

## A methodology for the selection of enterprise information system based on the analytic hierarchy process

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**Abstract:** In this paper, an evaluation and selection model is proposed. This new model combines the Analytic Hierarchy Process (AHP) with the Information System Management Planning (ISMP). The ISMP is chosen as the hierarchy-constructing method. That is to define the global enterprise information system scheme, and its evaluation criteria and weights by the headquarters of enterprise.

The group decision making method of the AHP is also modified in the proposed model in order that each organization (local enterprise) may apply this model easily. So that the goal of combining the evaluation and development for organization (local enterprise) information system can be reached.

It is found that the proposed model can not only match the global enterprise information system scheme but also meet the needs of group decision making under multi-criteria. Hence the new model is expected to be able to provide more reasonable and practical results.

**Key words:** Analytic hierarchy process, enterprise information system, group decision making, information system management planning, multi-criteria

## 1. Introduction

The evaluation and selection for an information system (IS) is quite different from the purchase of other goods. The major differences are: the various complex options of an IS, the demands of an IS depending on the total requirement of operations, the explosive growth of information technology, and the difficulties in estimating cost and benefit of total IS, etc. Many models which have been proposed for the evaluation and selection of an IS focused on various aspects; for example, the criteria like cost/benefit (Ahituv and Igbaria [2], Shoval and Lugasi [11]), empirical models (Griese and Kurpicz [4]), and mathematical models (Lehman, et al. [6], Shoval and Lugasi [10]).

But the most important aspect of an IS is that of management. So, when evaluating and selecting IS, it is important to select an appropriate model based on management characteristics and then evaluate under multiple criteria by group decision-making (Fichefet [3]). Also, practically, the evaluation and selection of an IS for each organization (local enterprise) depends on its development, environments, and budget. Whatever the result is, it should match the global enterprise information system scheme. The model presented combines the Analytic Hierarchy Process (AHP) and the Information System Management Planning (ISMP). It is expected to meet the above needs and provide more reasonable and practical results

## 2. Principles of the AHP

The AHP breaks down the decision problem into separate elements, i.e., a hierarchy structur-

ing, then obtains pairwise comparison matrices through the pairwise comparison of all elements. It sets the relative weights (importance) by the eigenvalue method. Finally, it determines the overall priorities of alternatives. In decision-making, it may measure the consistency of each level and the overall hierarchy by means of a consistency ratio (C.R.). The important foundations of the AHP's hierarchy constructing and group decision-making are as follows:

### (1) hierarchy construction

The AHP decomposes a complex problem from high level to low level by a hierarchy. In constructing a hierarchy, it assumes that all entities of each level are independent of each other, then it decomposes the problem into levels of goal, objective, criteria, and alternative (see Fig.1) (Saaty [7]).

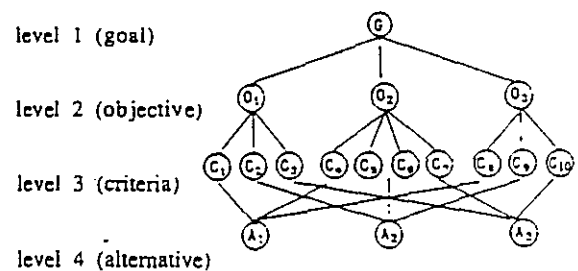


Fig.1 Hierarchy structure of the AHP

### (2) group decision making

In decision-making, individual judgments about the measurement or ratio of objects are always subjective and are easily changed because of the environment. By the way, the decision environment frequently changes and many decisions are hard to be made by individuals. In order to make better decisions, group decision making has recently been employed to conquer the risks in the

decision process and to mold individual opinions into a group opinion.

In [8], Saaty stated that there are two ways to integrate multiple decision makers' opinions in the process of the AHP. One is to debate the judgments and vote until consensus or compromise is reached, the other is to take the geometric mean of individual judgments to form a combined judgment in a group.

a. debating and voting

When in pairwise comparison, all decision makers have full debate on each priority. Undoubtedly, in social choice process, it is ideal that each decision is made by way of group interaction. But the process of debating and voting is liable to be time consuming.

