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Research on the Evaluation of Information Security Management under Intuitionisitc Fuzzy Environment

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Abstract

With the rapid development of computer technology and information technology, information has been a new asset of the enterprise and played more and more important role. How to protect information security is the problem that all companies need to solve together. In this paper, we propose a novel method to evaluate the enterprise's information security management under intuitionisitc fuzzy environment. The intuitionistic fuzzy set which considers not only membership and non-membership, but also hesitancy can express the decision maker's preferences more precise. The extended TOPSIS approach with correlation coefficient instead of distance measure is introduced in the procedure of decision making. Finally, the application and comparison analysis are demonstrated to verify validity and reliability of the method.

Keywords: *information security management, Intuitionistic fuzzy set, TOPSIS, correlation coefficient*

1. Introduction

With the growing spread of communication media and the exponential increase of electronic storage and transmission of information, the need for information security has risen to high levels. Systemized and standardized are main trend in the development of information security management. The setting-up of information security management system is the effective way to guarantee information security. The evaluation of information security management has received more and more attention. Li [1] introduced D-S evidence theory to evaluate the capacity of information security management. The characteristics of information security management were analyzed and based on the PDRR, the new information security management model was proposed. Huang [2] centered the study on the information security management of the personal data protection to promote their standardization. Bellone [3] proposed some specific operational plans and approaches to assess information security management. To evaluate a set of alternatives, the decision maker should give preferences on each attribute for each alternative. However, it is difficult to express the decision maker's preferences accurately. Fuzzy logic and fuzzy set are popular when handling imperfect, vague or imprecise preferences.

Since fuzzy set was proposed by Zadeh [4], it has been successfully used for handling fuzzy decision making problems. The main characteristic of fuzzy sets is that: the membership function assigns to each element x in a universe of discourse X a membership in interval [0, 1] and the non-membership degree equals one minus the membership degree. Fruitful research results of fuzzy sets have been achieved in many different fields [5, 6]. In application, however, the information combines not only evidence for x or evidence against x, but also uncertainty. Because of the lack of knowledge, the decision maker does not know whether evidence for x or not.

In order to solve this problem, Atanassov [7] introduced the concept of intuitionistic

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fuzzy set (IFS), which as a generalization of the concept of fuzzy set considers the membership degree, the non-membership degree and the uncertain degree. Meanwhile, Atanassov [8] defined some operational laws of intuitionistic fuzzy sets. The intuitionistic fuzzy set has received more and more attention since its appearance [9-11]. Szmidt and Kacprzyk [12] used intuitionistic fuzzy sets to solve group decision making problems. Xu and Yager [13] proposed some aggregation operators based on intuitionistic fuzzy sets, and applied them to multiple attribute decision making. Xu [14] developed some intuitionistic fuzzy aggregation operators, including the intuitionistic fuzzy weighted averaging operator, intuitionistic fuzzy ordered weighted averaging operator, and intuitionistic fuzzy hybrid aggregation operator, which can be used to aggregate intuitionistic fuzzy information. In [15], an automotive company is desired to select the most appropriate supplier for one of the key elements in its manufacturing process. It is difficult how to select the best supplier from five candidates. Meanwhile, four attributes should be considered.

TOPSIS(technique for order preference by similarity to an ideal), proposed by Hwang and Yoon [16], whose basic principle is to choose the alternative with the shortest distance from the positive ideal solution(PIS) and the farthest distance from the negative ideal solution(NIS). It has gained a lot of attention. Manish Agarwal [17] compared Choquet integral with TOPSIS in terms of solving the supplier selection problem under fuzzy environment. TOPSIS was applied to financial investment in advanced manufacturing systems [18]. G. R. Jahanshahloo [19] extended the TOPSIS method to decision-making problems with fuzzy data, where the rating of each alternative and the weight of each criterion are expressed in triangular fuzzy numbers.

