Benefit/cost AHP optimized over sample set of pairwise comparison judgments

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Summary: *A new AHP evaluation framework, benefit/cost AHP optimized for each alternative over a sample evaluator set of pairwise comparison judgments for benefit criteria and cost criteria, is proposed. With this new AHP framework, we take an evaluation standpoint of evaluating an alternative as high as possible in the benefit/cost score over the sample set of pairwise comparison matrixes, identifying whether or not the alternative belong to the frontier set, and measuring relative distance from the alternative to the frontier set in case the alternative dose not belong to the frontier set. An Excel spreadsheet software is constructed and is applied to two example decision making instances, teachers evaluating students' capability and high school students choosing university departments.*

１．Introduction

A new AHP-based group decision making framework is proposed, where not only relative positioning of each alternative in terms of benefit/cost efficiency, but also relative positioning of each evaluator in priority weight space of criterion, can be estimated. Benefit criteria and cost criteria are considered, and pairwise comparison judgments among benefit criteria and among cost criteria are asked to each group member (evaluator). Pairwise comparison judgments among alternatives from the viewpoint of each criterion are also asked, if necessary. This group decision making framework aims at providing relative positioning of both alternatives and evaluators, instead at providing one unique group decision. For each alternative, absolute benefit/cost efficiency is calculated for every evaluator, and then, relative benefit/cost efficiency is calculated from the absolute efficiency values. Supporter set, or the set of evaluators supporting an alternative, and neighboring alternative set to the alternative, are also identified. For each evaluator, the set of alternatives supported by the evaluator and the set of evaluators adjacent to the evaluator are identified. It is interesting to notice that for each evaluator there exists at least one alternative whose relative efficiency value is *1.0*.

Proposed evaluation framework is explained in Chapter 2 and its Excel spreadsheet software is outlined in Chapter 3. In Chapter 4, this spreadsheet software is applied to two example problems: the first is a 1-input 2-output 10-alternative(student) 6-evaluator(teacher) example and the second is a 3-input 3-output 3-alternative (university department) 20-evaluator(high school student) example.

2 . Proposal of new group decision making framework

2.1 Benefit/cost AHP

A group decision making environment with *Ne* evaluators and *Na* alternatives is considered. Each alternative has *Nb* benefit criteria and *Nc* cost criteria. Each evaluator independently makes benefit/cost AHP-type decision to the alternatives, that is, performs pairwise comparison judgments among within benefit criteria and within cost criteria, and further, from the viewpoint of each criterion the evaluator performs pairwise comparison judgments among alternatives(see *Fig.1*).

2.2 Measurement of pairwise comparison matrixes

Following pairwise comparison matrixes are measured for evaluator $k(=1,2,\ldots,\mathrm{Ne})$.

$\mathrm{A}_{g-b}(k)$: $Nb \times Nb$ pairwise comparison measurement matrix among benefit criteria by evaluator k from the viewpoint of the goal.

$\mathrm{A}_{g-c}(k)$: $Nc \times Nc$ pairwise comparison measurement matrix among cost criteria by evaluator k from the viewpoint of the goal.

$\mathrm{A}_{b(i)-a}(k)$: $Na \times Na$ pairwise comparison measurement matrix among alternatives by evaluator k from the viewpoint of benefit criterion i (=*1,2,…,Nb*).

$\mathrm{A}_{c(i)-a}(k)$: $Na \times Na$ pairwise comparison measurement matrix among alternatives by evaluator k from the viewpoint of cost criterion i (=*1,2,…,Nc*).

2.3 Estimation of priority weight

Following priority weight vectors are derived from the pairwise comparison measurement matrixes in Sec. 2.2.

$\mathrm{W}_b(k)$: $1 \times Nb$ priority weight vector for benefit criteria by evaluator k, or transposed right-principal-eigenvector of $\mathrm{A}_{g-b}(k)$.

$\mathrm{W}_c(k)$: $1 \times Nc$ priority weight vector for cost criteria by evaluator k, or transposed right-principal-eigenvector of $\mathrm{A}_{g-c}(k)$.

