The Fuzzy Evaluation of Knowledge Workers' Satisfaction

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Abstract. Knowledge workers are a company's valuable wealth. How to effectively improve their motivation is one of the entrepreneurs' most concerned issues. This paper works out an index system of knowledge workers' satisfaction. This satisfaction system which adopts Analytic Hierarchy Process with indicator weight and comprehensive evaluation assesses HX Company's workers' satisfaction and the results are given to themselves, which is finally highly approved by these knowledge workers.

The Definition and Features of Knowledge Workers

Peter Drucker proposed that knowledge workers refer to those who master and adopt symbols and concepts, and use these knowledge or information for working. Although Professor Peter Drucker proposed this term in the 1950s, there has not been a commonly accepted definition of *knowledge workers* among domestic scholars. Currently, the related terms are knowledge worker, knowledge employee, knowledge staff, etc. The scholars show their different understandings of these terms from different perspectives. However, the features of knowledge workers remain similar.

Independent. Most of the knowledge workers have received higher or vocational education. Generally, they own particular technologies or skills and engage in independent and creative work which is based on their own knowledge, complex thought process and activities rely on their own intelligence, which is easy to form a strong sense of independence.

High achievement motivation. In general, knowledge workers have some special skills and own higher income. Their lower-level needs have been met. Therefore, much more attention should be paid to their social needs, esteem needs and the needs of self-realization. Compared to others, knowledge workers are much eager to realize their self-fulfilment and recognized by organizations and society. Thus, they prefer the challenging work, which helps to achieve the sense of accomplishment and realization.

Noncopyable. One of the knowledge workers' most important features is creativity. They do not engage in the simple and repetitive work, but use their known knowledge to promote the continuous advances in technology, which promotes the constant update of the products and services. They master the core technology or business processes, which controls the company's key resource. Therefore, if they leave their company, it would be difficult to hunt another one to replace him, which would bring the company immeasurable loss.

High mobility. Knowledge workers can bring an enterprise huge wealth, which suggests that they would naturally become the competitors' hunting object in the same industry. These workers work harder to achieve their personal development and search the most suitable enterprises for themselves. If they do not believe that the company would be suitable for their future development, higher mobility would be shown.

The Establishment of the Evaluation Index System of Knowledge Workers' Satisfaction

The establishment of the index system of knowledge workers' satisfaction. Only a few references were found while establishing the index system of knowledge workers' satisfaction. Therefore, we adopted Delphi method, respectively visiting seven responsible offices of human resources and three university professors of human resources management. During our respective visit,

they answered the following question, *what will influence your satisfaction*. After removing the duplicate ones, the factors that influence the knowledge workers' satisfaction can be summarized as follows: business prospect, officers' leadership and management skills, access to training and logistics services and so on. All these twenty-one factors were given to thirty knowledge workers working in different types of enterprises. After further voting and choosing, ten items were chosen as the indexes of knowledge workers' satisfaction. They are business prospect, officers' leadership and management skills, access to training, logistics services, salary, pension and healthcare, working challenge, working achievement, teamwork and working independence. These ten factors are divided into three aspects, external incentive, internal incentive and growing-up incentive, which is shown Table 1.

Table 1 The indexes of knowledge workers' satisfaction

Items	Items	Items
Knowledge workers' satisfaction	External incentive	Business prospect
		Officers' leadership and management skills
		Access to training
	Internal incentive	Logistics services
		Salary
		Pension and healthcare
	Growing-up incentive	Working challenge
		Working achievement
		Teamwork
		Working independence

Weight of the evaluation indexes of knowledge workers' satisfaction. In this paper, Analytic Hierarchy Process (AHP) was adopted to assign a weight to the knowledge workers' satisfaction indexes.

The basic principles and implementation steps of AHP. AHP is an easy quantitative approach to analyze non-quantitative objects in system engineering, as well as an objective and effective way to carry out a description of human's subjective thoughts. The main steps of AHP are hierarchy establishment, judgment matrix construction and weight calculation.

Step 1. The construction of judgment matrix

Based on the method of (1/9, 9) EM, the judgment matrixes, E, P_1, P_2 and P_3, are constructed, which helps to compare the importance of one element and the upper one within the same evaluation hierarchy. The judgment matrix $E = (e_{ij})_{n\times n}$ is shown in Table 2, the other judgment matrix can be obtained in the same way.

