1. Introduction

One of the much touted traits of Japanese management is seniority wage system. This system is based on the value system and behavioral pattern of the corporation. The system's foundation is not just years of service, academic background, age and sex. The system establishes seniority according to the relative evaluation of its employees. [1] Yet that this system is rather outdated and needs modification in order for Japanese management to further flourish is proven by several researches. For example, the performance appraisal system, which is a sub-system of personnel management system that includes job classification, human resource development, etc., has gone through changes in mid-sixties, mid-seventies and mid-eighties after being adopted right after the second World War. [2] The third change was designed to introduce or apply appraisal systems in various way.

According to the survey "Japanese Performance Appraisal and Seniority System" [3] the most desired features on those systems were:

a. Establish accurate performance appraisal measures
b. Clarify the rules to appraise
c. Establish absolute appraisal measures
d. Establish appraisal system based on achievement
e. Accomplish predetermined objectives

The same survey showed that personnel and performance appraisal went following modifications:

a. Establish measures that reflect different requirement of different departments or jobs.
b. Establish measures to adjust deviation between different departments
c. Change to appraisal system that emphasize achievement
d. Change to appraisal system that emphasize human resource development

The Performance Appraisal System on Fuzzy Theory (hereof Fuzzy System) responds to such needs on the following way.

First, the system employs diversified job evaluation criteria. In Japan, jobs are vertically divided to such jobs as general job, integrated job and management job. Sometimes sales job, technical job and clerical job are added. Horizontally, these jobs are devided into several layers of positions. However, jobs are more and more diversified in recent years and to better appraise those specific jobs, criteria of appraisal have to be more detailed to enable fair evaluation. Under Fuzzy System, evaluation elements, levels and points are establish according the specification of different job groups and thus make it possible, for example, to establish different evaluation elements for sales people of different areas and different sub-groups.

Secondly, the system can establish ideal evaluation elements for assessing performance and potential. It is vital to establish adequate evaluation criteria to each job and people. If a system is with diversified criteria, the selection of criteria becomes complicated and difficult. Yet, jobs are becoming to be more and more specific these days. With Fuzzy System, one can easily establish mental structure model on evaluation criteria structure that depends on agreement of several appraisors.

Thirdly, the system can adjust the balance of different evaluation factors. The evaluation factors have the structure of tree in that trunks diversify into branches. Often, branches affect the evaluation of their belonging trunk to a different degree. The Fuzzy System can control and define the exact level of branches' contribution to trunks. The level of contribution is decided by designing the mental structure model of appraisors.

Fourthly, the system can also decide the evaluation according to the level of objective achievement. It is widely accepted that in Japan increased consideration to actual achievement should be reflected into the future appraisal. The achievement of an employee (sales, commission, etc.) is increasingly included as part of appraisal. The Fuzzy System can include the achievement as important criteria of appraisal.

Fifthly, the system does the human resource development. Performance appraisal is increasingly utilized not just as a tool for evaluation but for human resource development. The Fuzzy System is not for defining the area where training is necessary and thus to equip the system with ways to develop human resources is vital. That is to say that the feedback system between appraisee and appraisor is necessary.

The Fuzzy System compares pairs of appraisees by evaluation elements. In the process of compairing evaluation of certain criteria the system enables to find the problem or possibility in human resource development easily.

Sixthly, the system can shift relative evaluation to absolute evaluation. As stated before, the need for absolute evaluation is strong [3].

It is said that absolute evaluation is evaluation according to absolute measures, and that relative evaluation is evaluation that adjust the evaluation points given to numbers of appraisees [4]. Absolute evaluation calls for the establishment of absolute appraisal measure and define where the performance of appraisees falls in the predetermined levels of performance. However, this system is vulnerable to ambiguity of appraisors no matter how accurate the measure itself is. For example, it is possible to define if an appraisee could sell one million yen worth of goods. Yet, the environment that made or did not make this achievement possible has to be taken into account if the system is to make fair judgement.The evaluation system of humans has to have certain degree of flexibility in order to make fair evaluation. The Fuzzy System numerize the result of different evaluation criteria and therefore could be regarded as hybrid between absolute evaluation and relative evaluation.

2. Designing Process of Performance Appraisal Support System

The designing process of performance appraisal support system is based on the designing process of appraisor's evaluation factor structure and performance appraisal process that is defined accordingly. (Refer to Fig.1)[7]

(1) Designing Process of Evaluation Factor Structure

Most appraisors envision interwinded relations among different evaluation factors and do the appraisal accordingly. This model is defined in this paper as mental structure model of appraisors. (A)

To perform subjective appraisal, the evaluation factor and evaluation factor structure that is in the mind of appraisors has to be defined clearly and the mental structure model also has to be defined. (B)

The mental structure models of appraisors are expressed as an evaluation factor matrix. This matrix symbolizes the relation among evaluation factors.

