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Research Article

Ability Assessment of Researchers of Scientific Research Institution Using Integrated AHP

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Abstract

Talent is the main factor of progress and prosperity in the world, and all the developments in the present era are related to the efforts of talent. Identifying talent, assessing their ability, and promoting talent is an important requirement for the sustainable development and competitiveness of enterprise. If talent assessment and management are not properly conducted, the enterprise will not meet the requirements of the developing reality and will not be able to achieve the future development. AHP (Analytical Hierarchy Process) is a comparative assessment method using human sense, which models the influence of the criteria associated with decision making into a hierarchical structure and allow to choose the best among alternatives to be selected. AHP is widely used in various fields of economy, military, society, management, education, medicine, etc. In this paper, we have considered the problem of determining of the researchers' abilities objectively, intuitively and conveniently using the Integrated Analytical Hierarchy Process (IAHP). First, we have considered the development of IAHP tool in the Net-oriented System Description Language (NSDL) environment, developed by combining the advantages of Petri nets and object-oriented programming language VB. Compared with the previous AHP tools, the hierarchical structure model for the selection of the optimum alternative is built with Petri net diagrams to improve the intuition and convenience of tool. Also, the introduction of the File Alternative Element (SFile) allows us to build a hierarchical structure model more conveniently and simply in the case of a large number of alternatives.

Keywords

Integrated AHP, Petri Net, Object-oriented Programming Language, Net-oriented System Description Language, Ability Assessment

1. Introduction

AHP is a decision-making tool, which models the influence of the criteria associated with decision making into a hierarchical structure and selects the best one among several alternatives, is widely used in various fields of economy, military, society, management, education, medicine, etc.

In the past, AHP tools have been developed and used mainly in Excel software and in graphical user interface mode with the spreadsheet function. These tools include AHP

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Solver, XLSTAT, AHP Decision and Py-ahp calculator [1-5].

However, when the number of layers, criteria, and alternatives are large and the interaction is complex, the description of the structural and logical relationships of AHP tool takes a lot of time and effort and the intuition of the hierarchical structure model is lacking, and the users feel inconvenient.

There are many software development tools that combine the advantages of Petri nets and object-oriented programming languages with good intuition and convenience in modeling in the world [6-11].

Hence, we developed IAHP in NSDL environment that was developed by combining the advantages of Petri nets and object-oriented programming languages. In IAHP, the hierarchical structure model is described by Petri net diagrams to enhance the intuition and convenience of the AHP tool.

Also, the use of the File Alternative Element (SFile) has been used to conveniently solve the decision-making problem with a large number of alternatives and has been effectively applied to the assessment of the researchers' abilities.

2. Net-oriented System Description Language- NSDL

2.1. Formal Definition of NSDL

NSDL is a complex system modeling tool developed by combining the advantages of Petri nets and the object-oriented programming language VB based on Microsoft.NET Framework 4.0 library.

The formal definition of NSDL is as follows.

$$\text{NSDL} = [P, T, A, M, F, \theta, O] \quad (1)$$

P— set of places (includes integer, variable, real, stack, FIFO and equal place, in/out place terminal);

T— set of transitions (includes the GUI controls transitions), $P \cap T = \Phi$;

A— set of arcs (includes Flow, Reference and Inhibitor arc);

M— set of markings (includes the object tokens);

F— set of functional code of the element;

θ— set of attributes (delay time after firing, firing rate, priority, weight, capacity, type of elements, competition check and color, etc.);

O— set of user-defined objects modeled with NSDL's script;

S—set of sub-systems or sub-project models.

NSDL introduced elements including in/out place terminal, equal place, subsystem, model library management, code debugging and model compiling ability to further improve its flexibility, convenience, extensibility and productivity.

2.2. Modeling Element in NSDL

The modeling elements include place, transition, arc, subsystem elements and functional code.

2.2.1. Place

The place reflects the state of the system and includes the information and usage of the system, including Integer, Real (greater than zero), Stack, FIFO, Equal and Variable places.

The capacity of place may be given to Integer place, Stack place, and FIFO place. These places can be used to model continuous and hybrid systems as well as discrete event driven systems.