When applying this method, one will probably encounter the following special problems: unequal power and expertise, variable preferences, changes in preferences, and unwillingness to reveal preferences (Saaty [8]).

b. the geometric mean as synthesizing function

Let  $a_{ij}^{(k)}$  be the element of the Kth decision maker's judgment matrix, the element of the overall group may be get by

$$a_{ij} = \left( \prod_{k=1}^n a_{ij}^{(k)} \right)^{1/n} \quad (1 \leq i, j \leq n)$$

The primary reason for using the geometric mean is that it may preserve the reciprocal property after synthesizing. The way to decide how well an individual's set of judgment corresponds with the group's is also determined by the consistency ratio (C.R.).

Saaty [9] let  $(a_{ij})$  be an  $n \times n$  pairwise comparison matrix formed by taking the geometric mean of the individual judgments, and let  $(W_1, W_2, \dots,$

$W_n)$  be the weights derived from this matrix. Since  $A_w = \lambda_{max} W$ , so

$$\sum_j a_{ij} W_j = \lambda_{max} W_i$$

$$\sum_{i,j} a_{ij} W_j / W_i = n \lambda_{max}$$

The consistency index (C.I.) is computed by

$$(n \lambda_{max} - n^2) / (n^2 - n)$$

The consistency ratio (C.R.) is computed as usual by taking the ratio of C.I. to the random index (R.I.). Saaty [9] also suggested that if the C.R. is less than 0.10, then the group judgment is consistent. We have critique on the above point of view because the consistency (consensus) of the decision group can not simply be derived from individual consistency.

Besides the geometric mean, there are other synthesizing functions used. Aczel and Alsina [1] discussed the synthesizing judgment of the AHP, and compared some synthesizing functions.

From the above, it is known that up to now there is not an effective method to synthesizing group judgments in the AHP. Either the debate-and-vote method, or the synthesizing functions method has its own advantages and disadvantages. It is noticeable for the decision maker (DM) that the former has many difficulties in practice, while the latter can only simplify the problem, without diminishing the social intricacy.

### 3. Information system management planning (ISMP)

There is no certain process for constructing hierarchies in applying the AHP. This paper addresses the evaluation and selection of the enterprise IS, so we construct the decision hierarchy from the view of the management of the enterprise IS.

The most important part of developing an IS is to define its goal and scheme in order to meet the enterprise objectives. With a top-down flow, the planning and control hierarchy is determined, from strategic level, tactical level, to operational level. With a bottom-up flow, the development of the IS is identified by five stages as follows: start up, growth, control, planning, and strategic planning.

As Fig.2 (IBM [5]) shows, under each objective are the processes which are combined into several process groups. The information flow between the process groups also tells the relationship of processes. The above scheme may define the global IS strategic planning.

The accomplished IS planning should at least include the following tasks: 1) definition of business processes, 2) relationship of business processes and organization, 3) analysis of data utilization, 4) data classes, 5) relationship of data and business processes, 6) total IS scheme, 7) design of application system, 8) structure and performance specification of each application system, 9) information boundary of application system, 10) design of data base.

#### 4.The proposed model

The proposed model is based on the AHP, combines the ISMP as the hierarchy constructing method in order that it may match the global enterprise IS scheme. The group decision making method of the AHP is also modified. The P-

connectivity matrix procedure is chosen as the group decision making method on the level of alternative so that it may provide a more reasonable result in practice.

The proposed model, as shown in Fig.3, includes three methods: ISMP, AHP, and the group decision making method.

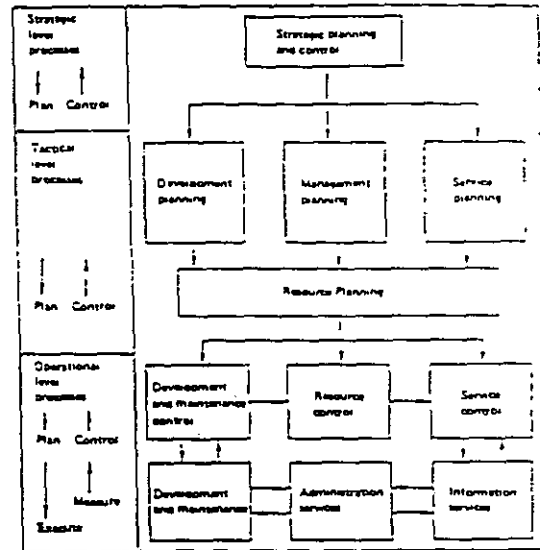


Fig.2 The IS management process groups (Adapted from IBM [5])

