Feedback Structure Model and its Application

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Abstract

We discuss the principle of priorities in systems with feedback and its application to the evaluation of departments of project engineering design. The principle of priorities in a system with feedback was derived from the priority theory of the hierarchy structure. It may be difficult to build a hierarchy structure model when the relations inside the system analyzed are too complex. The principle of priorities in a system with feedback appear to solve this decision problem. The method of feedback structure model is applied to the evaluation of the departments of the project design, a complex decision problem involving many relative elements. The analytic method of the graph theory is used in the analysis of these types of structures, and the calculating model of two kinds of structures is developed. The solutions of the feedback structure model and the hierarchy structure model are compared in the application.

I. Introduction

In the analysis of a system, the use of a hierarchic structure is based on assumptions. Although there are many systems that can satisfy these assumptions represented by the hierarchy, systems with complicated relations cannot be simply represented hierarchically, for consideration should be given to the interaction of elements in each level and the non-hierarchical relations between levels. At such times, the feedback structure model should be used to represent the system.

Similar to the construction of a hierarchic structure, the construction of a feedback structure also begins with the decomposition of a system or a problem. Although the analytical method from higher to lower level applied in a hierarchy no longer exists, the feedback structure represents all the interrelations of a system and can define more accurately the essence of a given system. When constructing a feedback structure, a system is decomposed into components which are interactive and comparable. Then one defines the elements consisting of these components to find out whether these elements are independent or connected with each other, and finally one confirms the connection of each component and the elements in each component. A feedback structure of system is thus built.

The priority of a feedback structure model is obtained as follows:

1. Make an overall and concrete analysis of the system;
2. Find out the system;s basic components, to define their interaction and find out all elements contained in each component;

3. Identify the type of system;
4. Construct a supermatrix through the prioritization of elements in every component in respect to all elements in the system;
5. Compute priorities of the related components based on the function of the system and use the results to normalize the supermatrix;
6. Adopt a suitable solution according to the kinds of system.

The steps one must follow to judge the type of system we must use are as follows:

1. Judge whether the directed graph of the system is strongly connected.
2. If so, find out whether the system has a cyclic structure. For those with strongly connected directed graph there is only one input and one output in each vertex in the cyclic structure. If the elements in each component of the system are independent, the system is cyclic, otherwise it is primitive.
3. If a directed graph of the system is not strongly connected, then analyze each branch. If every branch is primitive, then use of powers of the supermatrix to obtain LIP (limiting impact priorities) and LAP (limiting absolute priorities). If a cyclic sub-system appears in a branch, then find the least common multiple of the imprimitivity indices of all the sub-cyclic system and obtain the solution through the averaged LIP and LAP.

II. The Application of Feedback Structure Model

The evaluation of the departments of an engineering project by the Designing Engineer is a complicated task involving broad and varied operations and large investment. This evaluation has a direct bearing on whether the decision of the administration is correct, and whether the designing departments can make outstanding achievements. Consequently, the administration has set up a committee of experts in charge of the assessment of a large number of designing departments. It has obtained good results by adopting the Analytic Hierarchy Process and the feedback structure model is based on deep, and extensive investigations to discuss the feasibility reports.

1. Setting up index system of evaluation

The evaluation of the departments of project design relies mainly on the level of the designing departments carrying out the state policy on project development, the ability in project designing and practical experience, the general design and the grasp of various means in project designing including computer and software, various standards, handbooks on criteria and conditions for experiments needed by the project design.