When there are more than one appraisor, there is a need to make appraisals that is based on agreement among all appraisors. This need leads to the necessity of evaluation factor matrix that represents all appraisors. This matrix is called representative evaluation factor matrix.(D)
The elements of evaluation factor matrixes are defined by fuzzy binominal relation of fuzzy theory.

Next, a coefficient that expresses the relation among evaluation factors and fuzzy structure parameter that expresses the ambiguity is defined.(E)
(F) Then, a design algorithm of evaluation factor structure is applied to all appraisors' evaluation factor matrix and representative evaluation factor matrix to establish evaluation factor structure. That means the expression of mental structure model in the form of bar graphs. At the same time, documentation of evaluation factor structure and explanation of it are done. (I) At this time, it is critical to get agreement among appraisors on the representative structure model. If no agreement is made, further discussion on the particular group of evaluation factors on which agreement was not made and the correction of appraisor(s)' evaluation factor matrix may have to be made. For reference, the exposure of the difference between appraisors' evaluation factor structure model and representative factor structure model to all participating appraisors is suggested in (H). The threshold

and the structure parameter would be corrected if need be and utilized to establish evaluation factor structure model by once again applying the design algorithm of evaluation factor structure.

Above cycle has to be repeated until a consenting evaluation factor structure model supported unanimously is established.

(2) Designing of Performance Appraisal System

After evaluation factor structure model for performance appraisal is defined by above mentioned process, the proportion of different evaluation factor has to be defined by utilizing the nature of fuzzy transitive law and factors of evaluation factor matrix.(J)

(R) Appraisors are to select the necessary evaluation factor from evaluation factor structure, do the appraisal according to selected evaluation factors and express the result as performance appraisal matrix. Next, they are to define performance appraisal points according to these performance appraisal determinant. Here the method of getting eigen value and eigen vector by utilizing the theorem of Frobenius and the method of defining the appraisal point to apraisee by using the ratio are adopted.

(L) These results are further integrated to induce the general appraisal point that is the product of all participating appraisors. As the method to integrate the various evaluations that are based on different evaluation factor, (1) the method by multi-attributes appraisal and (2) the method of using fuzzy integral are adopted.

By following these procedures, the appraisal point on evaluation factor by appraisors is defined.

3. Development of Performance Apraisal Support System

This chapter deals with the development of performance appraisal support system based on the design algorithm of performance appraisal support system.

The support system for performance appraisal is developed according to the process shown in Fig. 2. The support system is composed of environmental sub-system with a part for interface with appraisors and performance appraisal support system that is basically a computer driven automatic calculation system as follows.

