Application of the AHP to the Evaluation of bidders of Hydraulic Resources Capital Construction

Wan Yaojun

Capital Construction Management Department, Tianjin Hydraulic Resources Bureau

ABSTRACT

In this paper the method of the evaluation of bidders of hydraulic resources capital construction using the AHP is presented. It sets up a Hierarchy Structure Model of evaluation of bidders and derives the priority vectors of each level. The calculating formula of the preference of synthetical evaluating bidders is proposed and the above method is illustrated in this paper.

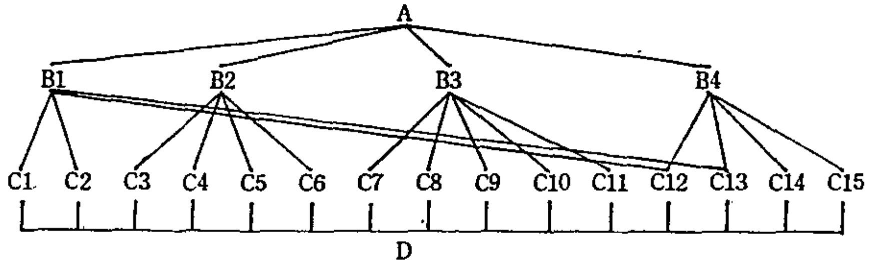
I. Introduction

It is a significant reform of construction industy and capital construction to devote the major efforts to carry out the Responsibility System under tendering contract of project and draw competitive mechanism into the area of construction. The practice that capital construction carries out the Responsibility System under tendering contract has proved that it is a effective measure of strengthening management and administration, shortening time limit for a project, guaranteeing construction quality, cutting down construction cost and enhancing the economic bedeficency to construction. The State Concil has proclaimed that every project within the state plan except specific projects can not start until the best unit is chosen by means of inviting tender.

The evaluation of bidders is an important thing of the Responsibility System under tendering contract. Its work is that the concrete substance of each bidders' correspondence will be checked up thoroughly and given comments and finally one of the units will be chosen by committee (or group) of the evaluation of bidders. It is that within the framework of reasonable market price (according as basis of market price or so) we assess candidate of unit chosen beginning with studying the rationality of construction scheme and feasibility of measures on guaranteeing construction quality and time limit for a project, then sythetically appraise rank's quality, engineering level and social prestige, etc of that, and determine the optimum unit to be chosen. Only the method of qualitative analysis used in evaluation of bidders is hard to avoid biased because each has his strong points of bidders and respective prejudice of committee (or group) is different. Consequently, it is a subject of merit study to provide a scientific and rational evaluation method. In this paper the method of the evaluation of bidders using the AHP is presented. proceeding from systematic viewpoint, it sets up a Hierarchy Structure Model of the evaluation of bidders; it derives the priority vectors of each level; then it makes a synthetical appraisal of biddrs. It makes qualitative analysis associated with quantitative analysis, which provides basis for scientific decision making.

II. A Hierarchy Structure Model of the evaluation of bidders

We must consider multitudinous influence factors such as market price, time limit for a project and the guarantee of construction quality when appraising each of bidders. If relations between those factors are properly arranged and those are classfied a certain number of relative ordered hierarchy according to their importance, which can make original complicated problem analyze step by step on the hierarchy to be much simpler than one. A subjective judgement of people is expressed and handled in numerial forms through pairwise comparisons between factors and correctness of the solution derived is judged by consistency test, hence the priority vectors of relative importance of all factor in each level is determined. That is the basic principle of the AHP. It incamates distinguishing feature of hierarchy for people's decision thinking, i.e. analysis, judgement and synthesis, which is a practical and handy method for Multiple Criteria Decision Making.
This paper built the Hirearchy Structure Model of the evaluation of bidders(Figure 1). It consists of four levels:



A : preference of the evaluation of bidders.
B1: economic beneficency; B2: engineering level;
B3: construction seniority and prestige; B4: other additional conditions.
C1: market price; C2: time limit for a project; C3: technological strength;
C4: construction equipment; C5: measure of guarateeing quality; C6: rationality of job practice;
C7: technological grade; C8: fulfil prestige; C9: limits of undertaking job;
C10: capacity for claim property; C11: quality of built project; C12: provisional prossess of site;
C13: dispath cost; C14: opening the way for water, electricity and road, and level off site;
C15: way of supply materials.
D : bidders to be evaluated.