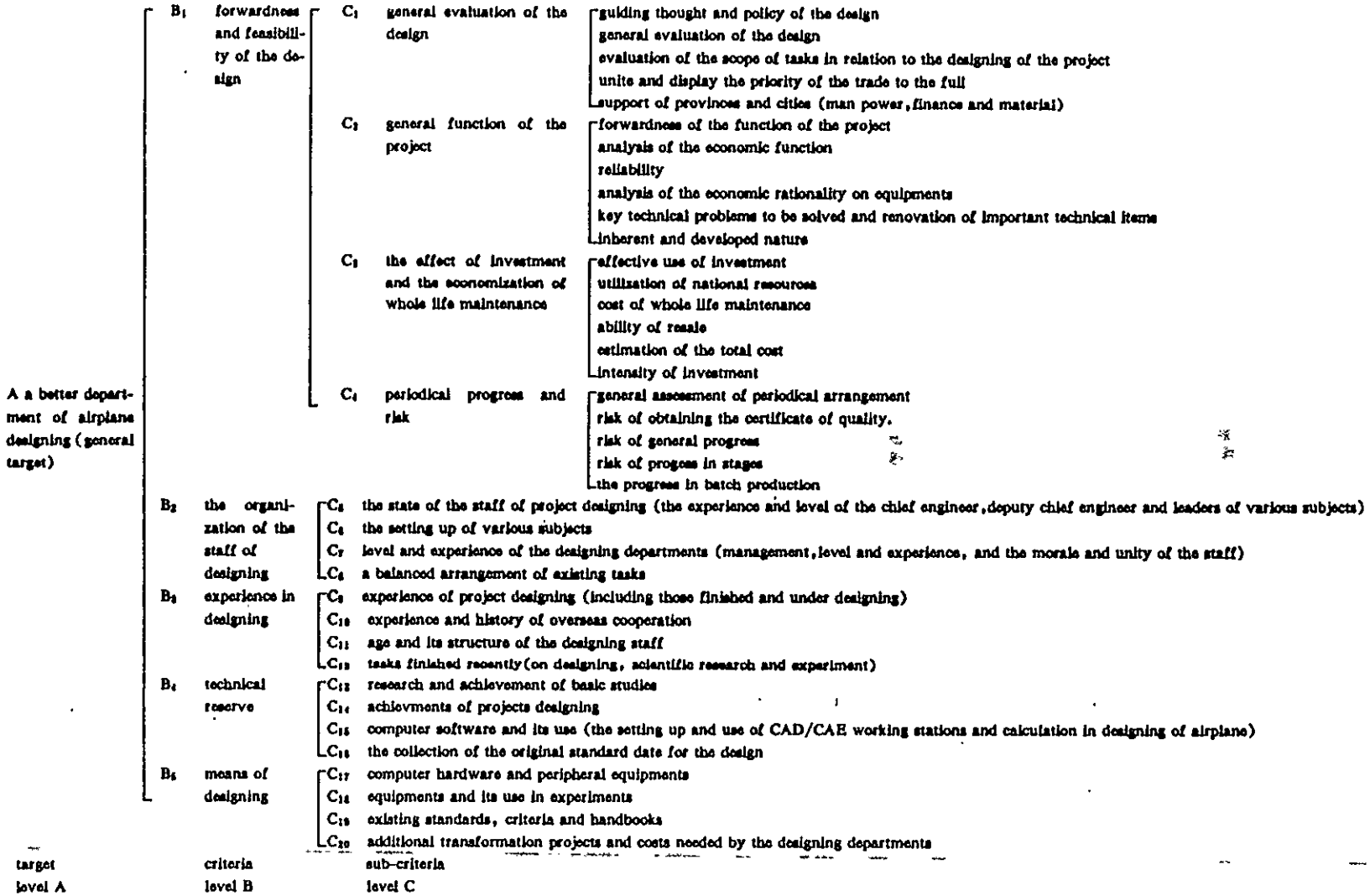

Fig. 1 Index system in the evaluation of the departments of an engineering project

Following these principles and through repeated investigation, and the factors analyzed by the committee of experts in relation to the evaluation, an index system can be developed (See Figure 1).