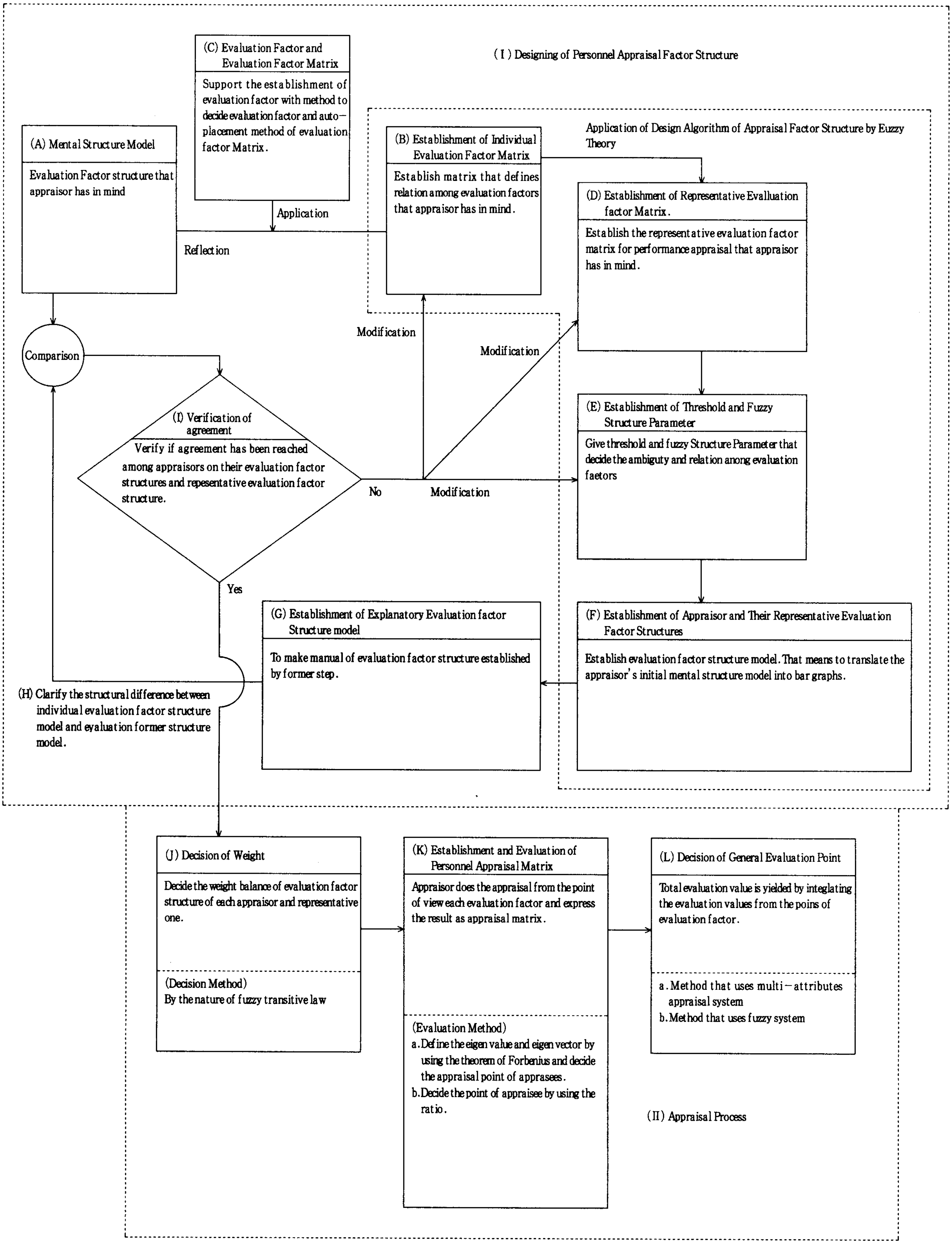

Fig. 1 Designing Process of Performance Factor Support System

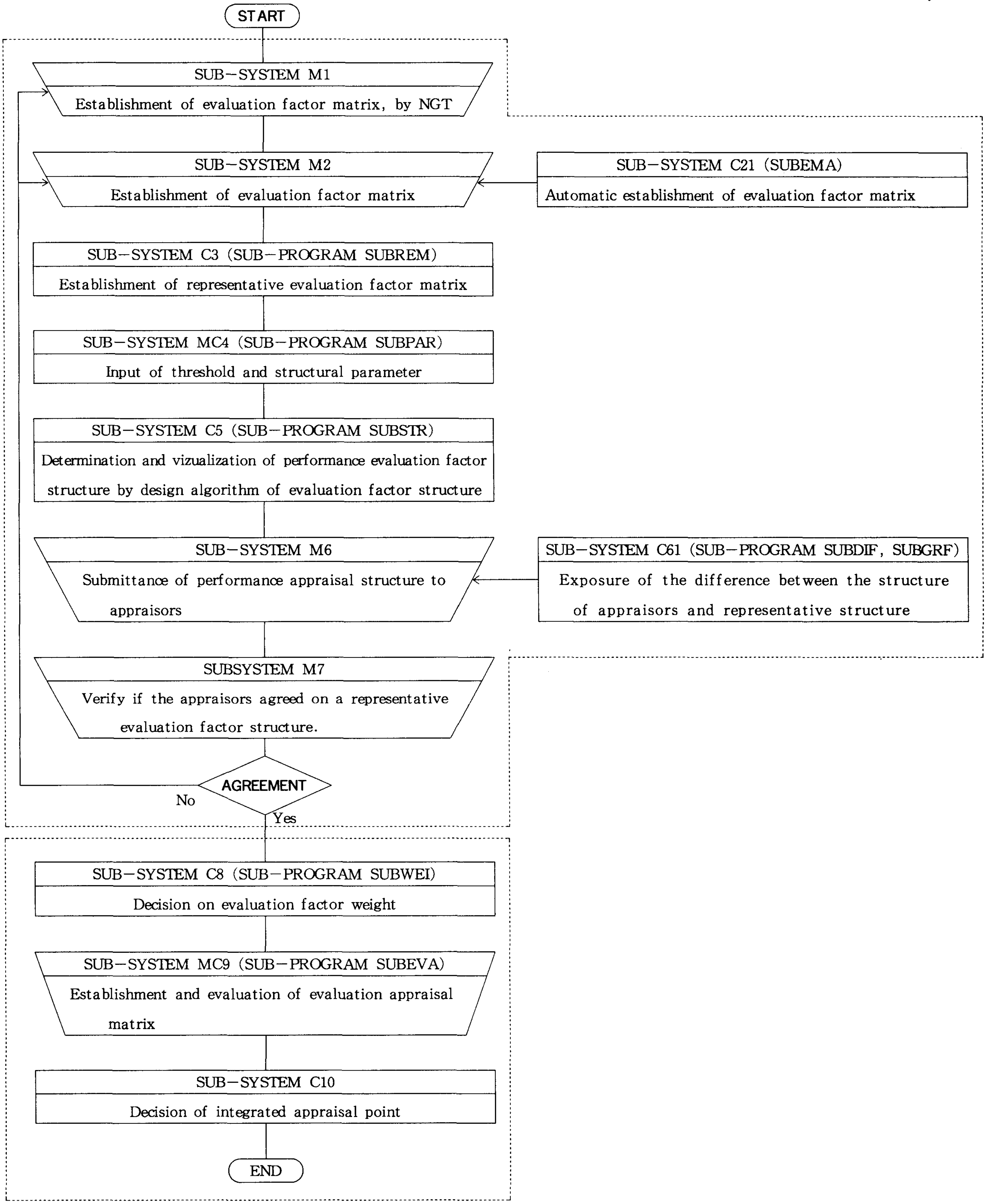

Fig. 2 Development Process of Performance Appraisal Support System

S=(M1, M2, C21, C3, MC4, C5, M6, C61, C62, M7, C8, M9, C10)

,where Mi, (i=1,2,6,7,9) are the factors of environmental sub-system to interface with appraisors.

Ci, (i=21,3,5,61,62,8,10) are the sub-systems for computerized automatic calculation, MC4 is a sub-system for co-existence of computer and appraisors.

Following describes the sub-system from the view points of subject, components, characteristics and mutual relations.

SUB-SYSTEM M1: this is a sub-system to establish evaluation factor of evaluation factor matrix according to NGT method. [8]
The objective of NGT method and its nature could be summerized as follows.

a) To assure to create the ideas for each member of group(appraisors).
b) To balance participation among members.
c) To incorporate mathematical voting techniques in the aggregation of group judgement.

Next, we shall propose the algorithm so as to determine the evaluation factors of the evaluation factor matrix.

Algorithm for the determination of evaluation factors in evaluation factor matrix

Step 1: Preparatory tasks
Preparing the Meeting Room Table Arrangement
Table arranged as an open "U" with a flipchart at the open end of the table.
Sufficient space between group members to avoid interference each other.
Supplies
Flipchart
Worksheets and pencils for each participant
Felt pen
Introducing the Meeting
Welcoming statement
Clarification of the important of each group appraisor's contribution.
Statement of the use or purpose of the meeting's output.
Step 2: Silent generation of evaluation factors in writing.
Step 3: Round - robin recording of evaluation factors on the flipchart.