Figure 1 The Hierarchy Structure Model of the Evaluation of bidders

A—level Focus: synthetical evaluating for each bidder (or preference of the evaluation of bidders).

B—level Criterion: B1=economic beneficency; B2=engineering level; B3=construction seniority and prestige; B4=other additional conditions.

C—level Factor: C1—C15. 15 indexes are given in Figure 1.

D—level Scheme: bidders to be evaluated.

Market price, time limit for a project, technological strength (be indicated as the ratio of technologist and worker to the entire personnel), capacity for claim property, provisional possess of site and dispath cost are quantitative indexes and the others such as construction equipment, etc 8 indexes are qualitative in factor level.

III. The Algorithms of Indeses' Weighting

The calculation of indexes' weighting based on building the Hierarchy Structure has the following steps:

1. To obtain the priorites of compared elements by constructing pairwise comparison matrix.

The judgements matrixes A—B, B1—C, B2—C, B3—C, B4—C are given numerial values from the 1—9 scale. In this paper the synthetical judgement matrix is constrncted by means of synthesizing judgement of persons concerned of Capital Construction Management Department and the method of geometric mean which is pressented by saaty (2). The weighting of relative importance of each element in the same level relative to a certain element of upper—level may be obtained by deriving eigenvalue and eigenvector of judgement matrix. That is the weighting of relative importance of each element in B—level relative to A—level and of each element in C—level relative to a certain element of B—level. The consistency test of priorities of compared elements in the pairwise comparison matrix may be found by C.R=(C.I./R.I.)<0.1. The average consistency random index (R.I.) is given in Xu's paper(1).

2. To obtain the composite priorities of the elements in C—level relative to A—level.

The consistency test of the composite priorities in the hierarchy based on deriving the weighting of relative imporance of each element in C—level relative to A—level may be found by

$$C.R. = \left(\sum_{j=1}^{4} bj * C.Ij. \Big/ \sum_{j=1}^{4} bj * R.Ij\right) < 0.1$$

The judgements matrixes constructed and the computed result are given below:

(1) A–B

A	B1	B2	B3	B4	W
B1	1	3	4	6	0.5583
B2	1/3	1	2	3	0.2279
B3	1/4	1/2	1	2	0.1355
B4	1/6	1/3	1/2	1	0.0782

λmax=4.0310, C.I.=0.0103, C.R.=0.0116

(2) B1–C

B1	C1	C2	C12	C13	W
C1	1	3	9	9	0.5911
C2	1/3	1	7	7	0.3010
C12	1/9	1/7	1	2	0.0632
C13	1/9	1/7	1/2	1	0.0340

λmax=4.1517, C.I.=0.0506, C.R.=0.0569

(3) B2–C

B2	C3	C4	C5	C6	W
C3	1	2	2	1	0.3246
C4	1/2	1	1/2	1/3	0.1233
C5	1/2	2	1	1/2	0.1930
C6	1	3	2	1	0.3591

λmax=4.0457, C.I.=0.0152, C.R.=0.0171

(4) B3–C

B3	C7	C8	C9	C10	C11	W
C7	1	1/2	2	3	2	0.2634
C8	2	1	2	3	1	0.3025
C9	1/2	1/2	1	2	1	0.1602
C10	1/3	1/3	1/2	1	1/2	0.0899
C11	1/2	1	1	2	1	0.1840

λmax=5.1539, C.I.=0.0385, C.R.=0.0347

(5) B4–C

B4	C12	C13	C14	C15	W
C12	1	4	2	3	0.4794
C13	1/4	1	1/2	2/3	0.1164
C14	1/2	2	1	3/2	0.2397
C15	1/3	3/2	2/3	1	0.1646

λmax=4.0017, C.I.=0.0006, C.R.=0.0006

Hence the Composite Priorities (C.W) of Ci relative to A–level are calculated by means of below table:

B \ C	B1	B2	B3	B4	
	0.5583	0.2279	0.1355	0.0782	C.W
C1	0.5911	0	0	0	0.3300
C2	0.3010	0	0	0	0.1680
C3	0	0.3246	0	0	0.0740
C4	0	0.1233	0	0	0.0281
C5	0	0.1930	0	0	0.0440
C6	0	0.3591	0	0	0.0818
C7	0	0	0.2634	0	0.0357
C8	0	0	0.3025	0	0.0410
C9	0	0	0.1602	0	0.0217
C10	0	0	0.0899	0	0.0122
C11	0	0	0.1840	0	0.0249
C12	0.0632	0	0	0.4794	0.0728
C13	0.0340	0	0	0.1164	0.0340
C14	0	0	0	0.2397	0.0187
C15	0	0	0	0.1646	0.0129