In Figure 1 the following criteria were used:

B1: the audacity and feasibility of designing;
B2: designing staff
B3: experience in designing
B4: technical reserve in designing
B5: means of designing

C1: general evaluation of the design
C2: general function of the project
C3: effect of investment and the economization of the whole life maintenance
C4: periodical progress and risk
C5: the state of the staff assigned to the designing project
C6: the setting up of various subjects
C7: managerial level and experience of designing departments
C8: current task and balanced arrangement
C9: experience of project designing
C10: experience and history of overseas cooperation
C11: age and its structure of the staff
C12: tasks to be finished recently (including design, scientific research and experiment)
C13: research and its achievement of basic studies
C14: achievements in projects designing
C15: computer software and its use
C16: collections of original standard data for designing
C17: computer and peripheral equipments
C18: equipment and its use in experiments.
C19: existing standards, criteria and handbooks
C20: additional transformation projects and costs needed by the designing departments

The development of an index made us decompose the general design of the project. This enables us to evaluate and judge these indices (elements or factors) to find their impact on the general aim of the system so as to give an overall evaluation of the departments of the project design, thus providing bases for decision making.

2. The Construction of the Model and priority in System with Feedback

After defining an index system, one can analyze the interaction between elements and construct a feedback system analytical model for the prioritization of the elements involved.

The first step in this analysis is the study of the interaction among the elements involved, many of which are

interdependent. Then we must consider how they interact. A forward and feasible design is inseparable from the state of the designing staff, experience, technical reserve and means of designing; while the state of the designing staff will directly affect the technical reserve of the designing departments, and the experience of the designing staff is also closely related to the state of the designing staff. A comprehensive consideration of the connections of all the elements will reveal the interaction of each element as is shown in Figure 2.

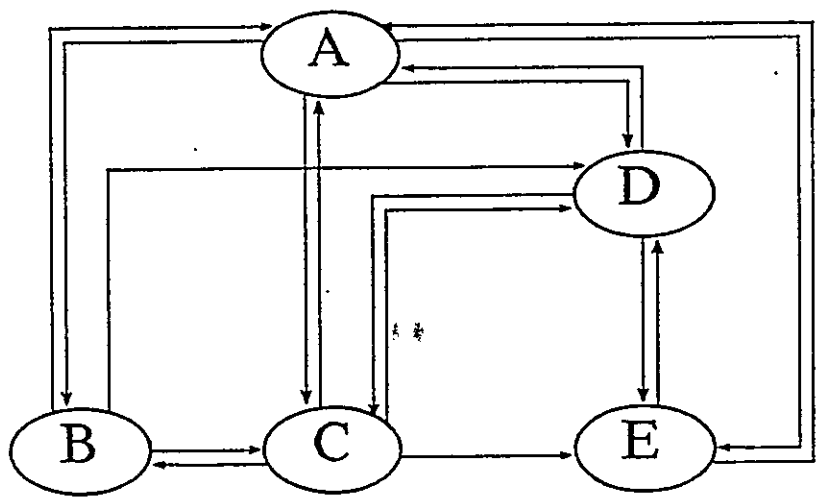

Fig. 2 The interaction of the elements of project design

The directed graph of the system is strongly connected because each element in the system has a direct or indirect impact on other elements. This system is primitive because according to the principle of these kinds of systems the supermatrix of the system is a primitive matrix.

After constructing the analytic model and adopting the general opinion of the committee of experts on the relative importance of the elements of each criterion, one derives the priorities of the elements of each component. Based on this, one considers the interaction between all the elements, and places the results in a supermatrix comprising all elements and representing their interdependence in quantity as is shown in Table 1.

To derive a normalization matrix, it is necessary to construct a weighted matrix according to the interaction of all elements. For element B1, apart from the interaction of its own, other elements in level B affect it. According to the judgment of the committee of experts on the relative importance of all elements, their priorities are:

$$(0.2632,\ 0.2346,\ 0.2289,\ 0.1555,\ 0.1178)^T$$

Table 1 The unweighted supermatrix

		B1				B2				B3				B4				B5			
		C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13	C14	C15	C16	C17	C18	C19	C20
B1	C1	.38	.38	.38	.38	.50	.25	.20	.50	.40	.40	.40	.40	.25	.25	.25	.25	.25	.25	.25	.25
	C2	.23	.23	.23	.23	.40	.50	.10	.20	.20	.20	.20	.20	.25	.25	.25	.25	.25	.25	.25	.25
	C3	.20	.20	.20	.20	.05	.10	.35	.20	.20	.20	.20	.20	.25	.25	.25	.25	.25	.25	.25	.25
	C4	.19	.19	.19	.19	.05	.10	.35	.20	.20	.20	.20	.20	.25	.25	.25	.25	.25	.25	.25	.25
B2	C5	.70	.50	.20	.20	.33	.33	.33	.33	.50	.50	.25	.30	.40	.40	.20	.40	.00	.00	.00	.00
	C6	.15	.20	.10	.00	.14	.14	.14	.14	.30	.00	.25	.00	.10	.10	.30	.10	.00	.00	.00	.00
	C7	.10	.30	.60	.40	.31	.31	.31	.31	.10	.50	.50	.40	.40	.40	.40	.40	.00	.00	.00	.00
	C8	.05	.00	.10	.40	.22	.22	.22	.22	.10	.00	.00	.30	.10	.10	.10	.10	.00	.00	.00	.00
B3	C9	.70	.50	.80	.80	.40	.50	.40	.60	.42	.42	.42	.42	.40	.80	.40	.50	.50	.50	.50	.50
	C10	.26	.20	.10	.10	.25	.10	.05	.05	.25	.25	.25	.25	.40	.10	.10	.10	.50	.50	.50	.50
	C11	.02	.25	.10	.10	.20	.20	.30	.05	.19	.19	.19	.19	.10	.05	.10	.10	.00	.00	.00	.00
	C12	.02	.05	.00	.00	.15	.20	.25	.30	.14	.14	.14	.14	.10	.05	.40	.30	.00	.00	.30	.30
B4	C13	.20	.25	.00	.00	.00	.00	.00	.00	.30	.40	.50	.40	.21	.21	.21	.21	.20	.40	.40	.40
	C14	.40	.25	.50	.50	.00	.00	.00	.00	.50	.20	.50	.40	.34	.34	.34	.34	.20	.40	.60	.60
	C15	.20	.30	.00	.20	.00	.00	.00	.00	.00	.00	.00	.00	.25	.25	.25	.25	.30	.00	.00	.00
	C16	.20	.20	.50	.30	.00	.00	.00	.00	.24	.40	.00	.30	.20	.20	.20	.20	.20	.20	.00	.00
B5	C17	.30	.25	.30	.25	.00	.00	.00	.00	.00	.00	.00	.00	.25	.25	.50	.50	.26	.26	.26	.26
	C18	.30	.50	.40	.25	.00	.00	.00	.00	.00	.00	.00	.00	.25	.25	.50	.50	.31	.31	.31	.31
	C19	.30	.25	.00	.25	.00	.00	.00	.00	.00	.00	.00	.00	.25	.25	.00	.25	.19	.19	.19	.19
	C20	.10	.00	.30	.25	.00	.00	.00	.00	.00	.00	.00	.00	.25	.25	.00	.25	.24	.24	.24	.24

The other elements that affect B2 are B1, B2, B3, and the priority of their relative importance are given by:

$$(0.3622,\ 0.3228,\ 0.3150)^{T}.$$

Applying the same method, a weighted matrix is derived:

$$\begin{bmatrix} .2632 & .3622 & .2983 & .2632 & .3439 \\ .2356 & .3228 & .2659 & .2346 & 0 \\ .2289 & .3150 & .2595 & .2289 & .2991 \\ .1555 & 0 & .1763 & .1555 & .2032 \\ .1178 & 0 & 0 & .1178 & .1539 \end{bmatrix}$$

The weighted supermatrix is given in Table 2. Because the system is primitive, then W^{∞}, and each one of its columns are the same. Each column in W^{∞} is the composite priority of all elements in the system (LAP). Under a given accuracy of 0.001, W^{∞} is given in Table 3.

The weighted supermatrix that it reflects the priority of the direct impact between elements. This priority is different for

different elements. For instance, for the element audacity of the project, the most important element is the organization and level of the designing staff, for the elements of direct influence, the most important is the audacity of the design made by the designing staff, and for the element feasibility of the design, the most important is the experience of the department of project designing. Of course, the organization and level of the designing staff is also related to the experience designing.