In this paper, motivated by the mentioned method of intuitionistic fuzzy set, we propose a new TOPSIS method with correlation coefficient. In traditional TOPSIS approach, distance measure is used to measure deviation of alternatives and the positive ideal solution (PIS) or the negative ideal solution (NIS). In the new TOPSIS approach, we define the weighted correlation coefficient to measure the correlation of two intuitionistic sets instead of distance measure. It can provide more choice to make best decision. Correlation indicates how well two variable move together in a linear fashion [20]. As an important content in fuzzy mathematics, correlation between fuzzy sets has gained much attention [21]. Przemyslaw Grzegorzewski introduced Kendall’s correlation coefficient for fuzzy preference [22]. Ye [23] used correlation coefficient to intuitionistic, interval-valued intuitionistic fuzzy multiple attribute decision making. The characteristics of the weighted correlation coefficient including commutativity, boundary, and reflexivity are demonstrated and proven. Similar to traditional TOPSIS approach, the correlation coefficient is used to compute the closeness coefficient to rank all the alternatives. The greater the closeness coefficient is, the better the alternative will be.

The main contribution of this paper includes the following: (1) the design of new evaluation model of information security management under intuitionistic fuzzy environment; (2) the introduction of weighted correlation coefficient of intuitionistic fuzzy set; (3) the creation of new TOPSIS approach with correlation coefficient; and(4) the practical application of the new method.

The rest of this paper is organized as follows. In Section 2, we review some basic concepts related to intuitionistic fuzzy set. Section 3 introduces the weighted correlation coefficient under intuitionistic fuzzy environment. In Section 4, a new TOPSIS approach is proposed. In Section 5, an evaluation problem of information security management is investigated to demonstrate the proposed method, and verify its validity and applicability. Finally, Section 6 concludes this paper.

2. Preliminaries

Intuitionistic fuzzy set which generates the concept of Zadeh’s fuzzy set is characterized by a membership degree, a non-membership degree and a hesitancy degree to describe uncertainty and vagueness more proper. In this section, we review some concepts of intuitionistic fuzzy set.

Definition 1 [7] Let X be an ordinary finite non-empty set. An intuitionisitc fuzzy set in *X* is an expression *A* given by

$$A=\left\{\left\langle x,u_A(x),v_A(x)\right\rangle \middle| x\in X\right\} \tag{1}$$

Where $u_A : X \to [0,1]$ denotes the degree of membership and $v_A : X \to [0,1]$ denotes the degree of non-membership with the condition: $0 \le u_A + v_A \le 1$, for all x in X.
For each intuitionistic fuzzy set *A* in *X*, if
the amount

$$\pi_A(x)=1-u_A(x)-v_A(x), \forall x\in X$$

Then $\pi_A(x)$ is called the degree of indeterminacy of x to A. Especially,
If

$$\pi_A(x)=1-u_A(x)-v_A(x)=0, \forall x\in X$$

Then the intuitionisitc fuzzy set A is reduced to a fuzzy set. For computational convenience, in this paper, we call $\left(u_A(x),v_A(x)\right)$ an intuitionistic fuzzy value.

Definition 2 [8] Let $\tilde{a}=(u_{\tilde{a}},v_{\tilde{a}})$ and $\tilde{b}=(u_{\tilde{b}},v_{\tilde{b}})$ be two intuitionistic fuzzy values, then

(1) $\tilde{a}\oplus\tilde{b}=(u_{\tilde{a}}+u_{\tilde{b}}-u_{\tilde{a}}u_{\tilde{b}},v_{\tilde{a}}v_{\tilde{b}})$

(2) $\lambda\tilde{a}=(1-(1-u_{\tilde{a}})^{\lambda},(v_{\tilde{a}})^{\lambda}),\lambda>0$

Definition 3 [13] Given two intuitionistic fuzzy values *a* and *b*, the following operations are valid:

(1) $\tilde{a}\oplus\tilde{b}=\tilde{b}\oplus\tilde{a}$

(2) $\lambda_1\left(\tilde{a}\oplus\tilde{b}\right)=\lambda_1\tilde{a}\oplus\lambda_1\tilde{b}$

(3) $\lambda_1\tilde{a}\oplus\lambda_2\tilde{a}=(\lambda_1+\lambda_2)\tilde{a}$

3. The Correlation Coefficient under Intuitionistic Fuzzy Environment

Considering the operational characteristic of intuitionistic fuzzy set, we introduce the following correlation coefficients between intuitionistic fuzzy sets: the correlation coefficient and the weighted correlation coefficient.

