered as the primary classes of the current methods [8]. To facilitate systematic research in the field of MCDM, Huang and Yoon suggested that MCDM problems can be classified into two main categories: Multiple Attribute Decision Making (MADM) and Multiple Objective Decision Making (MODM), based on the different purposes and different data types [9]. MADM deals with the problem of choosing an option from a set of alternatives. MODM is especially suitable for the design facet, which aims to achieve the optimal of aspired goals by considering the various interactions within the given constraints. On the basis of dealing with MADM problems, Technique for Order Preferences by Similarity to an Ideal Solution (TOPSIS) was proposed to derive the best alternatives order according the defined distance. TOPSIS method was proposed by Hwang and Yoon [10] to determine the best alternative based on the concepts of the compromise solution. Latterly, this principle has been suggested by Zeleny [11] and Hall [12], and it has been enriched by Yoon [13] and Hwang, Lai and Liu [14].

In the comprehensive evaluation problem, the subjective weights reflect the experience of the experts the objective weights imply the original data information. However, in the literature there are few subjective and objective fusion methods aimed at evaluating the relative performance by multidimensions. Then, this research applies subjective and objective fusion method to determine the performance weights of evaluation which embedded in the TOPSIS to improve the gaps of alternatives between real performance values and pursuing aspired levels in each dimension and criterion.

On the basis of previous research, this paper is to give a systematic and comprehensive analysis of various influential factors in the automotive industry human resource evaluation and enrich the human resource competitiveness index system, moreover, considering a national automotive human resource level as a whole evaluation object giving the quantitative evaluation and analysis based on the international perspective.

The evaluation procedure consists of the following main steps as summarized in Fig. 1.The detailed descriptions of each step are illustrated in the coming sections.

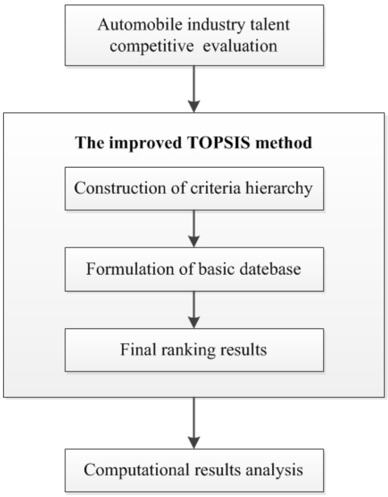

Fig. 1 Evaluation framework

II. METHODOLOGY

A. The TOPSIS method

TOPSIS defines an index called similarity (or relative closeness) to the positive ideal solution by combining the proximity to the Positive Ideal Solution (PIS) and the remoteness from the Negative Ideal Solution (NIS). Then the method chooses an alternative with the maximum similarity to the PIS. TOPSIS assumes that each attribute takes either monotonically increasing or monotonically decreasing utility. That is, the larger the attribute outcome, the greater the preference for benefit attributes and the less the preference for cost attributes.

Given a set of alternatives, $A=\left\{A_i | i=1,2,\cdots,m\right\}$, and a set of criteria, $C=\left\{C_j | j=1,2,\cdots,n\right\}$, where $X=\left\{X_{ij} \| i=1,2,\cdots,m,\ j=1,2,\cdots,n\right\}$ denotes the set of performance ratings and $W=\left\{w_j | j=1,2,\cdots,n\right\}$ is the set of weights, the information table $I=(A,C,X,W)$ can be represented [9].

Step1. Calculate normalized ratings.

The vector normalization is used for computing r_{ij}, which is given as

$$r_{ij}=\frac{x_{ij}}{\sum_{j=1}^{n} x_{ij}},\ \forall i \in [1,\ m]. \tag{1}$$

Step 2. Calculate weighted normalized ratings.

Subjective weight method based on questionnaire analysis in the industry enterprises and academia experts uses the analytic hierarchy process (AHP) for extracting weights. Objective weight method starts from the raw data and reflects the true importance of evaluation index, and entropy weight method is the measurement of the disorder degree of an evaluation system, which can measure the amount of useful information with the data provided. Selecting a combination of subjective and objective weights assignment methods, which reflects the magnitude of value indicators, namely the economic significance and the technical sense, but also reflects the amount of information data, so that the final evaluation results are more reasonable and objective.

The entropy of the i^{th} indicator is defined as

$$H_j=-k\sum_{i=1}^{m} f_{ij}\ln f_{ij} \tag{2}$$

The weight of entropy of ith indicator could be defined as

$$w_1^j=\frac{1-H_j}{m-\sum_{j=1}^{n} H_j},\ j=1,2,\cdots,n, \tag{3}$$

AHP is a common method for computing subjective weight which can be seen in many articles and books. Suppose the weights obtained by the AHP method are $w_2^j,\ j=1,2,\cdots,n$.