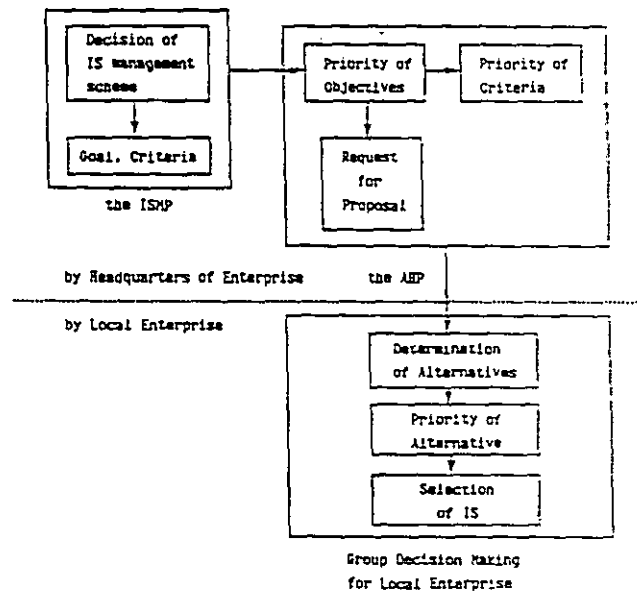


Fig.3 The model combined the AHP and the ISMP for evaluation and selection of enterprise IS

### *(1) the ISMP*

Each local enterprise has many IS needs in common, so the ISMP should be performed by a group made up of headquarters of enterprise and experts. In this way, it may be economical and provide foundations for latter developments. Then the global IS scheme may act as the decision hierarchy.

In hierarchy constructing, there are various aspects to be discussed. First, when the hierarchy is incomplete, one may get counterintuitive composite weights (Zahedi [13]). The process groups in ISMP may contribute to all levels above them in the hierarchy; that is, if well-planned there will not be any incomplete hierarchy. Second, the organizational hierarchy is different from a decision one, so the evaluation criteria table of each application system's performance and attributes is necessary. Third, the formulation of the decision structure may employ the backward process (is yet to be developed into an operational method). We suggest that the planners of the ISMP should decide what those important elements are in order to construct the decision hierarchy.

### *(2) the AHP*

From the global IS scheme, system function and system attributes of the ISMP decision hierarchy, the AHP here may decide the priorities of all subsystems; then define the weights of performance and attributes for evaluation. Also, the request for proposal (RFP) may be defined. Finally, the local enterprise may choose its own alternative from the above result submitted to it, then the overall decision hierarchy may be constructed.

### *(3) the group decision making*

Above the level of alternatives, for the sake of consistency and the reciprocal property, the geometric mean is employed to synthesize individual judgments into group judgment. While at the level of alternative, the P-connectivity matrix procedure is employed as a synthesizing function for the following reasons: firstly, to meet the developments of each local enterprise with the independence principles; and secondly, to meet the least violation principle, reflecting individual judgment into group judgment which is not dominated by anyone.

The P-connectivity matrix procedure is a modification of the Borda count method (Tzeng et al. [12]), it finds out the complete outranking order after the pairwise comparison of the alternatives by each individual; then assigns marks of  $n-1, n-2, \dots, 0$  to the first ranked, second ranked, ..., last ranked alternative ( $n$  is the number of alternatives). All individual preference can be calculated by the sum of outranking order position between pairwise alternatives ( $i, j$ ). Then the least violation principle may be satisfied, the group preference may be summarized by all individual preferences.

### *(4) the strategies to solve the possible problems*

In the AHP, all the elements (evaluation criteria) of any level should satisfy the trade-off property. Both the elements of the criteria and alternative level satisfy the above needs. In the present model, we can avoid the above need by taking into consideration the subsystems in the objective level separately and giving each subsystem its own hierarchy.

In addition to the inherent problems in AHP, such as evaluation ratio scale and consistency, other intrinsic problems are as follows:

- a. rank reversal

When we evaluate the alternatives, all alternatives must be evaluated at one time. There will possibly be rank-reversal (different ranking) when we add or delete alternatives after the evaluation.

b. adjustment of element's weights

The weight of each element should pertain its relative weight to each subsystem, without converting to the overall weight relative to the goal. In this way, the DM may flexibly choose the subsystem to be evaluated (e.g., choose part of the subsystems).

c. cost factor ratio

Generally, for example, the cost factor ratio of personal computer and peripheral equipments ranges from 30% to 50%. To meet the requirements of cost/benefit of IS, the cost factor ratio may be included in the model presented. The range may be decided by the decision group, whether the cost factor included in weighted calculation or not is also determined by the decision group.