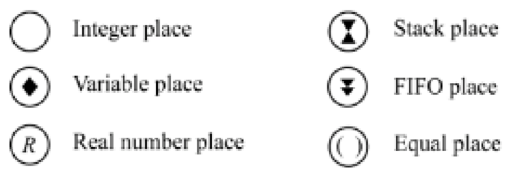

Figure 1. Places.

2.2.2. Transition

The transition is fired according to the state of the input places and the property of the input and output arcs attached to it and the condition function written by the user. When the event occurs, it will perform a user-defined function.

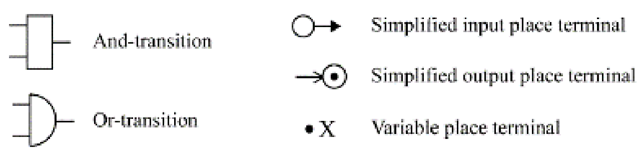

Figure 2. Transition and Simplified place terminal attached to transition.

For convenience of modeling, And-transition and Or-transition may be used (Figure 2). Also, the transition may have a Simplified input/output place and Variable terminal.

Boolean, integer, real number, string and object type, etc. can be used in these terminals while variable terminals are only used as defined variables here.

Several GUI controls transitions which are widely used in modeling, such as Graph, Table, Text Box, Button, CheckBox, ComboBox and OpenFileName may be used in NSDL to improve modeling ability (Figure 3).

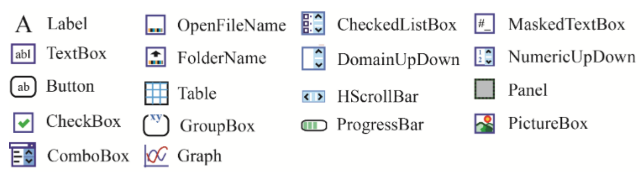

Figure 3. Typical GUI controls transitions.

Such transitions may fire according to function of GUI controls as well as standard transition. The attributes of firing time, firing rate, priority, etc. may be set in all the transitions.

2.2.3. Arc

An arc, which is a link element to represent the correlation between the place and the transition elements, includes an input arc and an output arc.

The input arc has three different types of information transfer. Flow arc allows the information of the input place to be passed to the firing transition associated with it and the information of the input place to be removed, while Reference arc maintains information at the input place, unlike the flow arc, even if the corresponding transition is fired. Also, Inhibitor arc is the one that becomes the firing state in the absence of information of the input place. The Multiplicity and Flow quantity may be defined in arcs. Also Conditional expression or Output function may be defined by user.

The output arc may be defined multiplicity, flow quantity, user-defined conditional expression and output function, in addition to the function of outputting information.

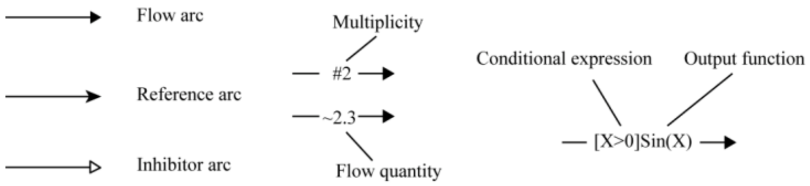

Figure 4*. Type of the arc.*

2.2.4. Subsystem Elements

In NSDL, the complex system structure may be modeled using a subsystem element (sub-project element) and a Simplified input/output place (Figure 5).

Here, the input place and the output one are connected only to the place of inside the subsystem model.

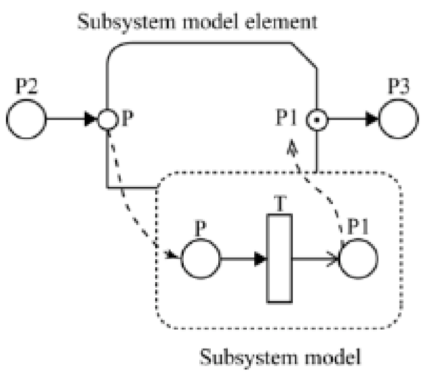

Figure 5*. Representation of input/output places of a subsystem model element.*

2.2.5. Functional Code Model

Functional code model describes the action of elements created in the diagram model. They may use not only the arbitrary functions and procedures that Framework4.0 library supports, but also NSDL‘s custom functions and procedures.

2.3. Firing of Transition

In NSDL, the system state changes with the occurrence of an event, i.e., the firing of a transition.