Table 2 The weighted supermatrix

		B1				B2				B3				B4				B5			
		C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13	C14	C15	C16	C17	C18	C19	C20
B1	C1	.10	.10	.10	.10	.18	.09	.07	.18	.12	.12	.12	.12	.07	.07	.07	.07	.09	.09	.09	.09
	C2	.06	.06	.03	.06	.14	.18	.04	.07	.06	.06	.06	.06	.07	.07	.07	.07	.09	.09	.09	.09
	C3	.05	.05	.05	.05	.02	.04	.13	.07	.06	.06	.06	.06	.07	.07	.07	.07	.09	.09	.09	.09
	C4	.05	.05	.05	.05	.02	.05	.13	.07	.06	.06	.06	.06	.07	.07	.07	.07	.09	.09	.09	.09
B2	C5	.16	.12	.05	.05	.11	.11	.11	.11	.13	.13	.07	.08	.09	.09	.05	.09	.00	.00	.00	.00
	C6	.04	.05	.02	.00	.05	.05	.05	.05	.08	.00	.07	.00	.02	.02	.07	.02	.00	.00	.00	.00
	C7	.02	.07	.14	.09	.10	.10	.10	.10	.03	.13	.13	.11	.09	.09	.09	.09	.00	.00	.00	.00
	C8	.01	.00	.02	.09	.07	.07	.07	.07	.03	.00	.00	.08	.02	.02	.02	.02	.00	.00	.00	.00
B3	C9	.16	.11	.18	.18	.13	.16	.13	.19	.11	.11	.11	.11	.09	.18	.09	.11	.15	.15	.15	.15
	C10	.06	.05	.02	.02	.08	.03	.02	.02	.06	.06	.06	.06	.09	.02	.02	.02	.15	.15	.06	.06
	C11	.00	.06	.02	.02	.06	.06	.09	.02	.05	.05	.05	.05	.02	.01	.02	.02	.00	.00	.00	.00
	C12	.00	.01	.00	.00	.05	.06	.08	.09	.04	.04	.04	.04	.02	.01	.09	.07	.00	.00	.30	.30
B4	C13	.03	.04	.00	.00	.00	.00	.00	.00	.05	.07	.09	.07	.03	.03	.03	.03	.04	.08	.08	.08
	C14	.06	.04	.08	.08	.00	.00	.00	.00	.09	.04	.09	.07	.05	.05	.05	.05	.04	.08	.12	.12
	C15	.03	.05	.00	.03	.00	.00	.00	.00	.00	.00	.00	.00	.04	.04	.04	.04	.06	.00	.00	.00
	C16	.03	.03	.08	.05	.00	.00	.00	.00	.04	.07	.00	.05	.03	.03	.03	.03	.04	.04	.00	.00
B5	C17	.04	.03	.04	.03	.00	.00	.00	.00	.00	.00	.00	.00	.03	.03	.06	.06	.04	.04	.04	.04
	C18	.04	.06	.05	.03	.00	.00	.00	.00	.00	.00	.00	.00	.03	.03	.00	.03	.05	.05	.05	.05
	C19	.04	.03	.00	.03	.00	.00	.00	.00	.00	.00	.00	.00	.03	.03	.00	.03	.03	.03	.03	.03
	C20	.01	.00	.04	.03	.00	.00	.00	.00	.00	.00	.00	.00	.03	.03	.06	.00	.04	.04	.04	.04

The results of the calculations show that the most important factors are the experience in making designs (C_9), the evaluation of the project (C_1) as well as the state of the staff (C_5). The general function of the project also has great impact on the project designing. It is reasonable to derive such results from the general design of engineering project.

III. Comparison Between the Hierarchy Structure Model and Feedback Structure Model

The construction of hierarchic structure ignores the interaction between elements and takes the five elements B1, B2, B3, B4, and B5 as independent. The hierarchy (see Fig.3) shows that target level A is a better department of project designing, and through the comprehensive evaluation of the experts it get C_i, the composite priority of level B and level C as is shown in the

following Table 4.