It is to record the evaluation factors of group members on flipchart visible.
Step 4: Serial discussion for clarification

This is to discuss each factor extracted in Step 3 in turn.

Through serial discussion, the appraisors will come to understand the meaning of factors.

Step 5: Preliminary vote on factors importance

The factors presented in Step 3 is put in order by making use the worksheet in Fig. 3 with rank-ordering, where Fig. 3 is the rating and rank-order form for NGT voting to formulate the evaluation factors of the evaluation factor matrix.

Step 6: Discussion of the preliminary vote

The purpose of the discussion is to examine inconsistent voting patterns and to provide for the opportunity to rediscuss factors which are perceived as receiving too many or too few votes.

Step 7: Final vote

This vote combines individual judgments into a group decision.

It is to determine the outcome of meeting, to provide a sense of closure an accomplishment and to document the group judgment.

By making use of the algorithm mentioned above, the evaluation factor terms can be determined.

Moreover, the values of elements of the matrix representing the subordination relations between evaluation factors are given on the basis of the result obtained by the following question.

Question : "How much grade does the term sj have influence on the evaluation factor si, from a certain aspect?"

We should, however, establish the more concretive aspect in practice. The worksheet so as to determine the values of elements of the evaluationfactor matrix is shown in Fig. 4.

It shows the worksheet so as to constitute the individual evaluation factor matrixes concerning evaluation factor determined on the basis of the algorithm mentioned above.

In this case, the subordination relations relating to twelve terms are shown in the worksheets.