The firing of a transition is done in the typical firing conditions of the Petri net and the type of transition (And/Or, GUI controls) and the properties of its input and output arcs (Conditional expression, Multiplicity, Flow quantity) (Figure 6).

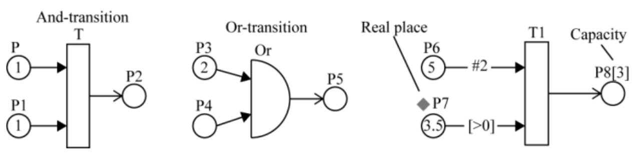

Figure 6*. Fire condition (firing state) of transition.*

For the transition where UserCondition () function is defined, it becomes firing state only when this function value condition and the above firing condition are satisfied.

3. Ability Assessment of Members of Scientific Research Institution by IAHP

3.1. Integrated Analytical Hierarchy Process (AHP) Method

IAHP is the decision- making tool which integrates AHP structural model constructed by Petri net diagram with AHP analytical algorithm constructed by VB language of NSDL.

Here, you may construct the AHP structural model which has 19 layers (including goal, criterion and alternative layer) to the maximum and 5000 criteria or alternatives. The algorithm diagram of IAHP is as follows:

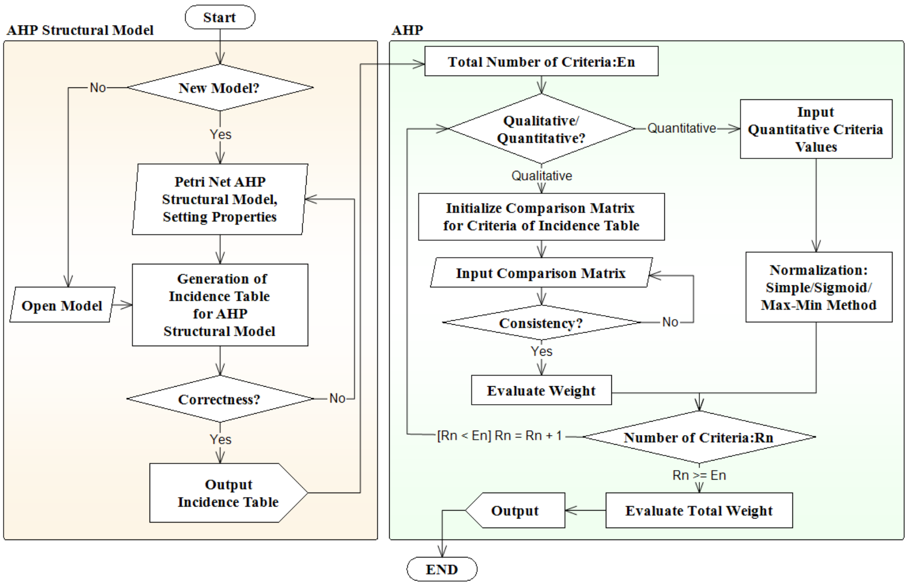

Figure 7. Algorithm diagram of IAHP.

3.2. Ability Assessment of Members of Scientific Research Institution

3.2.1. AHP Structural Modeling

First, AHP structural model for decision-making problem should be constructed. As can be seen in Figures 8 and 9, for example, AHP structural model has 3 layers, 15 criteria and 37 alternatives for researchers.

The goal layer and criteria layer may be modeled with goal element(A1) and criteria element (B1～K1) in IAHP model library. These elements are transitions having Simplified input/output place. The alternative layer may be modeled as S1 or SFile.

Using arc, AHP structural model can be constructed by connecting Simplified input /output place of each element as shown in Figures 8 and 9.

If use S1 element, the alternatives (S1～S37) for 37 researchers should be modeled. Else if use SFile element, Excel data file for 37 researchers should be pointed out. Both of them are equivalent each other but it has so many alternatives, the second structural model is more convenient and simpler than the first.