Let $w_j,\ j=1,2,\cdots,n$ are the combined weights, according to the the information entropy principle

$$\min R=\sum_{j=1}^{n} w_j\left(\ln w_j-\ln w_1^j\right)+\sum_{j=1}^{n} w_j\left(\ln w_j-\ln w_2^j\right), \tag{4}$$

$$s.t.\ \sum_{j=1}^{n} w_j=1,\ w_j>0,\ j=1,2,\cdots,n. \tag{5}$$

Using the Lagrange multiplier method to calculate the above optimization problem, then

$$w_j=\frac{\sqrt{w_1^j w_2^j}}{\sum_{i=1}^{m}\sqrt{w_1^j w_2^j}},\ j=1,2,\cdots,n. \tag{6}$$

The weighted normalized value is calculated as

$$v_{ij}=w_j r_{ij},\ i=1,2,\cdots,m,\ j=1,2,\cdots,n. \tag{7}$$

Step 3. Identify PIS and NIS.

$$\begin{aligned} PIS=A^+ &=\left\{v_1^+(x),v_2^+(x),\cdots,v_n^+(x)\right\} \\ &=\left\{\left(\max_i v_{ij}(x) | j\in J_1\right),\ \left(\min_i v_{ij}(x) | j\in J_2\right) \middle| i=1,2,\cdots,m\right\}, \end{aligned} \tag{8}$$

$$\begin{aligned} NIS=A^- &=\left\{v_1^-(x),v_2^-(x),\cdots,v_n^-(x)\right\} \\ &=\left\{\left(\min_i v_{ij}(x) | j\in J_1\right),\ \left(\max_i v_{ij}(x) | j\in J_2\right) \middle| i=1,2,\cdots,m\right\}, \end{aligned} \tag{9}$$

where J_1 is a set of benefit attributes (lager is better) and J_2 is a set of cost (smaller is better) attributes.

Step 4. Calculate separation measures.

The separation distance between alternatives can be measured by the n-dimensional Euclidean distance. The separation of each alternative from the PIS is given by

$$D_i^+=\sqrt{\sum_{j=1}^{n}\left[v_{ij}(x)-v_j^+(x)\right]^2},\ i=1,2,\cdots,m. \tag{10}$$

Similarly, the separation from the NIS is derived as

$$D_i^- = \sqrt{\sum_{j=1}^{n}\left[v_{ij}(x)-v_j^-(x)\right]^2},\ i=1,2,\cdots,m. \quad (11)$$

Step 5. Calculate similarities to PIS.

$$C_i^+ = D_i^- / \left(D_i^+ + D_i^-\right),\ i=1,2,\cdots,m. \quad (12)$$

Note that $0 \le C_i^+ \le 1,\ \forall i=1,2,\cdots,m$, where C_i^+ =0 when $A_i = A^-$, and $C_i^+ = 1$ when $A_i = A^+$.

Step 6. Rank preference order.

Choose an alternative with the maximum C_i^+ or rank alternatives according to C_i^+ in descending order.

B. Evaluation framework

According to the objective and principles of the automotive industry's human resource competitiveness evaluation index system, the hierarchical structure of the decision model with the alternatives and the criteria is portrayed in Table I.

The decision problem consists of three levels: at the highest level, the objective of the problem is situated while in the second level, the criteria are listed, and in the third level, the sub-criteria are listed. Three of the primary indices are respectively, human resource structure, human resource input and human resource output, and the other specific eight tertiary indicators depicting the main characteristics of the automotive industry's human resource competitiveness from multiple perspectives.

TABLE I

The hierarchical structure for the automotive industry's human resource competitiveness

Objective	Criteria	Sub-criteria
The automotive industry's human resource competitiveness	C1: Human resource structure	C11: Total personnel number
		C12: Density of technical personnel
	C2: Human resource input	C21: Cultivate spending per capita
		C22: Per R&D expenditure
	C3: Human resource output	C31: Published papers per person per year
		C32: Granted patents per person per year
		C33: Labor productivity
		C34: Per capita output

C. Data

Automotive industry find success when they can establish clear strategic goals and marshal all resources to achieve those objectives. Human resource performance management is a huge priority for competitive organizations. That is where superior software solutions come in. Valued human resource development not only improves professional skills and capabilities, but also solves the problem of measuring the effect of human resources on an organization [5].

Select the typical automotive industry countries around the world as the research sample, they are: the United States, Germany, Japan, South Korea, Italy, France, China and the United Kingdom. Choose the section data of year 2012, the main data sources for the countries are shown in Table II.

TABLE II

Data acquisition channels

Country	Data sources
The United States (A1)	2012 U.S. automotive industry survey and confidence index [15] NADA Data state of the industry report 2013 [16] http://www.bea.gov/iTable/index_industry_gdpIndy.cfm [17] Automotive industry outlook [18]
Germany (A2)	The automotive industry in Germany issue 2012/2013 [19] Automotive industry annual report [20] The automotive industry pocket guide [21] European vehicle market statistics [22]
Japan (A3)	The motor industry of Japan [23] Motor vehicle statistic of Japan [24] http://www.jama-english.jp [25]
South Korea (A4)	Korean automotive industry [26] Korean government status report the first automotive policy master plan (2012-2016) [27]
Italy (A5)	2003-2012 The Italian automotive industry [28] Observatory report on the Italian automotive sector [29] The Italian automotive industry [30]
France (A6)	French automotive industry analysis and statistics [31] The automotive industry pocket guide [21]
China (A7)	China automotive industry yearbook [32] Annual report on automotive industry in China [33]
The United Kingdom (A8)	The UK Automotive Industry and the EU[34] http://www.epo.org/[35]

D. Results

According to the above-mentioned procedure, the proposed method is currently applied to evaluate the human resource performance of the automotive industry and the computational procedure is summarized as follows:

Step 1. The performance ratings for the eight countries are normalized into the range [0,1] by Eq. (1) which have been depicted in Table III.