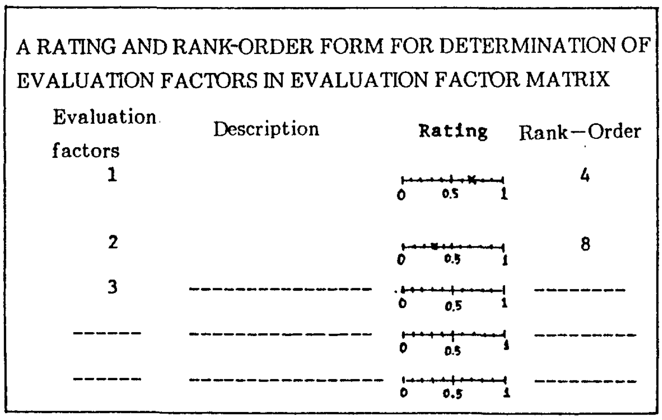

Fig. 3 Worksheet to Determine Elements of Evaluation Factor Matrix

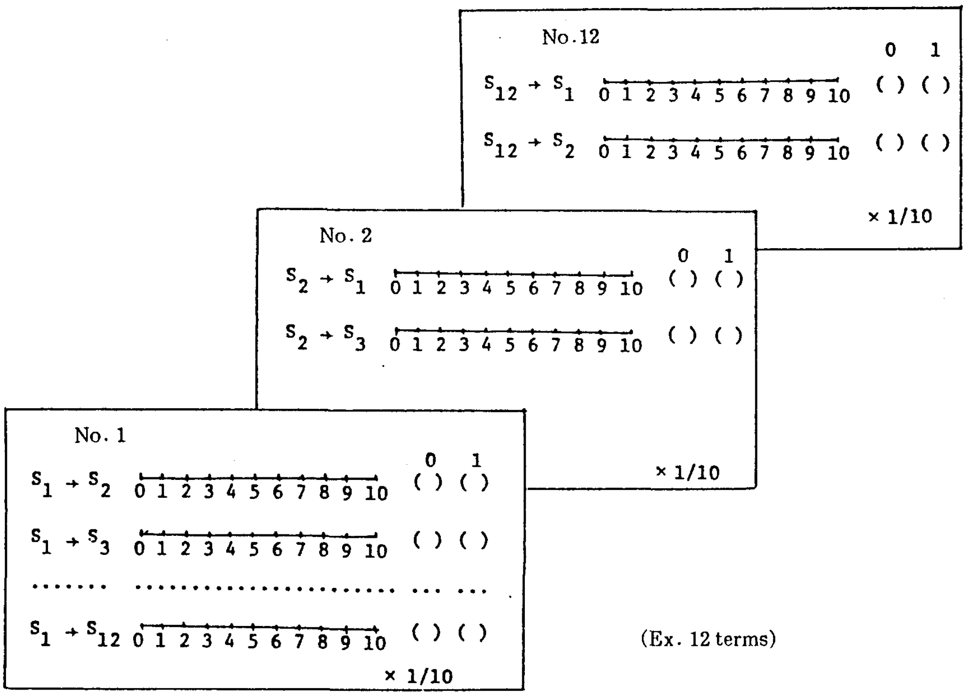

Fig. 4 Worksheet for Determination Evaluation Factor Matrix

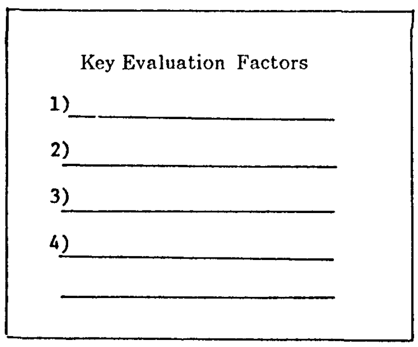

Fig. 5 Worksheet to Extract Evaluation Factors in Evaluation Factor Matrix

For example, the worksheet No.1 is one so as to represent the subordination relations between the factors s1 and the other factors.

Each relation in terms of its influence is rated on the 0−10 scale, with 0 being uninfluential,and 10 being very strongly influential. Moreover it also shows the numerical value 0 or 1 with a paired comparison written in addition on it.

From this, a representative evaluationfactor matrix which will be able to yield a representative structure model can be given by arithmetical mean value of individual member's one of group.

SUB-SYSTEM M2 : This is a sub-system that appraisors use to compile theevaluation factor matrix. This system is supported by sub-system C21 (sub-program SUBEMA) which automatically produces evaluation factor matrix.

Generating Method of Evaluation Factor Matrix

It is very expensive and troublesome to get the matrix by virtue of only the discussion of persons concerned with an objective problem.

In order to save such a difficulty and automatically determine the unknown entries of the matrix, we propose a generating method under the assumption that a part of the entries are known. [6]

Let $A(p')=[a_{ij}]$ be a $n\times n$ evaluation factor matrix, where a threshold p' must be given in advance.