C.I.=0.0370, R.I.=0.9197, C.R.=0.0402

It can be seen from priorities that the weighting of economic beneficency is maximum(0.5583) considering A—level (preference of evaluation bidders). which indicates that one occupies the important place in B—level. The priorities of other facotrs are engineering level (0.2279), construction seniority and prestige (0.1355), and other additional conditions (0.0782).

The compositive priorities of Ci relative to A—level are as follows: market price(0.3300), time limit for a project(0.1680), rationality of job practice (0.0818). technological strength (0.0740). provisional possess of site (0.0782), measure of guarateeing quality (0.0440). fulfil prestige (0.0410), technological grade (0.0357), dispath cost (0.0340), construction equipment (0.0281). quality of the built project (0.0249). limits of undertaking job (0.0217). opening the way for water, electricity and road, and level of the site (0.0187), way of supply materials (0.0129), and capacity for claim property (0.0122). The result above basically tallies with existing state of inviting bidders.

Ⅳ. The method of synthetical appraisal

The synthetical appraisal on each bidder is given by

$$(Y)m=(X)mxn * (W)n \qquad (1)$$

where

(Y)m—the preference eigenvector of the evaluation of bidders form bidders,

$(Y)m=(Y_1, Y_2, \cdots, Y_m)^T$.

(X)mxn—the numerisl evaluation matrix of n indexes pertinent to m bidders,

$$(X)mxn=(X1, X2, \cdots, Xn)=\begin{pmatrix} x_{11}, \cdots, x_{1n} \\ \vdots \quad \vdots \\ x_{1m}, \cdots, x_{mn} \end{pmatrix}$$

(W)n—the eigenvector of n indexes on Focus A (preference of the evaluation of bidders), $(W)n=(W1, \cdots, Wn)^T$.

The numerial evaluation for quantitative factors such as market price, time limit for a project, provitional possess of site and dispath cost, etc may be found as follows: suppose optimum value of j index is a_j which is a minimal value in permissive limits for the evaluation of bidders and an existing index's value of i bidder is c_{ij}, its non—dimentional relative value (a_j/c_{ij}) on j index is computed and then the result of all bidders on j index is normalization. That can compute numerial evaluation of i bidder on j index, which is given by

$$x_{ij}= (a_j/c_{ij}) \ / \sum_{i=1}^{m} (a_j/c_{ij}) \qquad (i=1,2,\cdots,m,\ j=1,2,3,7,10,12,13) \qquad (2)$$

when j=1, x_{i1} is the numerial evaluation of the market price and suppose it is out of reasonable market price, $x_{ij}=0$;

when j=2, x_{i2}=the numerial evaluation of the limit for a project;

when j=3, x_{i3}=the numerial evaluation of the technological strength;

when j=7, x_{i7}=the numerial evaluation of the technological grade;

when j=10, x_{i10}=the nemerial evaluation of capacity for claim property;

when j=12, x_{i12}=the numerial evaluation of provisional possess of site;

when j=13, x_{i13}=the numerial evaluation of the dispath cost.
The numerial evaluation for qualitative factors can be determined by concerned persons with evaluating bidders based on overall examining seniority and quality of bidders, and bidders correspondence, It gives score of the 1—5 scale for any qualitative index according to existing condition of bidders. The score is normalized and we regard it as this index s numerial evaluatin $(i=1,2,\cdots,m,\ j=4,5,6,8,9,11,14,15)$.