Definition 4. (Gerstenkorn and Manko, 1991)Given two intuitionistic fuzzy sets *M*= $\left\{\left\langle x,u_M(x),v_M(x)\right\rangle | x\in X\right\}$ and *N*= $\left\{\left\langle x,u_N(x),v_N(x)\right\rangle | x\in X\right\}$, the correlation coefficient between *M* and *N* is given as:

$$\rho_{IF}\left(M,N\right)=\frac{C(M,N)}{\sqrt{C(M,M)}\cdot\sqrt{C(N,N)}}$$

$$=\frac{\sum_{i=1}^{n}\left(u_M(x_i)u_N(x_i)+v_M(x_i)v_N(x_i)\right)}{\left\{\sum_{i=1}^{n}\left[u_M^2(x_i)+v_M^2(x_i)\right]\right\}^{\frac{1}{2}}\cdot\left\{\sum_{i=1}^{n}\left[u_N^2(x_i)+v_N^2(x_i)\right]\right\}^{\frac{1}{2}}} \tag{2}$$

Definition 5. Given two intuitionistic fuzzy sets *M*= $\left\{\left\langle x,u_M(x),v_M(x)\right\rangle | x\in X\right\}$ and *N*= $\left\{\left\langle x,u_N(x),v_N(x)\right\rangle | x\in X\right\}$, the weighted correlation coefficient between *M* and *N* is given as:

$$\rho_{IFW}\left(M,N\right)=\frac{C(M,N)}{\sqrt{C(M,M)}\cdot\sqrt{C(N,N)}}$$

$$= \frac{\sum_{i=1}^{n} w_i \left(u_M(x_i)u_N(x_i) + v_M(x_i)v_N(x_i)\right)}{\left\{\sum_{i=1}^{n} w_i \left[u_M^2(x_i) + v_M^2(x_i)\right]\right\}^{\frac{1}{2}} \cdot \left\{\sum_{i=1}^{n} w_i \left[u_N^2(x_i) + v_N^2(x_i)\right]\right\}^{\frac{1}{2}}} \quad (3)$$

Theorem1 Let M and N be two IFSs on a universe of discourse $X = \{x_1, x_2, \cdots, x_n\}$, the correlation coefficient between M and N should satisfy the following properties:

(1) Commutativity

$$\rho_{IFW}(M,N) = \rho_{IFW}(N,M)$$

(2) Boundedness

$$0 \le \rho_{IFW}(M,N) \le 1$$

(3) Reflexivity

$$\rho_{IFW}(M,N) = 1 \quad \text{, if } M=N$$

Proof.

(1) $\rho_{IFW}(M,N) = \dfrac{C(M,N)}{\sqrt{C(M,M)} \cdot \sqrt{C(N,N)}}$

$$= \frac{\sum_{i=1}^{n} w_i \left(u_M(x_i)u_N(x_i) + v_M(x_i)v_N(x_i)\right)}{\left\{\sum_{i=1}^{n} w_i \left[u_M^2(x_i) + v_M^2(x_i)\right]\right\}^{\frac{1}{2}} \cdot \left\{\sum_{i=1}^{n} w_i \left[u_N^2(x_i) + v_N^2(x_i)\right]\right\}^{\frac{1}{2}}}$$

$$= \frac{\sum_{i=1}^{n} w_i \left(u_N(x_i)u_M(x_i) + v_N(x_i)v_M(x_i)\right)}{\left\{\sum_{i=1}^{n} w_i \left[u_N^2(x_i) + v_N^2(x_i)\right]\right\}^{\frac{1}{2}} \cdot \left\{\sum_{i=1}^{n} w_i \left[u_M^2(x_i) + v_M^2(x_i)\right]\right\}^{\frac{1}{2}}}$$

$$= \rho_{IFW}(N,M)$$

(2)

