Abstract—To determine the choice of information security solutions, the method based on entropy weight was given to compute the weights of indexes of the solutions. And then, the weights were used to evaluate the solutions by multi-attributes decision and ideal indexes method. The gray situation decision-making was introduced for solutions decision, and entropy weights were also used with gray solution decision to choose the solutions. The characteristics of diverse methods mentioned were analyzed.

Keywords—entropy weight; gray situation decision; information security solution; investment decision

I. INTRODUCTION

The aims of the information security constructions are to achieve risk control, reduce risk possibility and decrease the loss and impact caused by the corresponding security incident. In this sense, the information security construction is an investment. The value of the investment is to prevent the crisis or safety incidents, achieve the balance between investment "benefit" and the mathematical expectation of the loss. Since there are various investment solutions in information security, we need to evaluate the solutions. For investment decisions, there are several different security strategies or investment principles including cost-minimizing strategies, benefit-maximizing strategy and the balance strategy between cost and benefit. For information security construction solutions, the cost-minimizing strategy refers to the minimum security investment to meet the basic security requirements, which are often mandatory security requirements of general information systems in administrative departments. Benefit-maximizing strategy is to achieve the maximum security by means of current security technologies and methods in some core or confidential information system without considering too much about cost. The balance strategy used in the majority of information systems is to achieve better security by moderate investment with the cost and benefit considered. According to diminishing marginal utility principle in economics, the optimal investment amount is the value of the corresponding investment when marginal cost is equal to marginal benefit. These different decision principles are reflected in the evaluation standard and its weight in the solution, which are the prerequisite of the evaluation. Only by considering each evaluation standard and its weight in a comprehensive way will we make a rational decision. Therefore, the weight research plays an important role in multi-attribute decisions[1]. There are two commonly used methods to determine the weight: subjective and objective. With the subjective method, the weight is empowered according to the importance of each standard evaluated by the decision makers, such as expert investigation (Delphi method), binomial coefficient method, DARE, Analytical Hierarchy Process(AHP), etc. With the objective method, the weight is automatically empowered to each standard according to certain rules, including the main principal component analysis, entropy weight law, the Standard Deviation and the objective programming. The subjective method reflects the intention of decision makers, for decision-making or the evaluation is very subjective and arbitrary while the objective method reflects the weight coefficient, for the decision-making or the evaluation is based on solid mathematical theory.

II. INFORMATION SECURITY INVESTMENT DECISION BASED ON ENTROPY WEIGHT METHOD

Based on the idea of entropy, information quantity and quality in decision is one of the determining factors affecting the accuracy and reliability of the decision. Entropy can be used to evaluate different decision-makings [2] or cases [3]. Entropy can also be used to measure the information utility of the received data [4]. Entropy weight method is that the weight of evaluation standard is calculated with the ideas of information entropy.

A. Principles of Entropy Weight Method

Providing that there are $p$ solutions with the solution decisions based on $n$ indexes to be evaluated, the solution and the index make the data matrix $X = (x_{ij})_{p \times n}$. For an index $x_i$, the greater gap between the index values is, the greater roles the index plays in the comprehensive evaluation, that is, the greater the weight is; if the smaller gap between the index values is, the smaller the weight is in the solution decision; if the index have the same value in each solution, the index doesn’t play any role in decision-making, then the weight is 0. In information theory, the great extent the index changes, the greater amount of information the index provides, and the greater the weight is, and vice versa [5]. Such is the exact meaning of the information entropy.

CHEN Lin\textsuperscript{1}  
\textsuperscript{1}Security Institute of Network  
Chengdu University of Information Technology  
Chengdu, China  
e-mail: to_chenlin@263.net

LI Li\textsuperscript{2}  
\textsuperscript{2}Institute of Information Security  
Sichuan University  
Chengdu, China

HU Yong\textsuperscript{2}  
\textsuperscript{2}Management School  
Tianjin University  
Tianjin, China

LIAN Ke\textsuperscript{3}  
\textsuperscript{3}Tianjin University  
Tianjin, China

EUROTOM-07695-3744-3/09 © 2009 IEEE  
DOI 10.1109/IAS.2009.9
B. Entropy Method procedures and samples

- Normalize each index, calculate the weight \( p_j \) of index \( j \) in solution \( i \):
  \[
p_j = \frac{x_j}{\sum_{j=1}^{g} x_j} \quad (1)
  \]

- Calculate the entropy of index \( j \)
  \[
e_j = -k \sum_{j=1}^{g} p_j \ln p_j \quad (2)
  \]

Here, \( k>0 \), then \( k = \frac{1}{\ln p} \), \( \ln \) is natural logarithm, \( e \geq 0 \). If \( x_j \) of a given \( j \) is equal to all \( i \), then \( e_j \) get the maximum value, the index \( j \) doesn’t work at all, the weight is 0.