We compute power matrices $A^i(p')$ of $A(p')$ and put A^* as follows;

$$A^* = \bigvee_{i=1}^{n} A^i \ (p') \qquad (1)$$

On the basis of A^*, any entries $a_{k\ell}$ and $a_{\ell k}$ of $A(p')$ may be determined by the following rules, where the fuzzy semi-transitive law is held in A^*.

Rule 1 : From the fuzzy semi-transitive law, let $e=\vee(a^*_{km} \wedge a^*_{m\ell}) \geq p'$ for any a^*_{km} and $a^*_{m\ell}$ $(k\fallingdotseq \ell)$ in A^*, then $a^*_{k\ell} \geq e$ is held. If $a_{k\ell}$ is unknown, then $a_{k\ell}$ is replaced with $a_{k\ell}$. When $a_{k\ell}$ is known, $a_{k\ell}$ is kept in the matrix without replacing with $a^*_{k\ell}$.

Rule 2 : When $a_{k\ell}$ is replaced with $a^*_{\ell k}$ according to the rule 4, a symmetric entry $a^*_{k\ell}$ is determined as follows;

(1) When $a_{\ell k}$ is unknown, $a_{\ell k}$ is replaced with $a^*_{\ell k}$.

(2) When $a_{\ell k}$ is known, $a_{\ell k}$ is kept in the matrix.

Next, we propose an automatic generating algorithm of evaluationfactor matrix on the basis of the rules described above.

Generating Algorithm

Step 1 Give the number of factors, n composing the system objects and a threshold p' to formulate the evaluation factor matrix.

Step 2 Give the diagonal entries satisfying the fuzzy irreflexive law.

Step 3 Give the evaluation factor relations to a part of entries of evaluation factor matrix $A(p')$ except the diagonal entries.

Step 4 Compute the power matrices $\{ A^k (p')\}$ for $A(p')$ and give a logical sum A^* as follows;

$$A^* = [a^*_{ij}]_{n \times n} = \bigvee_{k=1} A^k \ (p') \qquad (2)$$

Step 5 Determine $a_{k\ell}$ and $a_{\ell k}$ corresponding to $a^*_{k\ell}$ and $a^*_{\ell k}$ where $a^*_{k\ell} \vee a^*_{\ell k} \geqq p'$ in A^*.

(1) When $a_{\ell k}$ and $a_{k\ell}$ are unknown in $A(p')$, they are replaced with $a^*_{\ell k}$ and $a^*_{k\ell}$, respectively.

(2) When $a_{\ell k}$ and $a_{k\ell}$ are known in $A(p')$, they are kept in $A(p')$.
On the other hand, if $a^*_{k\ell} \vee a^*_{\ell k} < p'$ in A^*, $a_{k\ell}$ and $a_{\ell k}$ are kept in $A(p')$.

Step 6 If all of the entries of $A(p')$ are filled with the evaluation factor relations, this procedure terminates. Otherwise, the entries determined in Step 5 are cancelled from $A(p')$, and give the subordination relations to known entries in $A(p')$. Return to Step 4.

SUB−SYSTEM C3: This system produces the respresentative evaluation factor matrix out of evaluation factor matrix of all appraisors. The system is sub-program SUBREM, which works as follows. First, the evaluation factor matrix of "k"th appraisor, which consists of "n" factors is defined as follows.

$$A_k = [a_{ij}{}^k]_{n \times n} \qquad (3)$$

Next, the representative evaluation factor matrix is defined as

$$A = 1/n \left[\sum_{k=1}^{n} a^k_{ij} \right]_{n \times n} \qquad (4)$$

SUB−SYSTEM MC4: This is a sub-system for input of threshold "p" which defines the inter-relations among evaluation factors and the structure parameter λ, which defines the ambiguity among factors. These two figures are continuously adjusted until the agreement on the structure is made. Initial figure is generated automatically by computer but appraisors can feed adjusted figures later on. In computer, the system works as sub-program SUBPAR, which functions semi-automatically.

SUB−SYSTEM C5: This system is to produce and visualize performance evaluationfactor structure. On computer, the system is sub-program SUBSTR and has following contents.