The inequality $\rho_{IFW}(M,N) \ge 0$ is obvious. Below let us prove $\rho_{IFW}(M,N) \le 1$;

$$C(M,N) = \sum_{i=1}^{n} w_i \left(u_N(x_i)u_M(x_i) + v_N(x_i)v_M(x_i)\right)$$

$$= w_1 u_M(x_1)u_N(x_1) + \cdots + w_n u_M(x_n)u_N(x_n) + w_1 v_M(x_1)v_N(x_1) + \cdots + w_n v_M(x_n)v_N(x_n)$$

$$= \sqrt{w_1}u_M(x_1)\sqrt{w_1}u_N(x_1) + \cdots + \sqrt{w_n}u_M(x_n)\sqrt{w_n}u_N(x_n) +$$

$$+ \sqrt{w_1}v_M(x_1)\sqrt{w_1}v_N(x_1) + \cdots + \sqrt{w_n}v_M(x_n)\sqrt{w_n}v_N(x_n)$$

According to the Cauchy-Schwarz inequality:

$$\left(x_1 y_1 + x_2 y_2 + \cdots + x_n y_n\right)^2 \le \left(x_1{}^2 + x_2{}^2 + \cdots + x_n{}^2\right) \cdot \left(x_1{}^2 + x_2{}^2 + \cdots + x_n{}^2\right)$$

We can obtain:

$$\left(C(M,N)\right)^2 \le \left(w_1\left(u_M(x_1)\right)^2 + \cdots + w_n\left(u_M(x_n)\right)^2 + w_1\left(v_M(x_1)\right)^2 + \cdots + w_n\left(v_M(x_n)\right)^2\right)$$

$$\cdot\left(w_1\left(u_N(x_1)\right)^2 + \cdots + w_n\left(u_N(x_n)\right)^2 + w_1\left(v_N(x_1)\right)^2 + \cdots + w_n\left(v_N(x_n)\right)^2\right)$$

$$= \left(w_1\left[\left(u_M(x_1)\right)^2 + \left(v_M(x_n)\right)^2\right] + \cdots + w_n\left[\left(u_M(x_n)\right)^2 + \left(v_M(x_n)\right)^2\right]\right)$$

$$\cdot\left(w_1\left[\left(u_N(x_1)\right)^2 + \left(v_N(x_n)\right)^2\right] + \cdots + w_n\left[\left(u_N(x_n)\right)^2 + \left(v_N(x_n)\right)^2\right]\right)$$

$$= \left\{\sum_{i=1}^{n} w_i \left[u_N^2(x_i) + v_N^2(x_i)\right]\right\} \cdot \left\{\sum_{i=1}^{n} w_i \left[u_M^2(x_i) + v_M^2(x_i)\right]\right\}$$

$$= C(M,M) \cdot C(N,N)$$

Therefore

$$\left(C(M,N)\right)^2 \leq C(M,M)\cdot C(N,N)$$
$$C(M,N) \leq \sqrt{C(M,M)\cdot C(N,N)}$$

Then

$$\rho_{IFW}(M,N) = \frac{C(M,N)}{\sqrt{C(M,M)}\cdot\sqrt{C(N,N)}} \leq 1$$

(3) if M=N,

$$\rho_{IFW}\left(M,M\right) = \frac{C(M,M)}{\sqrt{C(M,M)}\cdot\sqrt{C(M,M)}} = 1$$

When $w_i = 1/n\,(\mathrm{i}=1,2,\ldots,n)$, intuitionistic fuzzy weighted correlation coefficient reduces to intuitionistic fuzzy correlation coefficient.

4. Decision Making Procedure based on TOPSIS Approach

In traditional TOPSIS approach, the deviation between the alternative and the positive ideal solution or the negative ideal solution is measured by distance. Its basic principle is to choose the alternative which has the smallest distance to the positive ideal solution and the biggest distance to the negative ideal solution.