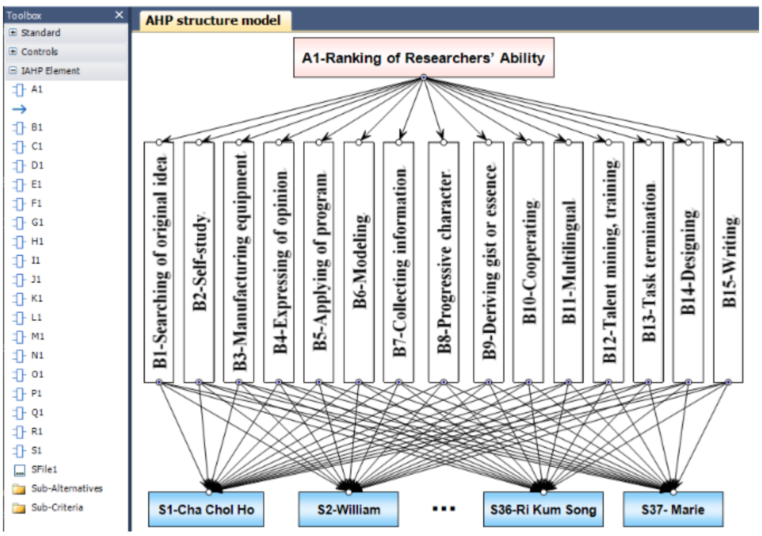

Figure 8. AHP structural model with S1 element.

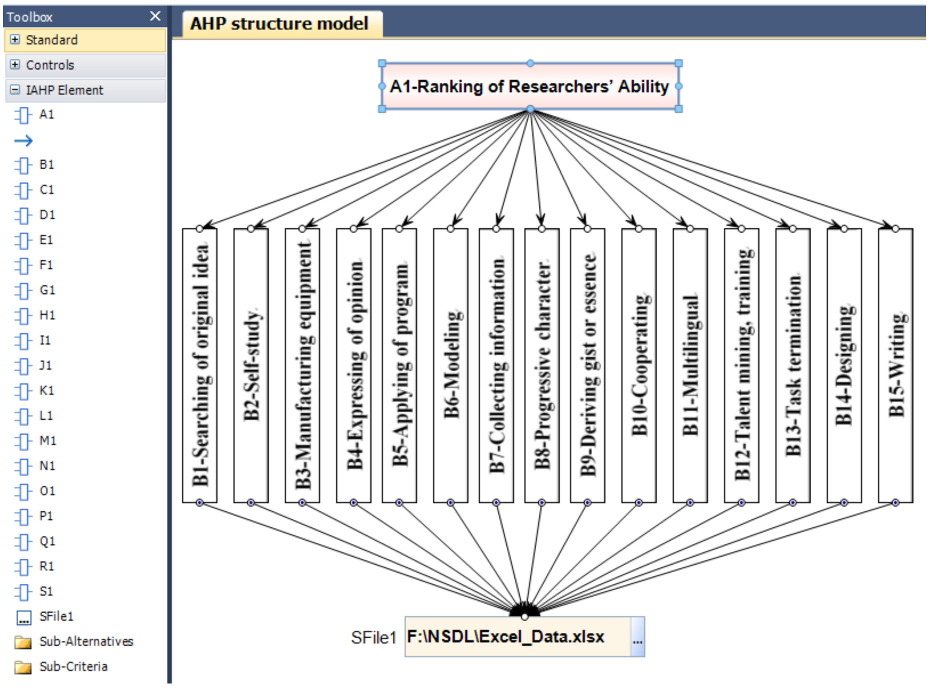

Figure 9. AHP structural model with SFile element.

The incidence table is generated from AHP structural model automatically as shown in Table 1.

Table 1. Incidence table generated from AHP structural model.

№	A1	B1	B2	B3	B4	B5	B6	B7	B8	B9	B10	B11	B12	B13	B14	B15
1	B1	S1	S1	S1	S1	S1	S1	S1	S1	S1	S1	S1	S1	S1	S1	S1
2	B2	S2	S2	S2	S2	S2	S2	S2	S2	S2	S2	S2	S2	S2	S2	S2
3	B3	S3	S3	S3	S3	S3	S3	S3	S3	S3	S3	S3	S3	S3	S3	S3
…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…
14	B14	S14	S14	S14	S14	S14	S14	S14	S14	S14	S14	S14	S14	S14	S14	S14
15	B15	S15	S15	S15	S15	S15	S15	S15	S15	S15	S15	S15	S15	S15	S15	S15
16		S16	S16	S16	S16	S16	S16	S16	S16	S16	S16	S16	S16	S16	S16	S16
17		S17	S17	S17	S17	S17	S17	S17	S17	S17	S17	S17	S17	S17	S17	S17
…		…	…	…	…	…	…	…	…	…	…	…	…	…	…	…
35		S35	S35	S35	S35	S35	S35	S35	S35	S35	S35	S35	S35	S35	S35	S35
36		S36	S36	S36	S36	S36	S36	S36	S36	S36	S36	S36	S36	S36	S36	S36
37		S37	S37	S37	S37	S37	S37	S37	S37	S37	S37	S37	S37	S37	S37	S37

3.2.2. Evaluation of Qualitative Criteria

Based on incidence table, the following AHP algorithm is constructed by VB language of NSDL.