TABLE III

Normalized data information

No.	C11	C12	C21	C22	C31	C32	C33	C34
A1	0.27	0.37	0.75	0.84	0.57	0.33	1.00	0.76
A2	0.24	0.69	1.00	1.00	0.26	1.00	0.89	0.32
A3	0.26	0.34	0.85	0.81	0.19	0.51	0.78	0.73
A4	0.05	0.00	0.75	0.76	0.00	0.04	1.00	1.00
A5	0.00	0.27	0.93	0.96	1.00	0.34	0.26	0.00
A6	0.02	1.00	0.56	0.80	0.12	0.49	0.00	0.45
A7	1.00	0.06	0.00	0.00	0.14	0.00	0.08	0.32
A8	0.28	0.36	0.77	0.82	0.45	0.43	0.73	0.56

Step 2. The normalized weights calculated by ITOPSIS method among three main criteria and eight sub-criteria and their ranking have been shown in Table IV. The weights for each dimension are: total personnel number (0.0228), density of technical personnel (0.1391), cultivate spending per capita (0.1414), per R&D

expenditure (0.1988), published papers per person per year (0.0942), granted patents per person per year (0.1055), labor productivity (0.1670), per capita output (0.1312).

TABLE IV
Weights of dimensions

Criteria	Weights	C-Rank	SC-Rank
C1	0.1619	3	——
C11	0.0228	——	8
C12	0.1391	——	4
C2	0.3402	2	——
C21	0.1414	——	3
C22	0.1988	——	1
C3	0.4979	1	——
C31	0.0942	——	7
C32	0.1055	——	6
C33	0.1670	——	2
C34	0.1312	——	5

Step 3. Determine PIS and NIS as:

Calculate the distance of each country's performance from PIS and NIS, respectively.

Step 4. Calculate the closeness coefficient of each candidate as Eq. (7) and rank the alternative as follows:

TABLE V
The distance measurement

Alternatives	Coefficient	Rank
A1	0.6842	2
A2	0.7218	1
A3	0.6473	3
A4	0.5769	5
A5	0.5406	6
A6	0.5203	7
A7	0.1282	8
A8	0.6301	4

III. DISCUSSION

From the proposed method, we can understand the first three important sub-criteria for the evaluation of the automotive industry human resource competiveness are R&D expenditure (0.1115), granted patents (0.1066) and published papers (0.1050). Moreover, the less important dimension is total personnel number (0.0886).

The R&D expenditure deals with how well the company support the strategic objectives. The majority of empirical studies have found that firm's R&D expenditure is associated with higher levels of performance. Higher R&D expenditure could provide more research environment and technological resources to the R&D employees. Defined as a set of knowledge and competencies, the firm's knowledge base remains a preliminary condition in the assimilation of spillovers from R&D efforts of environment. R&D activity does not only stimulate innovation, but it also enhances the firms' ability to assimilate outside knowledge [36].

Granted patents and published papers are both subordinate to technical literatures, which are the manifestation patterns of innovation. It is well known that automotive industrial enlivenment must continually cope with extremely rapid changes, which demand an innovative technological and managerial response. Such a response must redefine the companies' organizational assets in order to achieve a satisfactory degree of adaptation to the external environment. Innovation is a necessary condition, not only for increasing the companies' competitiveness, but primarily to ensure their produces' survival [37]. Innovation is about change, about doing different things, or doing things differently, and its directly style are the automotive products, theory and test style are the technical papers, patents are the protective style for them.

It is easy to understand that total personnel number is the least important since the quality of the automotive industry human resource competitiveness is of much more significance than the quantity.

IV. CONCLUSION

The aim of this research is to search for an improved solution to MCDM problems. The present study constructed an ITOPSIS model to evaluate different countries for automotive industry's human resource competitiveness. This method combines the subjective judgments with the objective calculation and thus enhances the credibility of the weight. ITOPSIS enables decision analysts to better understand the complete evaluation process. Furthermore, this approach provides a more accurate, effective, and systematic decision support tool. In the performance evaluation for the automotive industry include human resource structure, human resource input and human resource output. These factors are to generate a final evaluation ranking for priority among these automotive industry countries of the proposed model. The importance of the dimensions is evaluated by experts, and the data features are taken into account through the selection of weight in ITOPSIS environment. From the presented method, the important dimensions is human resource structure, human resource input and human resource output, respectively. Moreover, German and the United State rank the first two automotive industry's human resource performances for these countries. In addition, there exists other worth investigating evaluation methodology for a MADM problem. This becomes one of the future research opportunities in this classical, yet important, research area.

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