Table 3 Matrix of limiting absolute priority under a given accuracy of 0.001

		B1				B2				B3				B4				B5			
		C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13	C14	C15	C16	C17	C18	C19	C20
B1	C1	.11	.11	.11	.11	.11	.11	.11	.11	.11	.11	.11	.11	.11	.11	.11	.11	.11	.11	.11	.11
	C2	.07	.07	.07	.07	.07	.07	.07	.07	.07	.07	.07	.07	.07	.07	.07	.07	.07	.07	.07	.07
	C3	.06	.06	.06	.06	.06	.06	.06	.06	.06	.06	.06	.06	.06	.06	.06	.06	.06	.06	.06	.06
	C4	.06	.06	.06	.06	.06	.06	.06	.06	.06	.06	.06	.06	.06	.06	.06	.06	.06	.06	.06	.06
B2	C5	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10
	C6	.04	.04	.04	.04	.04	.04	.04	.04	.04	.04	.04	.04	.04	.04	.04	.04	.04	.04	.04	.04
	C7	.08	.08	.08	.08	.08	.08	.08	.08	.08	.08	.08	.08	.08	.08	.08	.08	.08	.08	.08	.08
	C8	.04	.04	.04	.04	.04	.04	.04	.04	.04	.04	.04	.04	.04	.04	.04	.04	.04	.04	.04	.04
B3	C9	.14	.14	.14	.14	.14	.14	.14	.14	.14	.14	.14	.14	.14	.14	.14	.14	.14	.14	.14	.14
	C10	.05	.05	.05	.05	.05	.05	.05	.05	.05	.05	.05	.05	.05	.05	.05	.05	.05	.05	.05	.05
	C11	.04	.04	.04	.04	.04	.04	.04	.04	.04	.04	.04	.04	.04	.04	.04	.04	.04	.04	.04	.04
	C12	.03	.03	.03	.03	.03	.03	.03	.03	.03	.03	.03	.03	.03	.03	.03	.03	.03	.03	.03	.03
B4	C13	.03	.03	.03	.03	.03	.03	.03	.03	.03	.03	.03	.03	.03	.03	.03	.03	.03	.03	.03	.03
	C14	.05	.05	.05	.05	.05	.05	.05	.05	.05	.05	.05	.05	.05	.05	.05	.05	.05	.05	.05	.05
	C15	.01	.01	.01	.01	.01	.01	.01	.01	.01	.01	.01	.01	.01	.01	.01	.01	.01	.01	.01	.01
	C16	.03	.03	.03	.03	.03	.03	.03	.03	.03	.03	.03	.03	.03	.03	.03	.03	.03	.03	.03	.03
B5	17	.02	.02	.02	.02	.02	.02	.02	.02	.02	.02	.02	.02	.02	.02	.02	.02	.02	.02	.02	.02
	C18	.02	.02	.02	.02	.02	.02	.02	.02	.02	.02	.02	.02	.02	.02	.02	.02	.02	.02	.02	.02
	C19	.01	.01	.01	.01	.01	.01	.01	.01	.01	.01	.01	.01	.01	.01	.01	.01	.01	.01	.01	.01
	C20	.01	.01	.01	.01	.01	.01	.01	.01	.01	.01	.01	.01	.01	.01	.01	.01	.01	.01	.01	.01