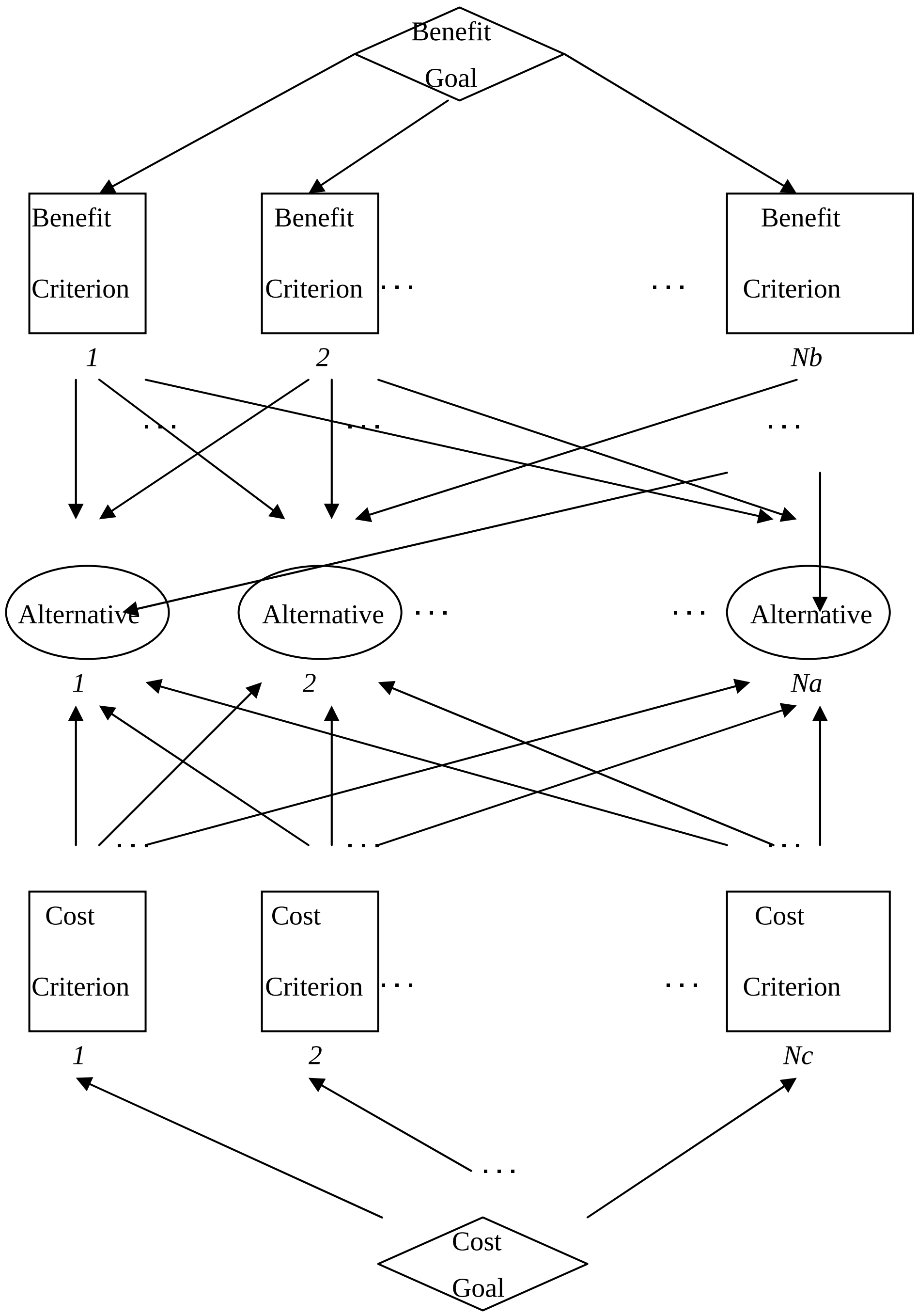

Fig.1 Benefit/cost AHP diagram

$W_{b(i)-a}(k)$: *1×Na* priority weight vector for alternatives by evaluator k from benefit criterion

i (=*1,2,…,Nb*), or transposed right-principal-eigenvector of $A_{b(i)-a}(k)$.

$W_{c(i)-a}(k)$: *1×Na* priority weight vector for alternatives by evaluator k from cost criterion

i (=*1,2,…,Nc*), or transposed right-principal-eigenvector of $A_{c(i)-a}(k)$.