Step 1: Judgment Matrix Construction

When AHP diagram is constructed, judgment matrix to reflect expert's subjective assessment is made. The judgment matrix may be made by comparison table.

Table 2. *Meaning of Comparison Values.*

Comparison value	Meaning
1	Equally importance
3	Moderately importance
5	Strongly importance
7	Very strongly importance
9	Extreme importance
2, 4, 6, 8	Intermediate values

Step 2: Calculation of the weight by geometric average

1) Calculate the product $M_i = \prod_{j=1}^{n} a_{ij}, i = \overline{1,n}$ of the elements of each row of judgment matrix A.

2) Calculate the n^th square root $\overline{w}_i = \sqrt[n]{M_i}$ of M_i.

3) Calculate the weight by normalizing vector $\overline{W} = [\overline{w}_1, \overline{w}_2, ..., \overline{w}_n]^T$.

$$w_i = \frac{\overline{w}_i}{\sum_{j=1}^{n} \overline{w}_j} \tag{2}$$

where $W = [w_1, w_2, ..., w_n]^T$ is an eigenvector.

Step 3: Consistency

The validity of the judgment matrix is determined by the *CI* (Consistency Index).

$$CI = \frac{\lambda_{\max} - n}{n - 1} \tag{3}$$

The consistency of the judgment matrix is determined by the average random consistency ratio.

If CI doesn't satisfy the following condition, though it is less than 0.1, must check the judgment matrix again.

$$CR = \frac{CI}{RI} \le 0.1 \sim 0.15 \tag{4}$$

Table 3. *Random Consistency Index.*

n	2	3	4	5	6	7	8	9	10	11	12
$R.I$	0	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.49	1.51	1.53

Comparative judgment matrices for qualitative criteria are made by experts. For example, Judgment matrix for goal A1 is shown in Table 4.

Table 4. *Judgment matrix for goal A1.*

A1	B1	B2	B3	B4	B5	…	B10	B11	B12	B13	B14	B15	Weight
B1	1	3	7	6	2	…	3	5	8	5	7	9	0.1772
B2	0.333	1	5	4	0.5	…	1	3	6	3	5	7	0.0866
B3	0.1428	0.2	1	0.5	0.1667	…	0.2	0.333	2	0.333	1	3	0.0181
B4	0.1667	0.25	2	1	0.2	…	0.25	0.5	3	0.5	2	4	0.0259
B5	0.5	2	6	5	1	…	2	4	7	4	6	8	0.1270

A1	B1	B2	B3	B4	B5	…	B10	B11	B12	B13	B14	B15	Weight
B6	0.333	1	5	4	0.5	…	1	3	6	3	5	7	0.0866
B7	0.2	0.333	3	2	0.25	…	0.333	1	4	1	3	5	0.0387
B8	0.25	0.5	4	3	0.333	…	0.5	2	5	2	4	6	0.0579
B9	1	3	7	6	2	…	3	5	8	5	7	9	0.1772
B10	0.333	1	5	4	0.5	…	1	3	6	3	5	7	0.0866
B11	0.2	0.333	3	2	0.25	…	0.333	1	4	1	3	5	0.0387
B12	0.125	0.1667	0.5	0.333	0.1429	…	0.1667	0.25	1	0.25	0.5	2	0.0130
B13	0.2	0.333	3	2	0.25	…	0.333	1	4	1	3	5	0.0387
B14	0.1429	0.2	1	0.5	0.1667	…	0.2	0.333	2	0.333	1	3	0.0181
B15	0.1111	0.1429	0.333	0.25	0.125	…	0.1429	0.2	0.5	0.2	0.333	1	0.0098

3.2.3. Evaluation of Quantitative Criteria

The quantitative criteria may be normalized by simple, max/min and sigmoid method according to the user's requirement. The Excel data file for 37 researchers indicated in SFile is shown in Table 5.