Table 2 Judgment matrix

E	P_1	P_2	P_3
P_1	e_{11}	e_{12}	e_{13}
P_2	e_{21}	e_{22}	e_{23}
P_3	e_{31}	e_{32}	e_{33}

Step 2. The calculation the maximum eigenvalue and eigenvector of each judgment matrix

The summation method was adopted to calculate the maximum eigenvalue and eigenvector of each judgment matrix:

(1) To normalize each column of all the judgment matrixes:

$$\overline{e}_{ij} = e_{ij} / \sum_{i=1}^{n} e_{ij} \qquad (j = 1, 2, \cdots n) \tag{1}$$

(2) To sum each row and gain the sum vector:

$$w_i = \sum_{j=1}^{n} \overline{e}_{ij} \qquad (i = 1, 2, \cdots n) \tag{2}$$

(3) To normalize the sum vector, that is weight vector:

$$\overline{w}_i = \frac{w_i}{\sum_{i=1}^{n} w_i} \qquad (i = 1, 2, \cdots n) \tag{3}$$

Therefore, the eigenvector would be gained $W = (\overline{w}_1, \overline{w}_2, \ldots, \overline{w}_n)$T, which is also relative weight vector.

(4) To calculate the maximum eigenvalue:

$$\lambda_{\max} = \sum_{i=1}^{n} \frac{(EW)_i}{nW_i} \tag{4}$$

The consistency index, CI, was adopted to assess the consistency of judgment matrix E.

$$CI = \frac{\lambda_{\max} - n}{n} \tag{5}$$

The lower the CI value is, the better the consistency would be. If $CI \le 0.1$, the consistency of judgment matrix could be accepted. With the increase of the number of judgment matrix dimensions, random consistency index Rh was adopted as revision value. The more reasonable random consistency index CR was used to measure the consistency of judgment matrix, $CR = CI / Rh$. If $CR = 0 < 0.1$, the consistency of judgment matrix could be accepted. Or it should be revised to meet this requirement. The values of Rh are shown in Table 3.

Table 3 The values of Rh

n	1	2	3	4	5	6	7	8	9	10
Rh	0.00	0.00	0.52	0.89	1.12	1.26	1.36	1.41	1.46	1.49

Weight of the evaluation indexes of knowledge workers' satisfaction based on AHP. After visiting many knowledge workers, the following judgment matrix was worked out.

Step 1. The construction of judgment matrix

By using AHP, judgment matrix E-P of the first-class hierarchy was worked out, which is shown in Table 4.

Table 4 Judgment matrix of the first-class hierarchy

E	P_1	P_2	P_3
P_1	1	1/2	1/3
P_2	2	1	1
P_3	3	1	1

Step 2. The calculation the maximum eigenvalue and eigenvector of each judgment matrix E-P

Through normalization, the calculation of each row, and renormalization, the results of single order weights were shown in Table 5.

Table 5 Single order weight

E	P_1	P_2	P_3	The sum of each row	Normalization
P_1	0.167	0.2	0.141	0.508	$\overline{w_1} = 0.169$
P_2	0.333	0.4	0.429	1.162	$\overline{w_2} = 0.388$
P_3	0.5	0.4	0.429	1.329	$\overline{w_3} = 0.443$

Therefore, the eigenvector is

$$W = \begin{bmatrix} 0.169 & 0.388 & 0.443 \end{bmatrix}^T$$

The calculation of the maximum latent root of the judgment matrix $\lambda_{\max}$:

$$EW = \begin{bmatrix} 1 & 0.5 & 0.333 \\ 2 & 1 & 1 \\ 3 & 1 & 1 \end{bmatrix} \begin{bmatrix} 0.169 \\ 0.388 \\ 0.443 \end{bmatrix} = \begin{bmatrix} 0.509 \\ 1.169 \\ 1.339 \end{bmatrix}$$

$$\lambda_{\max} = \sum_{i=1}^{n} \frac{(EW)_i}{nW_i} = \frac{(EW)_1}{3W} + \frac{(EW)_2}{3W_2} + \frac{(EW)_3}{3W_3} = 3.016$$

The examination of consistency of judgment matrix, that is the calculation of CI and CR:

$$CI = \frac{\lambda_{\max} - n}{n} = \frac{3.016 - 3}{3} = 0.006 \qquad CR = CI \big/ Rh = 0.012 < 0.1$$

It was found that the consistency of judgment matrix could be accepted. This approach can be also used to gain the judgment matrixes of the elements in the second-class hierarchy. The judgment matrixes of P_1-A are shown in Table 6.