(3) Define difference coefficient \( g_j = 1 - e_j \). The greater \( g_j \) is, the more important the index is.

(4) Determine the weight of index with entropy weight method.
  \[
w_j = \frac{g_j}{\sum_{j=1}^{n} g_j} , j=1,2,\ldots,n \quad (3)
  \]

In the process above, calculate the example in [6], \( h_j \) is the value of security solution \( p \) in the factor \( f_j \). In that case, \( h_i \) shows the extent to which the security is consistent to laws and regulations; \( h_2 \) is performance index of the security solution; \( h_3 \) is the cost in the purchase, operation and maintenance of the security solution. The evaluated indexes in the solution are illustrated as TABLE I.

### TABLE I. THE INDEX EVALUATION AND ENTROPY

<table>
<thead>
<tr>
<th>Index</th>
<th>Entropy</th>
<th>Solution 1</th>
<th>Solution 2</th>
<th>Solution 3</th>
<th>Solution 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Laws and regulations</td>
<td>0.3287</td>
<td>80</td>
<td>60</td>
<td>40</td>
<td>90</td>
</tr>
<tr>
<td>Performance</td>
<td>0.0174</td>
<td>84</td>
<td>93</td>
<td>87</td>
<td>100</td>
</tr>
<tr>
<td>Costs</td>
<td>0.6539</td>
<td>60</td>
<td>90</td>
<td>30</td>
<td>40</td>
</tr>
</tbody>
</table>

The index weights in Solution 1: \( p_{11} = 80/270 \), \( p_{12} = 84/364 \), \( p_{13} = 60/220 \). The index weights in Solution 2: \( p_{21} = 60/270 \), \( p_{22} = 93/364 \), \( p_{23} = 90/220 \). The index weights in Solution 3: \( p_{31} = 40/270 \), \( p_{32} = 87/364 \), \( p_{33} = 30/220 \). The index weights in Solution 4: \( p_{41} = 90/270 \), \( p_{42} = 100/364 \), \( p_{43} = 40/220 \). Based on the above procedures, the entropy weight is shown in TABLE I.

When such factors as expert and decision maker are considered, the weight can be amended as follows
  \[
w_j = \frac{\lambda g_j}{\sum_{j=1}^{n} \lambda g_j} , j=1,2,\ldots,n \quad (4)
  \]

Calculate the weight with the entropy weight method, and further follow the procedures of the text [6], calculate the decision data with the weights and evaluation values, as shown in TABLE II, or calculate \( d_i \) by adding up all the distance difference between the indexes in the solution and ideal index value \( h_i^* \) in the solution. (In the would-be solution, the ideal index is the minimum value of cost-based index, and the maximum value of benefit-based index.)
  \[
d_i = \sum_{j=1}^{g} w_j \mid h_i^* - h_j \mid , i=1,2,\ldots, p \quad (5)
  \]

When \( d_i \) is the smallest, the solution is the best. The results are shown in TABLE II.

### TABLE II. SOLUTION ENTROPY WEIGHT AND COMPREHENSIVE EVALUATION

<table>
<thead>
<tr>
<th>Security Solution</th>
<th>Multi-attribute decision</th>
<th>Ideal index</th>
</tr>
</thead>
<tbody>
<tr>
<td>Solution 1</td>
<td>66.9916</td>
<td>23.1824</td>
</tr>
<tr>
<td>Solution 2</td>
<td>80.1912</td>
<td>49.2168</td>
</tr>
</tbody>
</table>

As shown in TABLE II, in multi-attribute solutions, Solution 2 is the best solution for there is a great gap between maximum and minimum values in the cost of purchase, operation and maintenance, and then there is a high entropy weight while in an ideal index method, Solution 4 is the best solution for two indexes are the best. Therefore, different decision-making methods may result in different solution choices due to the different method of measurement.

III. INFORMATION SECURITY INVESTMENT DECISION-MAKING METHODS BASED ON GRAY SITUATION DECISION

Gray situation decision-making is made up of gray elements in the decision-making model, or it is conducted by combining the general decision-making model and gray model that combines the conduct of decision-making, focusing on the solution choice [7]. Gray situation decision-making is researched and applied in many fields, such as flooding [8], multi-attribute decision making [9], security production [10], service satisfaction evaluation [11], agricultural advantages in regional differences [12], management evaluation [13], game [14], and investment [15]. All these show that Gray situation decision-making is a practical evaluation method and decision-making. However, it is seldom applied in information security. According to the gray situation principle, each index is transformed into the dimensionless result measurement in a certain range, then all the benefit measurement in the same solution is converged into a comprehensive result measurement, which is used to make decisions and evaluate the solutions. Gray situation decision-making contains four basic elements: the incident (the issue required solving), measures, results and objectives (evaluation criteria) [16].