## 5. Applications

In this paper, an evaluation example is cited. In this enterprise, the first part of this model (ISMP) is already completed, and then this model is applied to the evaluation and selection of the enterprise's data base management system (DBMS).

*(1) a brief view of the example*

The enterprise requests an information Co. to plan a long-term development scheme of its national IS. With the ISMP (e.g., Business System Planning developed by IBM Co.), the business processes/data classes have been analyzed several

times and the business processes via similar data utilization are clustered in one group. The total group numbers are 26; that is, 26 management subsystems are planned. The global IS scheme has been constructed. Most tasks as the Section 3 proposed are done. It takes half a year to finish the "Global Planning Report" and the "Construct Planning Report".

The above reports suggest that a huge and efficient DBMS is quite necessary in order that all business may be included in the DBMS. Here comes the problem of how to evaluate and select a proper DBMS.

*(2) the evaluation process*

As the Table 1. shows, the primary requirements of the DBMS are determined according to the IS scheme.

Table 1. The primary requirements of the enterprise's DBMS

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1. Performance under the mainframe of IBM 4381 and the operating system of VM/SP.
  2. The 4th generation language.
  3. The Chinese processing.
  4. Large quantity of data.
  5. Transfer current file.
  6. High level language interface.
  7. Installation experience.
  8. Technical support service.
- 

The decision group (composed of five individuals, e.g., A,B,C,D, and E), by referring to the above reports, determines the important criteria (I criteria) and the reference criteria (R criteria) for evaluation of the DBMS. Then the evaluation hierarchy of the DBMS may be constructed, as the Fig.4 shows.

The decision group determines the weights of each element (except the level of alternatives) by pairwise comparisons. The results of the second level are as follows:

A	I	R	B	I	R	C	I	R	D	I	R	E	R
I	1	9	1	1	3	1	1	3	1	3	1	3	3
R	1/9	1	1/3	1/3	1	1/3	1	1	1/3	1	1/3	1/3	1

- $v_1 = (0.90, 0.10)$
- $v_2 = (0.75, 0.25)$
- $v_3 = (0.75, 0.25)$
- $v_4 = (0.75, 0.25)$
- $v_5 = (0.75, 0.25)$

the  $V_i$  means the outranking vector of DM  $i$ 's pairwise comparison matrix. The synthesized judgments are

G	I	R	Weights
I	1	$\sqrt[5]{9 \times 3 \times 3 \times 3 \times 3}$	0.79
R	$\sqrt[5]{1/9 \times 3 \times 3 \times 3 \times 3}$	1	0.21

$\lambda_{max} = 2.00 ; C.I. = 0.00$

to the overall evaluation, the weight of the I criteria is 0.79; while the weight of the R criteria is 0.21.

The nine evaluation criteria under the I criteria, and the six evaluation criteria under the R criteria, may also be pairwise compared as the above procedure does. Each result is shown in Table 2 and Table 3.