Table 6 The judgment matrix of P_1-A

P_1	A_1	A_2	A_3	W_{p1}	$\lambda_{\max} = 3.039$ $CI = 0.019$ $CR = 0.033 < 0.1$
A_1	1	5	3	0.633	
A_2	1/5	1	1/3	0.106	
A_3	1/3	3	1	0.261	

The judgment matrixes of P_2-B satisfaction is shown in Table 7.

Table 7 Judgment matrixes of P_2-B satisfaction

P_2	B_1	B_2	B_3	W_{p2}	$\lambda_{\max} = 3.000$ $CI = 0$ $CR = 0 < 0.1$
B_1	1	1/4	2	0.182	
B_2	4	1	8	0.727	
B_3	1/2	1/8	1	0.091	

The judgment matrixes of P_3-C satisfaction is shown in Table 8.

Table 8 Judgment matrixes of P_3-C satisfaction

P_3	C_1	C_2	C_3	C_4	W_{p3}	$\lambda_{\max} = 4.031$ $CI = 0.003$ $CR = 0.003 < 0.1$
C_1	1	1/4	1/2	1/3	0.095	
C_2	4	1	3	2	0.467	
C_3	2	1/3	1	1/2	0.160	
C_4	3	1/2	2	1	0.287	

Step 3. The index weight of the knowledge workers' satisfaction is shown in Table 9.

Table 9 The index weight of the knowledge workers' satisfaction

First-class index		Second-class index	
Items	Weight $\overline{w}$	Items	Weight
External incentive	0.169	Business prospect	0.112
		Officers' leadership and management skills	0.018
		Access to training	0.044
Internal incentive	0.388	Logistics services	0.071
		Salary	0.282
		Pension and healthcare	0.035
Growing-up incentive	0.443	Working challenge	0.042
		Working achievement	0.207
		Teamwork	0.071
		Working independence	0.127

The Fuzzy Evaluation of Knowledge Workers' Satisfaction

Fuzzy comprehension evaluation is also called multi-objective decision. It can make an overall evaluation of various matters and phenomenon. Therefore, fuzzy comprehension evaluation is very suitable to evaluate knowledge workers' satisfaction. The steps are shown as following:

Step 1: To establish the evaluation factors

$U = (u_1, u_2, \cdots, u_m)$, m refers to the number of the evaluation factors

Step 2: To establish a comment set

$V = (v_1, v_2, \cdots, v_n)$, a comment set is the fuzzy scale collection of the comment levels. Generally, the comments include "very satisfactory", "satisfactory", "fair", "unsatisfactory" and "very unsatisfactory".

Step 3: To confirm the weight

$\alpha = (\alpha_1, \alpha_2, \cdots, \alpha_m)$, α_i refers to the weight of evaluation factor u_i. Each weight α_i should meet the requirement of $\sum_{i=1}^{m} \alpha_i = 1$.

$\alpha_i \geq 0 \quad (i = 1, 2, \cdots m)$

Step 4: To construct fuzzy matrix

While evaluating the degree of membership between the single factor U_{ij} and comment set V, if the number of the indexes is m and the number of comment levels is n, the fuzzy matrix is:

$$R = \begin{bmatrix} r_{11} & r_{12} & \cdots & r_{1n} \\ r_{21} & r_{22} & \cdots & r_{2n} \\ \cdots & \cdots & \cdots & \cdots \\ r_{m1} & r_{m2} & \cdots & r_{mn} \end{bmatrix} \tag{6}$$

In $r_{ij} = \frac{h_{ij}}{H}$, h_{ij} refers to that there are h experts supposed that index i belongs to level j. H refers to the total number of the experts.