The incident set \( A \) is the would-be solutions. The measure set \( B \) is the specific indexes in the would-be solutions. The
dual combination of $A$ and $B$ is known as a situation, marked as $S_{ij} = (a_i, b_j)$, then the whole incident and measure set is known as the situation set, marked as $S$, and $S = (S_{ij})_{i, j = 1, 2, ..., n}$. For objective $K$, the responding result is $U_{ij}^{(k)}$. The gray situation decision-making is to choose the best solution in which the very measures are taken to solve the issues in the gray situation [16].

When there are $P$ indexes, all the objectives are treated as follows:

For index $K$, the result measure is $\gamma_{ij}^{(k)}$ and its corresponding decision unit is $\delta_{ij}^{(k)} = \frac{\gamma_{ij}^{(k)}}{S_{ij}}$.

The situation result analysis is the key to decision-making. The result measure is the compared measure between the actual results in the situation. Since different objectives, different measure dimensions, different kinds of results can not be compared, and the result measure should be normalized by using the cost-based and efficiency-based formula to meet the different indexes.

Cost-based normalized formula
$$x^* = \{x_1^+, x_2^+, ..., x_r^*\} = \begin{cases} \frac{a_{ij}}{\max a_{ij}}, j \in J \\ \min a_{ij}, j \in I \end{cases}$$

Efficiency-based normalized formula
$$x^- = \{x_1^-, x_2^-, ..., x_r^-\} = \begin{cases} \max a_{ij}, j \in J \\ \min a_{ij}, j \in I \end{cases}$$

Steps of gray situation decision-making: (1) present the solution $a_i$ and the measure $b_j$; (2) present the situation $S_{ij}$: the goal $P_i$ as well as the nature of the index; (3) present the actual results $U_{ij}$ of different goals: calculate the result measure matrix $M^k$; (4) calculate the comprehensive result measure matrix $M^k_{ij}$; (5) transform $M^k_{ij}$ in excellent sequence (such as adding the index values) into the excellent sequenced matrix $M^k_{ij}$; (6) select the best situation according to the maximum result measure.

TABLE I is transformed into the integrated measure matrix as shown in TABLE III.

### TABLE III.  THE INTEGRATED MEASURE MATRIX

<table>
<thead>
<tr>
<th>Index</th>
<th>Security solutions</th>
<th>Solution 1</th>
<th>Solution 2</th>
<th>Solution 3</th>
<th>Solution 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Laws and regulations</td>
<td>0.89</td>
<td>0.67</td>
<td>0.44</td>
<td>1.00</td>
<td></td>
</tr>
<tr>
<td>performance</td>
<td>0.84</td>
<td>0.93</td>
<td>0.87</td>
<td>1.00</td>
<td></td>
</tr>
<tr>
<td>costs</td>
<td>0.50</td>
<td>0.33</td>
<td>1.00</td>
<td>0.75</td>
<td></td>
</tr>
</tbody>
</table>

The integrated result measure value $r = (2.23, 1.93, 2.31, 2.75)$. It is seen that Solution 4 is the best solution. The information security solution decision can be made by combining entropy weight method and the gray situation decision-making [17]. By using the entropy weight and the gray situation decision-making, the comprehensive evaluation value of each security solution can be calculated, as shown in TABLE I, and Solution 4 is the best solution.

### TABLE IV.  THE SOLUTION EVALUATION BASED ON ENTROPY WEIGHT AND GRAY SITUATION DECISION-MAKING

<table>
<thead>
<tr>
<th>Security solutions</th>
<th>Entropy weight</th>
<th>Evaluation value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Solution 1</td>
<td>0.3287</td>
<td>0.6341</td>
</tr>
<tr>
<td>Solution 2</td>
<td>0.0174</td>
<td>0.4522</td>
</tr>
<tr>
<td>Solution 3</td>
<td>0.6539</td>
<td>0.8137</td>
</tr>
<tr>
<td>Solution 4</td>
<td>0.3287</td>
<td>0.8365</td>
</tr>
</tbody>
</table>

IV. CONCLUSION

Information security construction is a complicated task, which requires the rational planning and implementation to meet different needs. However, in order to achieve the goal of information security, you can have a variety of different solutions. This paper explores how to choose information security solutions. As can be seen, different evaluation methods may have different evaluation results and solution selection. Decision-makers should select the suitable information security solutions to meet the realities.

REFERENCES