Each priority weight vector is normalized so that the sum of all the elements in a vector is 1. Their associated consistency indexes are also derived, and they are named in a similar way, such as by $CI_b(k)$, $CI_c(k)$, $CI_{b(i)-a}(k)$ and $CI_{c(i)-a}(k)$.

From $W_{b(i)-a}(k)$(i =*1,2,…,Nb*), following *Nb×Na* matrix is constructed.

$$W_{b-a}(k)=\begin{bmatrix} W_{b(1)-a}(k) \\ W_{b(2)-a}(k) \\ \vdots \\ W_{b(\mathrm{Nb})-a}(k) \end{bmatrix} \tag{1}$$

From $W_{c(i)-a}(k)$(i =*1,2,…,Nc*), following *Nc×Na* matrix is constructed.

$$W_{c-a}(k)=\begin{bmatrix} W_{c(1)-a}(k) \\ W_{c(2)-a}(k) \\ \vdots \\ W_{c(\mathrm{Nc})-a}(k) \end{bmatrix} \tag{2}$$

Then, *1×Na* benefit-side integrated priority weight vector for alternatives by evaluator k, $W_{ba}(k)$, is evaluated by Eq.(3).

$$W_{ba}(k)=W_b(k)\cdot W_{b-a}(k) \tag{3}$$

Similarly, *1×Na* cost-side integrated priority weight vector for alternatives by evaluator k, $W_{ca}(k)$, is evaluated by Eq.(4).

$$W_{ca}(k)=W_c(k)\cdot W_{c-a}(k) \tag{4}$$

2.4 Absolute efficiency and relative efficiency

Let's denote the i th element of $W_{ba}(k)$ by $W_{ba}(k)[i]$, which is the benefit-side integrated priority weight for alternative i by evaluator k. Similarly, $W_{ca}(k)[i]$ is defined. Then, the benefit/cost ratio for alternative i by evaluator k, $W_{b/c}(k)[i]$, is defined by Eq.(5).

$$W_{b/c}(k)[i] = W_{ba}(k)[i] / W_{ca}(k)[i] \quad (5)$$

$$W_{b/c}(k) = \{ W_{b/c}(k)[i] \} \quad (6)$$

Its $1 \times Na$ vector is denoted by $W_{b/c}(k)$ as in Eq.(6). We call this vector $W_{b/c}(k)$, absolute efficiency vector by evaluator k, in the sense that 'benefit divided by cost' is a kind of efficiency measure and the measure is *relatively* absolute when compared to $1 \times Na$ relative efficiency measure E(k) defined next by Eq.(7). The i *th* element of relative efficiency vector E(k) is given by Eq.(7), which means the absolute efficiency of alternative i divided by the largest absolute efficiency among alternatives.

$$E(k)[i] = W_{b/c}(k)[i] / \max_{j} \{ W_{b/c}(k)[j] \} \quad (7)$$

The value of E(k)[i] can take between 0 and 1. When E(k)[i]=1, alternative i is evaluated the highest among the alternatives by evaluator k and alternative i is on the efficient frontier of evaluator k, and when E(k)[i]< 1, alternative i is evaluated not the highest among the alternatives by evaluator k and its value E(k)[i] shows the degree of discrepancy from the frontier.

2.5 Maximum relative efficiency over evaluator group

E(k) is $1 \times Na$ relative efficiency vector by evaluator k and at least one element of the vector takes *1*, which means that for every evaluator there is at least one alternative whose relative efficiency is *1*. In general, E(G), $1 \times Na$ efficiency vector over the evaluator group G, can be expressed as in Eq.(8).

$$E(G) = F(E(1), E(2), \ldots, E(Ne)) \quad (8)$$

Here, E(G) is expressed by some function F of E(*1*), E(*2*),…, and E(*Ne*), which is a general formula for group decision making. More specifically, in this paper, we try to evaluate each alternative as high as possible over the evaluator group G. If an alternative is evaluated as its relative efficiency =1.0 even by one evaluator, the alternative is considered on the top frontier. That is, we take the highest relative efficiency value of an alternative among the evaluators as its group decision

judgment.
Therefore, the i th element of E(G), E(G) [i], is defined by Eq.(9).

$$E(G)[i]=\max\{E(1)[i], E(2)[i],\ldots,E(Ne)[i]\} \qquad i=1,2,\ldots,Na \qquad (9)$$

Finally, E(G), $1\times Na$ relative efficiency vector over the evaluator group G, is defined by Eq.(10), where G={$1,2,\ldots,Ne$}.

$$E_{max}(G)=\left(\max_{k\in G} E(k)[1],\ \max_{k\in G} E(k)[2], \ldots, \max_{k\in G} E(k)[i], \ldots, \max_{k\in G} E(k)[\mathrm{Na}]\right) \qquad (10)$$

We call this vector as 'maximum relative efficiency vector over evaluator group G', and is denoted by E_{max}(G) as in Eq.(10).