Table 5*. Public assessment marks for 37 researchers.*

Assessment method	《Very High: 30, High: 20, Middle: 10, Low: 5》must be chosen only one mark for all researchers.															
№	**Name**	**B1**	**B2**	**B3**	**B4**	**B5**	**B6**	**B7**	**B8**	**B9**	**B10**	**B11**	**B12**	**B13**	**B14**	**B15**
1	Cha Chol Ho	30	20	30	30	20	20	30	20	30	20	30	30	30	20	30
2	William	20	30	30	20	20	30	20	30	20	30	20	30	20	30	30
…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…
36	Ri Kum Song	10	10	10	10	10	10	10	20	10	10	20	5	10	5	10
37	Marie	10	10	10	10	10	10	10	10	10	10	20	5	10	5	10

3.2.4. Evaluation Total Weight

The results are analyzed from the overall data. The results are as follows.

Table 6*. Summary of Results.*

Goal	B- Criteria Layer		S– Alternative Layer		Ranking
	Criteria	**Weight**	**Alternatives**	**Weight**	
A1- Assessment of Researchers' Ability	B1-Searching of original idea	0.1771915	S12- K. H. Choe	0.0389	1
			S3- S. H. Han	0.0385	2
			S13- David	0.0379	3
	B2-Self-study	0.0866958	S28- R. H. Kim	0.0377	4

Goal	B- Criteria Layer		S– Alternative Layer		Ranking
	Criteria	Weight	Alternatives	Weight	
			S7- Köster	0.0368	5
			S8- K. J. Jon	0.0364	6
			S16- Vörös	0.0361	7
	B3-Manufacturing equipment	0.0180524	S4- K. C. Jong	0.0359	8
			S5- U. I. Ri	0.0348	9
			S1- C. H. Cha	0.0346	10
	B4-Expressing of opinion	0.0259385	S6- Y. M. Pak	0.0344	11
			S26- S. K. Jo	0.034	12
			S21- O. C. Choe	0.0331	13
	B5-Applying of program	0.1270065	S24- John	0.0329	14
			S2- William	0.0328	15
	B6-Modeling	0.0866958	S32- J. H. Kim	0.0328	16
			S15- J. Y. Ra	0.0265	17
	B7-Collecting information	0.0385686	S33- Henry	0.0264	18
			S9- D. H. Ryu1	0.0253	19
	B8-Progressive character	0.0579582	S10- Kare	0.025	20
			S11- Marcio	0.0229	21
	B9-Deriving gist or essence	0.1771915	S14- Cha Ming Hong	0.0229	22
			S18- Dzakiyah	0.0225	23
	B10-Cooperating	0.0866958	S17- Karolina	0.0225	24
			S22- S. M. Ju	0.0221	25
	B11-Multilingual	0.0385686	S25- U. C. Cheo	0.0209	26
			S27- Reisig	0.0208	27
	B12-Talent mining, training	0.0129829	S19- Dawid	0.0206	28
			S31-H. S. Kim	0.0201	29
			S20- D. H. Ryu 3	0.0198	30
	B13-Task termination	0.0385686	S23- J. S. Ri	0.0194	31
			S29- M. S. Kang	0.0188	32
			S30- David	0.0181	33
	B14-Designing	0.0180524	S35- K. H. Pak	0.0155	34
			S36- Ri Kum Song	0.0146	35
	B15-Writing	0.0098331	S34- C. Han	0.0141	36
			S37- Marie	0.0138	37

As shown in the Table 6, IAHP can be solved for AHP problem having so many alternatives.

4. Conclusion

In this paper, we discussed about method to assess the researchers' abilities of scientific research institution intuitively and conveniently by using IAHP in the NSDL environment.

In the IAHP tool proposed, the hierarchical structure model can be constructed in Petri nets diagram in NSDL environment to improve the intuition and convenience of modeling.

With the introduction of File Alternative Element (SFile), AHP structural model can be constructed more conveniently, simply and effectively in the case of so many alternatives.

Abbreviations

IAHP	Integrated Analytical Hierarchy Process
NSDL	Net-oriented System Description Language
VB	Visual Basic
GUI	Graphical User Interface
FIFO	First-In First-Out

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Conflicts of Interest

The authors declare no conflicts of interest.

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