Table 2. The weights of criteria under the I criteria

Criteria	Weight
a	0.13
b	0.12
c	0.17
d	0.10
e	0.02
f	0.11
g	0.20
h	0.12
i	0.03

$\lambda_{max} = 9.95 ; C.I. = 0.12$

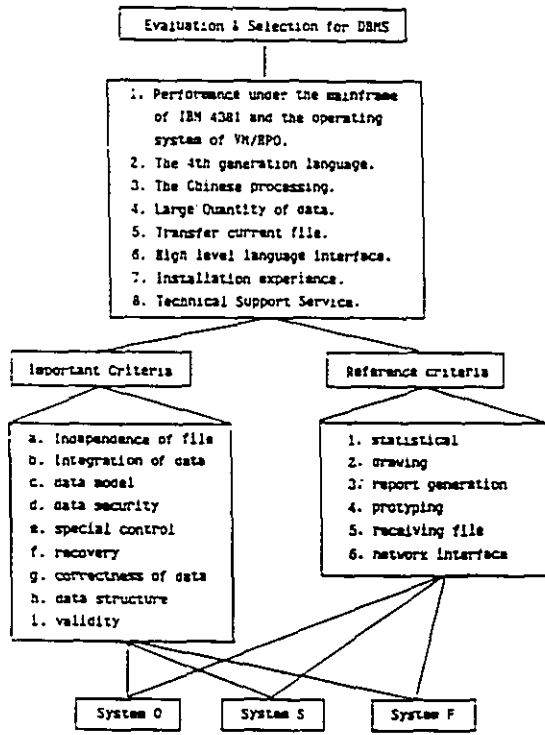


Fig.4 Evaluation hierarchy of the DBMS

Table 3. The weights of criteria under the R criteria

Criteria	Weight
1	0.25
2	0.18
3	0.20
4	0.04
5	0.18
5	0.15

$\lambda_{ij} = 2.35; C.I. = 0.07$

Then all weights of evaluation criteria relative to the overall hierarchy are computed, shown in the Table 4.

Table 4. The weights of all criteria

Criteria	Weight
a	0.103
b	0.095
c	0.134
d	0.079
e	0.016
f	0.087
g	0.158
h	0.095
i	0.024
1	0.053
2	0.038
3	0.042
4	0.008
5	0.038
5	0.032

With the bench-mark or the questionnaire about all evaluation criteria for each vendor; the decision group makes pairwise comparison of the three alternative (i.e., O.S. and F) under each evaluation criterion. The complete outranking order may be computed from the complete outranking weight of each alternative by every DM. The evaluation of DM A is shown in the Table 5. In synthesizing judgments about alternative, as the Section 4 mentioned, the P-connectivity matrix procedure is as follows:

Table 5. Evaluation of alternative for DM A

Alternative weight Criteria	System O	System S	System F
a(0.103)	0.40	0.20	0.40
b(0.095)	0.43	0.14	0.43
c(0.134)	0.40	0.20	0.40
d(0.079)	0.74	0.63	0.24
e(0.016)	0.47	0.47	0.07
f(0.087)	0.10	0.33	0.57
g(0.158)	0.32	0.22	0.46
h(0.095)	0.77	0.17	0.05
i(0.024)	0.13	0.21	0.55
1(0.053)	0.28	0.65	0.07
2(0.038)	0.51	0.13	0.35
3(0.042)	0.40	0.20	0.40
4(0.008)	0.33	0.43	0.24
5(0.038)	0.43	0.14	0.43
5(0.032)	0.15	0.33	0.52
complete outranking weight	0.37	0.28	0.35
complete outranking order		3	2

the Borda count matrix of the three alternative is

$$\begin{matrix}
 & A & B & C & D & E \\
 O & 2 & 2 & 1 & 1 & 1 \\
 S & 0 & 0 & 0 & 0 & 0 \\
 F & 1 & 1 & 2 & 2 & 2
 \end{matrix}$$

In P-connectivity matrix procedure, the Borda count matrix is

	O S F	Sum of row	Order
O	$\begin{bmatrix} 0 & 7 & 2 \end{bmatrix}$	9	(2)
S	$\begin{bmatrix} 0 & 0 & 0 \end{bmatrix}$	0	(3)
F	$\begin{bmatrix} 3 & 3 & 0 \end{bmatrix}$	6	(1)

It is known that the system F is the 1st ranked choice. If the cost factor is taken into consideration, the decision group has to determine each ratio of cost under the above technique. The weights multiplied by the ratio may also determine the complete outranking weight of each alternative.

## 6. Summary and conclusions



The evaluation and selection of IS possesses the characteristics of multi-criteria and group participation. To meet the reasonable and practical purpose, the group decision making under multiple criteria is applied in this proposed model.

The ISMP is chosen as the hierarchy-constructing method which may define the global enterprise IS scheme. The evaluation criteria and weights are also determined by the headquarters of enterprise.

For the selection of alternatives, the group decision making method of the AHP is modified in order that each organization (local enterprise) may easily apply this model. Since the least violation principle is met, the modified method is reasonable.

The proposed model, combining the AHP and the ISMP, can surely match the global enterprise IS scheme. Once the global enterprise IS scheme is constructed, all organizations may follow the scheme, and then a long term development is expected.

The proposed model derives the evaluation criteria from the global enterprise IS scheme to form a decision hierarchy. All the evaluation criteria will match the global enterprise IS scheme, the alternatives evaluated from the above criteria will always do so.

Future research may make efforts in the following three topics. One is the development of other evaluation and selection models which are more practical and effective for enterprise IS. Another is a better synthesizing method to eliminate the broad criticism about the group decision making of the AHP. The other is the employment of more empirical studies to refine the present model.

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