In this section, we extend the TOPSIS with correlation coefficient instead of distance measure in the procedure of decision making problem. The proposed TOPSIS approach's basic principle is to choose the alternative which has the biggest value of correlation coefficient to the positive ideal solution and the smallest value of correlation coefficient to the negative ideal solution. The correlation is introduced to compare the alternative with the positive ideal solution or the negative ideal solution.

Under intuitionistic fuzzy environment, the intuitionistic fuzzy PIS, denoted by A^+, and the intuitionistic fuzzy NIS, denoted by A^- can be defined as follows:

$$A^+ = \left\{x_j, \max_i\left\langle u(x_j)\right\rangle, \min_i\left\langle v(x_j)\right\rangle \middle| j=1,2,\ldots,n\right\} \tag{4}$$

$$A^- = \left\{x_j, \min_i\left\langle u(x_j)\right\rangle, \max_i\left\langle v(x_j)\right\rangle \middle| j=1,2,\ldots,n\right\} \tag{5}$$

In order to simplify, we use the Eq. (6) and Eq. (7) instead of the Eq. (4) and Eq. (5).

$$A^+ = \left\{x_j, 1, 0 \middle| j=1,2,\ldots,n\right\} \tag{6}$$

$$A^- = \left\{x_j, 0, 1 \middle| j=1,2,\ldots,n\right\} \tag{7}$$

The relative closeness coefficient of an alternative A_i with respect to the hesitant intuitionisic fuzzy PIS A^+ is expressed as follows:

$$CC_i = \frac{\rho_i^+}{\rho_i^+ + \rho_i^-} \tag{8}$$

Where $0 \leq CC_i \leq 1, i=1,2,...m$. Obviously, when an alternative is closer to the intuitionistic fuzzy PIS and farther from the intuitionistic fuzzy NIS, CC_i will be closer to 1. Hence, according to the closeness coefficient CC_i, the ranking-order of all alternatives can be determined and the best alternative can be found.

According to the above models, we can present a novel approach to solve MADM problem, where attribute values take the form of intuitionistic fuzzy information. The approach involves the following step:

Step 1. For a MADM problem, we construct the decision matrix $D=[\tilde{a}_{ij}]_{m\times n}$, where all the arguments $\tilde{a}_{ij}(i=1,2,...m; j=1,2,...n)$ are IFS, given by the DM. As for every alternative $a_i(i=1,2,...,m)$, the decision maker is invited to express evaluation or preference according to each attribute $c_j\,(j=1,2,...,n)$ by a intuitionistic fuzzy value $\tilde{\alpha}_{ij}=(u_{ij},v_{ij})(i=1,2,\ldots,m;\ j=1,2,\ldots,n)$, Where u_{ij} indicates the hesitant degree that the decision maker considers what the alternative α_i should satisfy the criteria c_j, v_{ij} indicates the hesitant degree that expert e considers what the alternative α_i should not satisfy the criteria c_j .Then we can obtain a decision making matrix as follow:

$$D=\begin{pmatrix} \tilde{\alpha}_{11} & \tilde{\alpha}_{12} & \cdots & \tilde{\alpha}_{1n} \\ \tilde{\alpha}_{21} & \tilde{\alpha}_{22} & \cdots & \tilde{\alpha}_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ \tilde{\alpha}_{m1} & \cdots & \cdots & \tilde{\alpha}_{mn} \end{pmatrix}$$

Step 2: Utilize Eq. (6) and Eq. (7) to determine the corresponding intuitionistic fuzzy PISA^+ and the intuitionistic fuzzy NISA^-.

$$PISA^+=\left(\{1\}\{0\}\right)$$

$$NISA^-=\left(\{0\}\{1\}\right)$$

Step 3: Utilize the intuitionistic fuzzy correlation coefficient to calculate the correlation between the alternative α_i and the PISA$^+$ and the correlation between the alternative α_i and the NISA$^-$.