V. Case study

The unit in charge of construction of Xiaoyuzhang reservoir in Wuqing County, Tianjin is assessed by the evaluation of bidders. There are 7 units of bidders. Among others there are 4 units in earthwork and 6 units in structure works. These units are as follows:
T1——Beijin Hydraulic Engineering Foundation Total brigate;
T2——Tianjin Mechanical construction company;
T3——Architectural & Installation Company of the Baoding Prefecture Hydraulic Resources Bureau;
T4——Architectural & Installation Company of the Xingtai Prefecture;
T5——First Architectural & Installation company of the Wuqing County;
T6——Second Architectural & Installation Company of the Wuqing County;
T7——Third Architectural & Installation Company of the Wuaing County.
There are T1, T2, T3 and T4 among unit of bidders of earthwork and T1, T3, T5, T6, and T7 among one of structure works. The method above is illustrated with the evaluation of bidders of earthwork. Only market price, technological grade, construction equipment, measure of guarateeing quality and limits of undertaking job which are marked as basis of the evaluation of bidders in view of material is not completed. Among them numerial evaluation vectors for quantitative indexes such as market price and technological grade are given through computer according to formula (2) in Paper: $X1=(0.2345, 0.2095, 0.2831, 0.2729)^T$, $X2=(0.3333, 0.3333, 0.1667, 0.1667)^T$ (for details, see the Appendix (1)). Numerial evaluation vector for qualitative indexes such as construction equipment, measure of guarateeing quality and limits of undertaking job are given using the method in paper: $X3=(0.2778, 0.2778, 0.1667, 0.2778)^T$, $X4=(0.2778, 0.2778, 0.2222, 0.2222)^T$, $X5=(0.2632, 0.2632, 0.2632, 0.2105)^T$ for details see the Appendix (2)). As a result, numerial evaluation matrix of 5 indexes for 4 units for 4 units of bidders may be indicated as: $X=(X, X2, X3, X4, X5)$. The preperence eigenvector of the evaluation of bidders for each bidder can be computed by means of formula(1) in paper:

$$(Y)_4=(x)_{4\times5}\cdot(W)_5=(X1, X2, \ldots, X5)_{4\times5}\ (W)_5$$

$$= \begin{bmatrix} 0.2345 & 0.3333 & 0.2778 & 0.2778 & 0.2632 \\ 0.2095 & 0.3333 & 0.2778 & 0.2778 & 0.2632 \\ 0.2831 & 0.1667 & 0.1667 & 0.2222 & 0.2632 \\ 0.2729 & 0.1667 & 0.2778 & 0.2222 & 0.2105 \end{bmatrix} \begin{bmatrix} 0.3333 \\ 0.0357 \\ 0.0281 \\ 0.0440 \\ 0.0217 \end{bmatrix} = \begin{bmatrix} 0.1150 \\ 0.1068 \\ 0.1195 \\ 0.1182 \end{bmatrix}$$

The result above given expression that preperence of T3 is maxium (0.1195) and one of T4 is second (0.1182), which agrees the actual outcome of the evaluation of bidders.

VI. Conclusion

In this paper a Hierarchy Structure Model of the evaluation of bidders based on multiobjective program with AHP is presented. It synthesizes 15 indexes, provides a lot of information for policymaker and makes the result of the evaluation of bidders overall rational and pithy, so that it is strongly invincing.

Not only the Model above is used for inviting tenders of hydraulic resourcs capital construction but also it is used for determining optimum programme of planning and designing, optimum selection management department of hydraulic engineering superior to the others and other complex socio—economic system on condition that the relevant evaluation index system is determined.

References

1. Xu Shubo, "The priciple of the AHP", Tianjin University press, May 1988 (in Chinese).
2. T. L. Saaty, "The Analytic Hierarchy Process", McGraw—Hill Inc, 1980.

Appendix

(1) The nemerial evaluation of quantitative indexes:

index \ unit		T1	T2	T3	T4	total
market price	c_{ij} (yuan/m^3)	2.27	2.54	1.88	1.95	
	a_j (yuan/m^3)			1.88		
	a_j/c_{ij}	0.8282	0.7402	1.000	0.9640	3.5324
	x_{ij}	0.2345	0.2095	0.2831	0.2729	
technological grade	c_{ij} (yuan/m^3)	1	1	2	2	
	a_j (yuan/m^3)	1				
	a_j/c_{ij}	1	1	0.5	0.5	3
	x_{ij}	0.3333	0.3333	0.1667	0.1667	

(2) The numerial evaluation of qualitative indexes:

index \ unit		T1	T2	T3	T4	total
construction equipment	score(sj)	5	5	3	5	18
	x_{ij}	0.2778	0.2778	0.1667	0.2778	
heasure of uarateeing quality	score(sj)	5	5	4	4	18
	x_{ij}	0.2778	0.2778	0.2222	0.2222	
limit of undertaking job	score(sj)	5	5	5	4	19
	x_{ij}	0.2632	0.2632	0.2632	0.2105	