Let S be a set of personnel evaluation factors s_i ,i=1,2,....,n.

$$S = \{s_1, s_2, s_3, \ldots, s_n\} \quad (5)$$

We formulate the evaluation factor matrix of appraisor from an aspect of relationship " the means to the purpose" as shown in eq. (6).

$$F = \begin{array}{c} \\ s_1 \\ s_2 \\ \cdot \\ s_i \\ \cdot \\ s_n \end{array} \begin{array}{c} \begin{array}{cccccc} s_1 & s_2 & \cdot & s_j & \cdot & s_n \end{array} \\ \begin{pmatrix} f_{11} & f_{12} & \cdot & f_{1j} & \cdot & f_{1n} \\ f_{21} & f_{22} & \cdot & f_{2j} & \cdot & f_{2n} \\ \cdot & \cdot & \cdot & \cdot & \cdot & \cdot \\ f_{i1} & f_{i2} & \cdot & f_{ij} & \cdot & f_{in} \\ \cdot & \cdot & \cdot & \cdot & \cdot & \cdot \\ f_{n1} & f_{n2} & \cdot & f_{nj} & \cdot & f_{nn} \end{pmatrix} \end{array} \quad (6)$$

where the f_{ij} shows to what degree the means factor s_i contributes to the purpose factor s_j and $0 \leqq f_{ij} \leqq 1, (i,j=1,2,\ldots,n)$. The algorithm to identify the structure of personnel evaluation factors is given by applying the fuzzy structural modeling (FSM) method as follows.[6] [7]

ALGORITHM TO IDENTIFY THE STRUCTURE OF PERSONNEL EVALUATION FACTORS

Step 1: Modification of the evaluation factor matrix

Modify the evaluation factor matrix so as to satisfy the irreflexive law, the asymmetric law and the semi-transitive law in the current evaluation factor matrix F. Here in order to determine the relationship "whether or not the means factor contributes to the purpose factor", a threshold $p, (0 < p \leqq 1)$ is introduced, The p is called the structure parameter.

Step 2: Determination of the group level of evaluation factors

Each of evaluation factors belongs to each of the following group levels. It shows that si(a means)does not contribute to sj(a purpose), when $f_{ij} < p$.

Step 3: Formulation of the hierarchy matrix

For the evaluation factors belonging to the L_t , L_b and L_i obtained in Step 2, the following operations are carried out:

(a) The row of the evaluation factors belonging to L_b is eliminated from the evaluation factor matrix F;

(b) The column of the evaluation factors belonging to L_i are eliminated from the evaluation factor matrix F;

(c) Both the row and column of the evaluation factors belonging to L_i are eliminated from the factor evaluation matrix F.

The matrix obtained after the operations mentioned above is called the hierarchy matrix F'.

Step 4: Construction of the structure of evaluation factors.

Set up parameter λ which expresses uncertainty between the evaluation factors from the aspect of " the means to the purpose". If there is the regular row s_j of s_k, the s_j row is eliminated by replacing [a.k] with $[a._k^*]$, obtained after the following calculations:

$$[a._k^*] = [a._k] \wedge [\bar{a}._j] \qquad (7)$$

$$[\bar{a}._j] = (1 - [a._j])/(1 + \lambda[a._j]) \qquad (8)$$

where the bar symbol over the a denotes the complement of a. The regular row is defined by " if there is only s_j such that $a_{ij} \geq p$, the row s_j is the regular row". The flowchart for this procedure is shown in Fig.6.

SUB−SYSTEM M6: Provide appraisors with comparison of performance evaluation factor structure of themselves and representative performance evaluation factor structure as data to make agreement, sus-system C61 supports M6.

SUB−SYSTEM C61: Provide appraisors with the degree of difference between their evaluation factor structure and representative evaluation factor structure. Also has the function to display the difference. The system consists of sub - programs SUBDIF and SUBGRF. They work as follows.

Disagreement Grade between Representative and Individual Evaluation Factor Structures and its Influence on an Evaluation Factor Structure With Consensus

We calculate the disagreement grade concerning structure between the representative and individual evaluation factor structures.

We reflect the degree of grade on modifying the evaluation factor matrix which yields a representaive evaluation factor structure in the process constituting a consensus of group members.

We take it as assistant so as to more effectively obtain an evaluation factor structure with consensus.

Now, let A be the evaluation factor matrix such that

$$A = \begin{array}{c} \\ s_1 \\ s_2 \\ \cdot \\ s_n \end{array} \begin{array}{c} \begin{array}{ccccc} s_1 & s_2 & \cdots & & s_n \end{array} \\ \begin{pmatrix} a_{11} & a_{12} & \cdots & a_{1n} \\ a_{21} & a_{22} & \cdots & a_{2n} \\ \cdot & \cdot & a_{ij} & \cdot \\ a_{n1} & a_{n2} & \cdots & a_{nn} \end{pmatrix} \end{array}, \quad 0 \leqq a_{ij} \leqq 1 \quad i,j=1,\ldots,n \qquad (9)$$