$$\rho_{IFW}\left(A,A^*\right)=\frac{C(A,A^*)}{\sqrt{C(A,A^*)}\cdot\sqrt{C(A,A^*)}}$$

$$\rho^+=\frac{\sum_{j=1}^{n}w_j\left(u_A(x_j)\right)}{\left\{\sum_{j=1}^{n}w_j\left[u_A^2(x_j)+v_A^2(x_j)\right]\right\}^{\frac{1}{2}}} \tag{9}$$

$$\rho^-=\frac{\sum_{j=1}^{n}w_j\left(v_A(x_j)\right)}{\left\{\sum_{j=1}^{n}w_j\left[u_A^2(x_j)+v_A^2(x_j)\right]\right\}^{\frac{1}{2}}} \tag{10}$$

Step 4: Calculate the closeness coefficient of each alternative:

$$CC_i=\frac{\rho_i^+}{\rho_i^+ + \rho_i^-}=\frac{\rho(\tilde{\alpha}_i,\tilde{\alpha}^+)}{\rho(\tilde{\alpha}_i,\tilde{\alpha}^+)+\rho(\tilde{\alpha}_i,\tilde{\alpha}^-)},\ i=1,2,\ldots,m. \tag{11}$$

Step 5: Rank all the alternative a_i according to the closeness coefficient CC_i, where the greater the value of the closeness coefficient CC_i, the better the alternative a_i .

Step 6: End.

5. Numerical Example

In this section, an evaluation problem of information security management is analyzed by the proposed method to demonstrate its applicability and validity.

5.1 Description of the Efficient Evaluation Problem

The most often cited reference for which protective measures that comprise good information security is the ISO 17799 standard. The scope of ISO 17799 is to "establish guidelines and general principles for initiating, implementing, maintaining and improving information security management in an organization" [25]. However, it does not provide any instructions on how to achieve an evaluation problem of information security management in a specific company. Then, we take some large state-owned enterprises as an example. A relevant expert from a famous university acts as the decision maker. He chooses five large state-owned enterprises denoted as a_1, a_2, a_3, a_4, a_5. Meanwhile, he identifies four attributes based on the former studies denoted as c_1, c_2, c_3, c_4 in Table 1 and specifies w = (0.35, 0.25, 0.3, 0.1)

Table 1. The Meaning of the Seven Attributes

Attributes	Meaning
c_1	Physical security management (It includes equipment security management, Environment security management *etc.*,)
c_2	Operation security management (It includes operating system maintenance security management, network maintenance security management, database maintenance security management *etc.*,);
c_3	Risk management (It includes environment risk, operation risk, database risk, control risk *etc.*,,)
c_4	Human resources and policy management (It includes human resources management, strategy management, enterprise's relevant policy management, *etc.*,)

5.2 Solution to the Evaluation Problem with Novel TOPSIS Method

As mentioned above, the proposed method which extends the TOPSIS approach with correlation coefficient is introduced to evaluate this five enterprises' information security management. The evaluation model is demonstrated in the Figure 1.