And (U, V, R) forms a model of fuzzy evaluation. Based on the comprehensive evaluation concept of Fuzzy Sets Theory, the results are shown as follows:

$$D = \alpha \circ R = (\alpha_1, \alpha_2, \cdots \alpha_m) \circ \begin{bmatrix} r_{11} & r_{12} & \cdots & r_{1n} \\ r_{21} & r_{22} & \cdots & r_{2n} \\ \cdots & \cdots & \cdots & \cdots \\ r_{m1} & r_{m2} & \cdots & r_{mn} \end{bmatrix} = (d_1, d_2, \cdots, d_n) \tag{7}$$

α refers to the weight vector of each factors. $\circ$ refers to synthetic relationship. R refers to the matrix of degree of membership from U to V.

Empirical Analysis on the Comprehensive Evaluation of Knowledge Workers' Satisfaction

A questionnaire of knowledge workers' satisfaction was designed. The ten indexes that influence knowledge workers' satisfaction are included. Eighty-seven pieces of questionnaire were handed out. The effective ones are eighty. For instance, the index of *officers' justice*. The results are shown in Table 10.

Table 10 The results of the questionnaire

	The levels of satisfaction						
The officers are just.	The levels of satisfaction	Very satisfactory	Satisfactory	Fair	Unsatisfactory	Very unsatisfactory	Total
	Number	8	24	32	16	0	40
	Percentage	10%	30%	40%	20%	0%	100%

The factor evaluation of business prospect is shown as follows:

$f(a_1) = (0.1, 0.3, 0.4.0.2, 0)$

Similarly, the factor evaluation of officers' justice is:

$f(a_2) = (0.30, 0.30, 0.24.0.16, 0)$

The factor evaluation of officers' justice is:

$f(a_3) = (0.20, 0.30, 0.20.0.20, 0.10)$

Therefore, the comprehensive judgment matrix can be constructed:

$$R_1 = \begin{bmatrix} 0.10 & 0.30 & 0.40 & 0.20 & 0 \\ 0.30 & 0.30 & 0.24 & 0.16 & 0 \\ 0.20 & 0.30 & 0.20 & 0.20 & 0.10 \end{bmatrix}$$

The evaluation of HX Company's external incentive is:

$$D_1 = P_1 * R_1 = (0.633, 0.106, 0261) * \begin{bmatrix} 0.10 & 0.30 & 0.40 & 0.20 & 0 \\ 0.30 & 0.30 & 0.24 & 0.16 & 0 \\ 0.20 & 0.30 & 0.20 & 0.20 & 0.10 \end{bmatrix}$$

$= (0.147, 0.300, 0.331, 0.196, 0.026)$

The results reflected that "very satisfactory" is 0.147, "satisfactory" is 0.300, "fair" is 0.331, "unsatisfactory" is 0.196, "very unsatisfactory" is 0.026. Based on the Maximum Membership Principle, the evaluation result of external incentive is "fair".

Similarly, the evaluation results of internal incentive and grow-up incentive respectively are:

$D_2 = p_2 * R_2 = (0.101, 0.232, 0.460, 0.206, 0.010)$

$D_3 = p_3 * R_3 = (0.145, 0.194, 0.361, 0.180, 0.120)$

The second-class evaluation index set is

$E = (D_1, D_2, D_3)$

The second-class matrix of comprehensive evaluation is

$$R = \begin{bmatrix} D_1 \\ D_2 \\ D_3 \end{bmatrix} = \begin{bmatrix} 0.147 & 0.300 & 0.331 & 0.196 & 0.026 \\ 0.101 & 0.232 & 0.460 & 0.206 & 0.010 \\ 0.145 & 0.194 & 0.361 & 0.180 & 0.120 \end{bmatrix}$$

The weights of each index are:

$P = (0.169, 0.388, 0.443)$

The second-class fuzzy comprehensive evaluation is

$$D = P * R = (0.128, 0.227, 0.394, 0.193, 0.061)$$

Based on the Maximum Membership Principle, the comprehensive evaluation result of knowledge workers' satisfaction is "fair".

Conclusions

By adopting both qualitative and quantitative methods, this paper constructed an index system of knowledge workers' incentive factors, which uses fuzzy method to gain the XH company's overall evaluation of its incentives. The final results were given to its officers and workers, which has been recognized by the vast majority of the staff. The comprehensive evaluation method which combines AHP and fuzzy evaluation is objective and fair. Meanwhile, it would help to improve the knowledge workers' satisfaction in the future.

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