2.6 Consistency measure for E_{max}(G)

For each element of the maximum relative efficiency vector E_{max}(G), say for the i th element, there exists at least one evaluator who supports the value of $\max_{k\in G} E(k)[i]$. Supporter set for alternative i, S(i), is defined by Eq.(11).

$$S(i)=\{\arg\max_{k\in G} E(k)[i]\} \qquad (11)$$

Then, the consistency index set for alternative i associated with the maximum relative efficiency vector E_{max}(G), CI(i), is given by Eq.(12).

$$CI(i)=\left\{CI_{B/C}(k) \,\middle|\, k \in S(i)\right\} \qquad (12)$$

$$CI_{B/C}(k)=\left(0.5\sqrt{CI_{Benefit}(k)}+0.5\sqrt{CI_{Cost}(k)}\right)^2 \qquad (13)$$

$$CI_{Benefit}(k)=\left(\sqrt{CI_b(k)}+\sum_{i=1}^{Nb} W_b(k)[i]\cdot\sqrt{CI_{b(i)-a}(k)}\right)^2 \qquad (14)$$

$$CI_{Cost}(k)=\left(\sqrt{CI_c(k)}+\sum_{i=1}^{Nc} W_c(k)[i]\cdot\sqrt{CI_{c(i)-a}(k)}\right)^2 \qquad (15)$$

Here, CI(i) is the set of CI's for the whole benefit/cost AHP decision making by the evaluators belonging to supporter set S(i). Here, $CI_{B/C}(k)$, the consistency measure for the whole AHP decision making by evaluator k, is estimated by the square root formula [3]. Essentially, CI(i) is the set of CIs by evaluators belonging to supporter set S(i), and if a single scalar CI is needed, you can take their arithmetic mean as by Eq.(16).

$$\mathrm{CI}_{mean}(i) = \frac{1}{|\mathrm{S}(i)|}\sum_{k \in \mathrm{S}(i)} \mathrm{CI}_{\mathrm{B/C}}(k) \tag{16}$$

3. Spreadsheet software

Excel spreadsheet software is constructed for performing the proposed evaluation. All the processings are done on the sheet and no internal stored processing is required. Input data, intermediate data and output data are listed in Table 1.

Table 1 Input data, intermediate data and output data

Input data	・ Pairwise comparison matrixes: $\{\mathrm{A}_{g-b}(k), \mathrm{A}_{g-c}(k), \{\mathrm{A}_{b(i)-a}(k); i=1,..,\mathrm{Nb}\}, \{\mathrm{A}_{\mathrm{c(i)}-a}(k); i=1,..,\mathrm{Nc}\}; k=1,..,\mathrm{Ne}\}$
Intermediate data	・ Priority weight vectors: $\{\mathrm{W}_b(k), \mathrm{W}_c(k), \{\mathrm{W}_{b(i)-a}(k); i=1,..,\mathrm{Nb}\}, \{\mathrm{W}_{\mathrm{c(i)}-a}(k); i=1,..,\mathrm{Nc}\}; k=1,..,\mathrm{Ne}\}$ ・ Consistency indexes: $\{\mathrm{CI}_b(k), \mathrm{CI}_c(k), \{\mathrm{CI}_{b(i)-a}(k); i=1,..,\mathrm{Nb}\}, \{\mathrm{CI}_{\mathrm{c(i)}-a}(k); i=1,..,\mathrm{Nc}\}; k=1,..,\mathrm{Ne}\}$ ・ Absolute efficiency vectors: $\{\mathrm{W}_{\mathrm{b/c}}(k); k=1,..,\mathrm{Ne}\}$ ・ Relative efficiency vectors: $\{\mathrm{E}(k); k=1,..,\mathrm{Ne}\}$
Output data	・ Maximum relative efficiency vector over G: $\mathrm{E}_{\mathrm{max}}(\mathrm{G})$ ・ Supporter sets: $\{\mathrm{S}(i); i=1,..,\mathrm{Na}\}$ ・ Consistency index sets: $\{\mathrm{CI}(i); i=1,..,\mathrm{Na}\}$ ・ Arithmetic mean CI: $\{\mathrm{CI}_{\mathrm{mean}}(i); i=1,..,\mathrm{Na}\}$