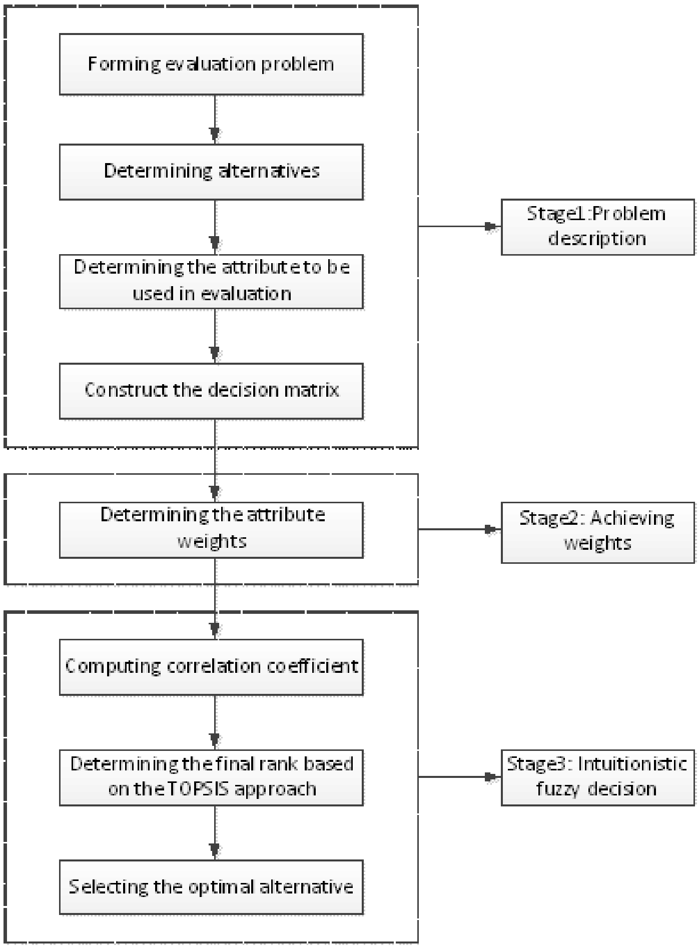

Figure 1. The Evaluation Model of Information Security Management

Based on the evaluation model, the procedure of the decision making problem is as follows:

Step 1: With respect to attribute $c_j\,(j=1,2,\cdots,n)$ the evaluation of the alternative $a_i\,(i=1,2,\cdots,m)$ is made by an intuitionistic fuzzy value $\tilde{\alpha}_{ij}=(u_{ij},v_{ij})\left(i=1,2,\cdots,m;\, j=1,2,\cdots,n\right)$. Then we can obtain a decision making matrix as follow:

Table 2. The Transpose of Intuitionistic Fuzzy Decision Matrix

Attributes	a_1	a_2	a_3	a_4	a_5
c_1	{0.7}{0.2}	{0.5}{0.3 }	{0.4}{0.4}	{0.4}{0.6}	{0.7}{0.1 }
c_2	{0.6}{0.2}	{0.5}{0.3}	{0.3}{0.6}	{0.5}{0.4}	{0.6}{0.3}
c_3	{0.7}{0.1}	{0.2}{0.7}	{0.2}{0.6}	{0.6}{0.2 }	{0.7}{0.3}
c_4	{0.3}{0.6}	{0.5}{0.4}	{0.6}{0.2}	{0.6}{0.2}	{0.3}{0.6}

Step 2: The corresponding intuitionistic fuzzy PISA$^+$ and the intuitionistic fuzzy NISA$^-$ can be acquired:

$$PISA^{+}=\left(\{1\}\{0\}\right)$$

$$NISA^{-} = (\{0\}\{1\})$$

Step 3: The correlation coefficient between the each alternative α_i and the PISA^{+} and between the each alternative α_i and the NISA^{-} can be calculated:

Table 3. The Correlation Coefficient of Each Alternative

	ρ_i^{+}	ρ_i^{-}
a_1	0.9161	0.3030
a_2	0.6450	0.6765
a_3	0.5403	0.7902
a_4	0.7575	0.5850
a_5	0.8922	0.3653

Step 4: Based on the correlation coefficient, the closeness coefficient of each alternative can be obtained:

Table 4. The Closeness Coefficient of Each Alternative

	CC_i
a_1	0.7515
a_2	0.4881
a_3	0.4061
a_4	0.5642
a_5	0.7095

Step 5: According to the closeness coefficient CC_i, the rank-order of all the alternative a_i can be demonstrated:

$a_1 \succ a_5 \succ a_4 \succ a_2 \succ a_3$

Therefore, we can acquire that the a_1 is the best enterprise of information security management. In the next step, we can analyze the advantage of a_1 to improve all the enterprises' information security management.

5.3 Comparison Analysis with Traditional TOPSIS Approach

In order to further realize the new approach, we compare this proposed TOPSIS method with the traditional TOPSIS approach. In the traditional TOPSIS approach, step 1 and step 2 is as same as them in the novel method.