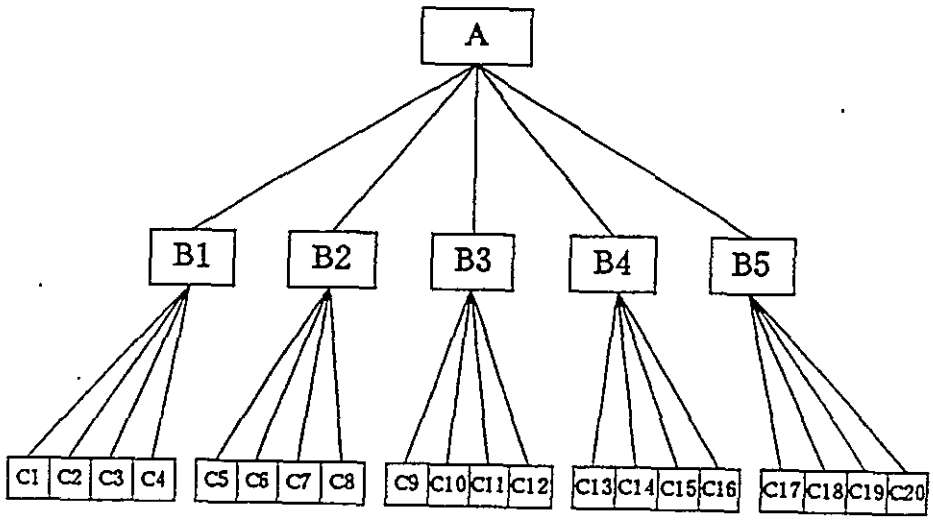

Fig. 3 The hierarchy structure model of elements

Table 4 The composite priority of the hierarachy structure model

	B1	B2	B3	B4	B5	Ci
	.2632	.2336	.2239	.1555	.1178	
C1	.3822	.0000.	.0000	.0000	.0000	.1006
C2	.2274	.0000	.0000	.0000	.0000	.0598
C3	.1962	.0000	.0000	.0000	.0000	.0516
C4	.1942	.0000	.0000	.0000	.0000	.0511
C5	.0000	.3289	.0000	.0000	.0000	.0771
C6	.0000	.1340	.0000	.0000	.0000	.0316
C7	.0000	.3138	.0000	.0000	.0000	.0736
C8	.0000	.2225	.0000	.0000	.0000	.0522
C9	.0000	.0000	.4201	.0000	.0000	.0962
C10	.0000	.0000	.2463	.0000	.0000	.0564
C11	.0000	.0000	.1905	.0000	.0000	0436
C12	.0000	.0000	.1431	.0000	.0000	.0328
C13	.0000	.0000	.0000	.2118	.0000	.0329
C14	.0000	.0000	.0000	.3390	.0000	.0527
C15	.0000	.0000	.0000	.2470	.0000	.0385
C16	.0000	.0000	.0000	.2013	.0000	.0313
C17	.0000	.0000	.0000	.0000	.2580	.0304
C18	.0000	.0000	.0000	.0000	.3124	.0368
C19	.0000	.0000	.0000	.0000	.1937	.0228
C20	.0000	.0000	.0000	.0000	.2359	.0278

The analysis of these two models shows that the priorities of the hierarchic structure (H-model) and the feedback system structure (F-model) are almost identical and the three elements with bigger influence are: the comprehensive evaluation of the design, the experience in designing, and the level and organization of the designing staff.

Because the construction of the H-Model ignores the interaction between elements, its priority value is different from that of the F-model. In the results of the hierarchic structure, the comprehensive evaluation of the design has the biggest influence on the system (0.101), then comes the experience in designing (0.096), and the level and organization of the designing staff (0.077). In the calculations of the feedback structure, the experience in designing has the biggest influence (0.14), which is followed by comprehensive evaluation of the designing (0.11) and the level and organization of the designing staff (0.10). These results show that the feedback structure model has taken into consideration long-term and comprehensive affect of the interaction of all elements. In evaluating a project designing department, the comprehensive evaluation of the design is a very important factor, but it ignores the active influence of the experience of the

designing staff. From a long term point of view, the enforcement of a design must rely on the experience and level of the designing staff.

Another difference between the two models is that the weights in the H-model are more even, and the sum of the weight of the first three elements make up to 27% of the total, while in the F-model the weight of the first three elements account for 35%. This is because it has taken into consideration all the direct and indirect effects so that the influence of other elements towards the system has been added to these three elements and thus their weight has increased. Meanwhile the H-model ignores the effects of certain elements and no cumulative effects take place.

The above mentioned analyses shows that although the H-model ignores certain interaction between elements, it, nevertheless, still reflects the importance of all elements in the system, especially at a time when this interaction is not obvious, such a priority of importance can basically reflect the objective reality of the system. When the interaction between elements becomes important, the feedback structure model should be used in the analysis. A comparison of the result of the two models will lead to an overall and closer-to-reality result.

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