4. Application examples of proposed evaluation scheme

The proposed evaluation scheme is applied to two example decision making instances. In both applications, the spreadsheet software is used to calculate the output data. The first example is teachers evaluating students' capability in mathematics and science, which took place when selecting the most excellent student. Only two benefit criteria, mathematics score and science score, are considered, and hence the evaluation framework is very simplified and specialized. The second example is high school students choosing university departments, which took place when high school students have been admitted to enter a university but still have right of choosing departments; Twenty high school students are evaluating three university departments from the viewpoint of three benefit criteria and three cost criteria.

4.1 1-input 2-output 10-alternative 6-evaluator example (Example 1)

Ten students(alternatives) are evaluated by six teachers(evaluator) in two subject scores, mathematics and science. Scores in mathematics and science for the ten students and teacher-dependent priority weight vector on the two subjects are given data. This example is too simple to follow the formal input, intermediate and output data listed in Table 1. All the pairwise comparison judgments in the list of input data is omitted and priority weight vectors in the list of intermediate data are given directly (see Table 2 and Table 3).

Table 2 Students' scores of math and science in Example 1

Student(alternative) No	1	2	3	4	5	6	7	8	9	10
INPUT	1	1	1	1	1	1	1	1	1	1
OUTPUT1(Math score)	7	9	3	9	6	5	10	8	5	6
OUTPUT2(Science score)	8	5	8	7	7	9	7	6	8	9
Normalized OUTPUT1	0.1	0.13	0.04	0.13	0.09	0.07	0.15	0.12	0.07	0.09
Normalized OUTPUT2	0.11	0.07	0.11	0.09	0.09	0.12	0.09	0.08	0.11	0.12

Table 3 Teachers' priority weight on math and science in Example 1

	Priority weight on subjects		Neighbor evaluators within distance d=0.3
	Math	Science	
Teacher 1	0.5	0.5	4,6
Teacher 2	0.8	0.2	3,6

Teacher 3	0.9	0.1	2
Teacher 4	0.3	0.7	1,5
Teacher 5	0.2	0.8	4
Teacher 6	0.6	0.4	1,2

In Table 2, the input item means cost criterion and the output item means benefit criterion. Since no cost criterion is considered, all the input item data for the ten students are set equally at 1, suggesting their existence. All the output scores(raw data) range from 1 to 10. Since the subject scores are objective data, they do not depend on evaluators and hence suffix k (meaning evaluator k) is omitted in Table 2. Since the sum of output1 data and the sum of output2 data are different, output data values are normalized so that each row sum is equal to 1.0. In Table 3, his/her neighboring teachers are also shown for each teacher.

Since priority weight vectors are given priori, all the consistency indexes are 0. Absolute efficiency vectors for the six teachers $\{\mathrm{W}_{b/c}(k); k = 1,..,6\}$ are shown next.

Table 4 Absolute efficiency vectors in Example 1

Student No	1	2	3	4	5	6	7	8	9	10
Teacher 1	0.106	0.100	0.076	0.113	0.091	0.098	0.121	0.099	0.091	0.105
Teacher 2	0.104	0.119	0.057	0.125	0.090	0.083	0.137	0.110	0.080	0.095
Teacher 3	0.103	0.126	0.051	0.129	0.089	0.078	0.142	0.114	0.077	0.092
Teacher 4	0.107	0.087	0.089	0.106	0.093	0.107	0.110	0.092	0.098	0.112
Teacher 5	0.107	0.081	0.095	0.102	0.093	0.112	0.105	0.088	0.101	0.115
Teacher 6	0.105	0.106	0.070	0.117	0.091	0.093	0.126	0.103	0.087	0.102