Step 3: The Euclidean distance measure between the each alternative α_i and the PISA^{+} and between the each alternative α_i and the NISA^{-} can be calculated:

$$d_{ifw}(\tilde{\alpha}_i, \tilde{\alpha}^{+}) = \sqrt{\frac{1}{2}\sum_{j=1}^{n} w_j \left((u_{ij} - u^{+})^2 + (v_{ij} - v^{+})^2 \right)}$$

$$d_{ifw}(\tilde{\alpha}_i, \tilde{\alpha}^{-}) = \sqrt{\frac{1}{2}\sum_{j=1}^{n} w_j \left((u_{ij} - u^{-})^2 + (v_{ij} - v^{-})^2 \right)}$$

Table 5. The Euclidean Distance Measure of Each Alternative

	d_i^+	d_i^-
a_1	0.2125	0.5071
a_2	0.3664	0.3512
a_3	0.4138	0.3058
a_4	0.3180	0.3966
a_5	0.2276	0.4883

Step 4: Based on the Euclidean distance measure, the closeness coefficient of each alternative can be obtained:

$$CC_i = \frac{d_i^-}{d_i^+ + d_i^-} = \frac{d_i(\tilde{a}_i, \tilde{a}^-)}{d(\tilde{a}_i, \tilde{a}^+) + d(\tilde{a}_i, \tilde{a}^-)}, i = 1, 2, ...m$$

Table 6. The Closeness Coefficient of Each Alternative

	CC_i
a_1	0.7046
a_2	0.4894
a_3	0.4249
a_4	0.5550
a_5	0.6821

Step 5: According to the closeness coefficient CC_i, the rank-order of all the alternative a_i can be demonstrated:

a_1 f a_5 f a_4 f a_2 f a_3

Therefore, we can acquire that the a_1 is the best enterprise of information security management.

Then, it is obviously that the final result in the traditional approach is as same as the proposed method in this evaluation problem. But the extent of changes between two curves is not quite as same in Figure2. The black line and the red line denote the changes of closeness coefficient with correlation coefficient and closeness coefficient with distance measure, respectively. The extent of changes of the closeness coefficient with correlation coefficient's change is bigger than the extent of changes of closeness coefficient with Euclidean distance measure. So it is easy to compare the alternatives in the TOPSIS approach proposed in this paper, especially there are many complex and similar alternatives.

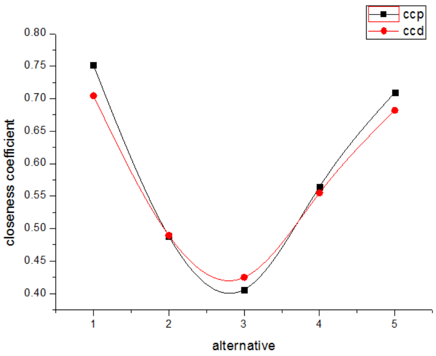

Figure 2. The Comparison between the Propose Method and the Traditional Method

6. Conclusions

Because of the inherent vagueness of human preferences, the attributes involved in decision making problems are not always expressed in real numbers, and some are better suited to be denoted by fuzzy values, such as intuitionistic fuzzy values. In this paper, considering membership, non-membership and the uncertainty of the decision maker's preference, we extend the TOPSIS approach with correlation coefficient under intuitionistic fuzzy environment. The contribution of this paper include the following: (1) the design of new evaluation model of information security management under intuitionistic fuzzy environment; (2) the introduction of weighted correlation coefficient of intuitionistic fuzzy set; (3) the creation of new TOPSIS approach with correlation coefficient; and (4) the development of the evaluation problem of information security management; (5) comparison analysis between the new TOPSIS approach and traditional TOPSIS approach in this evaluation model.

Although the proposed method in this paper is a good solution to the evaluation problem of information security management, it cannot analyze more complex problems where many different decision makers take part in this evaluation problem. In the future, we will extend the method to analyze the group decision making problem of information security management.

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