Table 5 shows the relative efficiency vectors(REVs) for the six teachers $\{\mathrm{E}(k); k = 1,..,6\}$, the maximum relative efficiency vector over the group G of the six teachers(Max REV over G)E_{max}(G), and the supporter sets for the ten students $\{\mathrm{S}(i); i = 1,..,10\}$. The arithmetic mean relative efficiency vector averaged over the group G(Ave REV over G), E_{mean}(G), which is defined by Eq.(17), is also shown in Table 5.

$$\mathrm{E}_{mean}(\mathrm{G}) = \left(\frac{1}{Ne}\sum_{k\in G} E(k)[1], \frac{1}{Ne}\sum_{k\in G} E(k)[2], \ldots, \frac{1}{Ne}\sum_{K\in G} E(k)[Nd] \right) \qquad (17)$$

Table 5 Relative efficiency vectors in Example 1

Student No	1	2	3	4	5	6	7	8	9	10
Teacher 1 REV	0.873	0.827	0.63	0.939	0.757	0.808	1	0.822	0.752	0.868
Teacher 2 REV	0.761	0.874	0.417	0.914	0.655	0.609	1	0.808	0.589	0.695
Teacher 3 REV	0.73	0.888	0.356	0.907	0.627	0.552	1	0.804	0.543	0.646
Teacher 4 REV	0.955	0.78	0.797	0.949	0.83	0.96	0.989	0.825	0.876	1
Teacher 5 REV	0.932	0.701	0.829	0.889	0.812	0.974	0.914	0.769	0.88	1
Teacher 6 REV	0.833	0.844	0.553	0.93	0.72	0.736	1	0.817	0.693	0.806
Max REV over G	0.955	0.888	0.829	0.949	0.83	0.974	1	0.825	0.88	1
Supporter Set	4	3	5	4	4	5	1,2,3,6	4	5	4,5
Ave REV over G	0.847	0.819	0.597	0.921	0.734	0.773	0.984	0.808	0.722	0.836

Student No.7 is on the frontier supported by four teachers as well as has the highest average efficiency while Student No.10 is also on the frontier supported by two teachers but his/her average efficiency is not so high.

4.2 3-input 3-output 3-alternative 20-evaluator example (Example 2)

Three selected departments of a university are evaluated by twenty high school students from viewpoints of three cost criteria(3-input) and three benefit criteria(3-output). The three are Mechanical(ME), Architectural(AR), and Mathematical Information(MI) departments. The three cost criteria are: economical burden necessary for completing study course(EB), physical burden necessary for completing study course(PB), and mental burden for completing study course(MB). The three benefit criteria are: field of interest(FI), occupational opportunity(OO), and brand image(BI). Each of the twenty high school students is asked which cost criterion is how much important in choosing college departments, which benefit criterion is how much important and which department is how much effective from the viewpoint of each criterion. All the questions asked are in the form of pairwise comparison. As a result, we have two 3×3 pairwise comparison measurement matrixes, $\mathrm{A}_{g-b}(k)$ and $\mathrm{A}_{g-c}(k)$, and six 3×3 pairwise comparison measurement matrixes, $\{\mathrm{A}_{b(i)-a}(k); i=1,2,3\}$ and $\{\mathrm{A}_{c(i)-a}(k); i=1,2,3\}$, for each of the twenty high school students (or evaluator k). One hundred and sixty(=(2+6)×20) pairwise comparison measurement matrixes in total are the input data in Table 1. From these input data, all the intermediate data of Table 1, such as priority weight vectors, consistency indexes, etc., are calculated by the spreadsheet software. All the output data of Table 1 are also calculated by the spreadsheet software.

Table 6 shows the summary sheet of pairwise comparison measurement matrixes and calculated priority weight(PW) vectors and CIs for evaluator 1(high school student No.1).

Table 6 Pairwise comparison measurement matrixes for evaluator 1

among 3 cost-criteria			PW	among 3 benefit-criteria			PW
1	2	6	0.6	1	1	1	0.333
0.5	1	3	0.3	1	1	1	0.333
0.167	0.333	1	0.1	1	1	1	0.333
CI=	0			CI=	0		

among 3 alts from C1			PW	among 3 alts from C2			PW	among 3 alts from C3			PW
1	0.5	0.5	0.2	1	1	0.5	0.26	1	0.5	0.5	0.2
2	1	1	0.4	1	1	1	0.327	2	1	1	0.4
2	1	1	0.4	2	1	1	0.413	2	1	1	0.4
CI=	0			CI=	0.027			CI=	0		

among 3 alts from B1			PW	among 3 alts from B2			PW	among 3 alts from B3			PW
1	0.5	1	0.26	1	0.5	1	0.26	1	1	1	0.327
2	1	1	0.413	2	1	1	0.413	1	1	2	0.413
1	1	1	0.327	1	1	1	0.327	1	0.5	1	0.26
CI=	0.027			CI=	0.027			CI=	0.027		

Table 7 shows the relative efficiency vectors for the twenty high school students $\{\mathrm{E}(k); k=1,..,20\}$. The maximum relative efficiency vector over the group G of the twenty high school students E_{max}(G), the supporter sets for the three departments $\{\mathrm{S}(i); i=1,2,3\}$, the arithmetic mean CI averaged over each supporter set $\{\mathrm{CI}_{mean}(i); i=1,.., \mathrm{Na}\}$, and the neighbor evaluator set within priority weight distance d=0.2 are also shown in Table 7, where the priority weight distance between evaluator k_1 and evaluator k_2 is defined by $|\mathrm{W}_b(k_1) - \mathrm{W}_b(k_2)|_2 + |\mathrm{W}_c(k_1) - \mathrm{W}_c(k_2)|_2$, the sum of Euclidean distance between two benefit criterion priority weight vectors and Euclidean distance between two cost criterion priority weight vectors.

Table 7 Relative efficiency vectors for the twenty high school students

High School Student No	Relative Efficiency Vectors(REVs)			Neighbor evaluators within distance 0.2
	ME	AR	MI	
HSS 1	1	0.984587	0.9919506	11,13,19
HSS 2	0.727692	0.9384	1	4,12,14,20
HSS 3	0.765132	1	0.8297771	
HSS 4	0.811404	0.807238	1	2,12,14,20
HSS 5	0.98045	1	0.9626236	17
HSS 6	1	0.950317	0.8915642	
HSS 7	0.905354	0.876001	1	
HSS 8	1	0.955432	0.9086382	
HSS 9	0.992283	1	0.9710946	13
HSS 10	0.968987	1	0.9471533	15,16
HSS 11	0.800244	0.962743	1	1,13,19
HSS 12	0.889772	0.89095	1	2,4,20
HSS 13	0.896665	1	0.8242229	1,9,11,19
HSS 14	1	0.990922	0.973329	2,4
HSS 15	0.771126	0.884502	1	10,16
HSS 16	1	0.982797	0.9599579	10,15
HSS 17	0.962173	0.8652	1	5
HSS 18	0.889381	1	0.9418619	
HSS 19	0.904632	0.660671	1	1,11,13
HSS 20	1	0.862457	0.9079001	2,4,12
Ave REV	0.913265	0.930611	0.9555037	
Max REV	1	1	1	
Supporter set	1,6,8,14,16,20	3,5,9,10,13,18	2,4,7,11,12,15,17,19	
Ave CI	0.235482	0.146615	0.1188706	

Since the number of alternatives is very small, the maximum relative efficiency vector $E_{max}(G)$ consists of only *1*'s. That is, there is no difference among the three departments in the maximum relative efficiency. But a significant difference is found among the three in the average relative efficiency. Supporters of a department can be interpreted as promising enrollees in the department. It is interesting to notice that logical consistency for the high school students choosing Mathematical Information(MI) department is high(AveCI=0.119) and that for the high school students choosing

Mechanical(ME) department is low(AveCI=0.235).

5. Conclusion

A new AHP evaluation framework is proposed. Its Excel spreadsheet software is constructed and is applied to two example decision making instances. With this new AHP framework, we take an evaluation standpoint of evaluating an alternative as high as possible in the benefit/cost score over the sample set of pairwise comparison matrixes (self-justification). This evaluatin framework based on the self-justification can be regarded same as that of DEA (Data Envelopment Analysis). If $\mathrm{W}_{b-a}(k)$ of (1) and $\mathrm{W}_{c-a}(k)$ of (2) are given as data which do not depend on evaluators, and $\mathrm{W}_{b}(k)$ and $\mathrm{W}_{c}(k)$ are given directly instead from pairwise comparison matrixes, the proposed benefit/cost AHP evaluation framework has the same structure as that of discrete scored DEA [4].

Evaluation frameworks whose group optimization is not based on the self-justification are future research subjects.

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