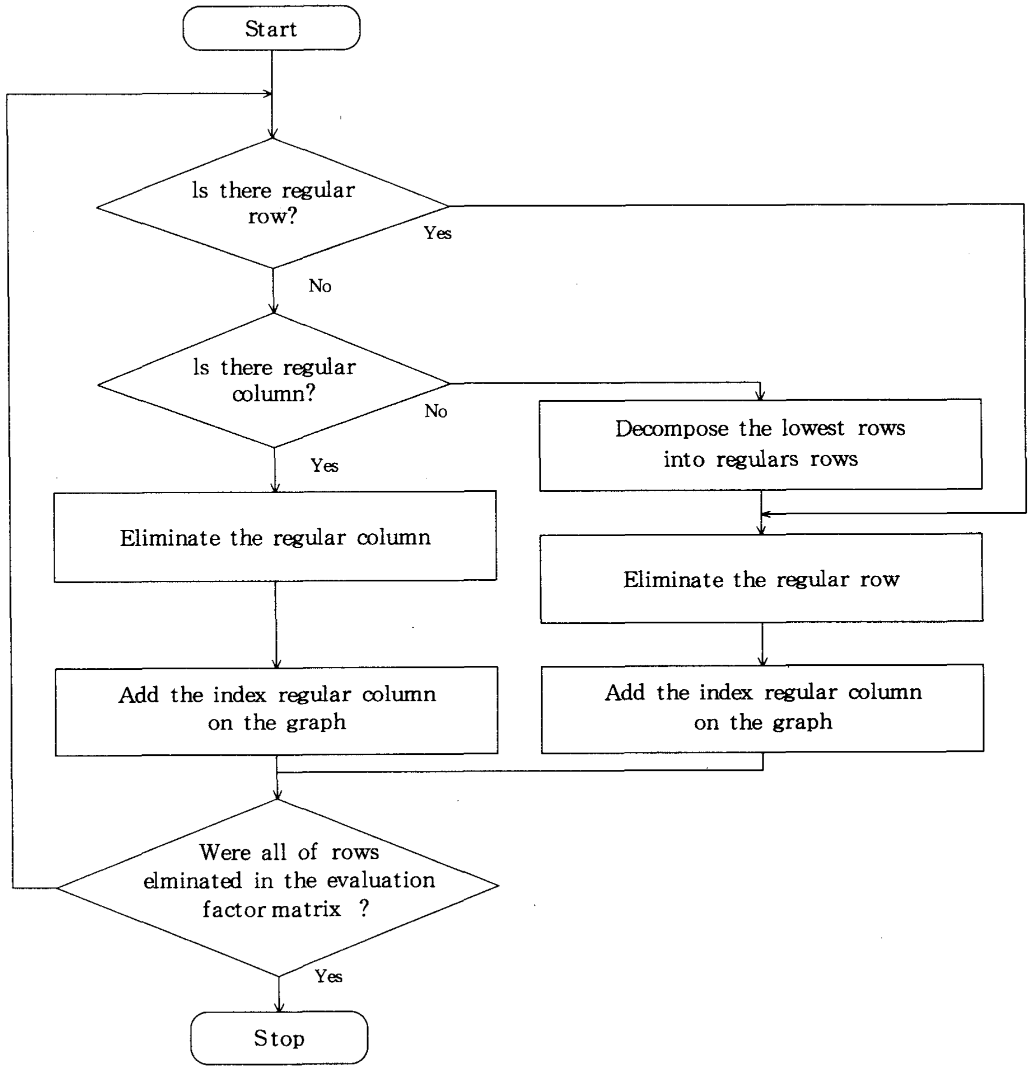

Fig.6 Flow-chart to obtain the evaluationfactor structure

Let the transpose of A be the fuzzy adjacent matrix M_f .

$$M_f = \begin{pmatrix} a_{11} & a_{21} & \cdots & a_{n1} \\ a_{12} & a_{22} & \cdots & a_{n2} \\ \cdots & \cdots & a_{ji} & \cdots \\ a_{1n} & a_{2n} & \cdots & a_{nn} \end{pmatrix} \qquad (10)$$

where the element a_{ij} of M_f is considered as the grade which s_i may win over s_j in victory or defect table of tournament.

Conversly, if p becomes smaller, then the subordination relation is more increasing. This fact implies that the strongly connected set may increase in the structural model.

In such a mean, the fuzzy adjacent matrix will be considered as a kind of extension of the tournament.

Let $e=(1,1,\dots,1)^t$, then the fuzzy victory point vector of k order, $w^{(k)}$ is given as follows:

$$w^{(k)} = (w_1, w_2, \dots, w_n) = M_f^{(k)}.e \tag{11}$$

where w_i, $(i=1,2,\dots,n)$ means contribution grade of factor for the structural model obtained by making use of the FSM.

The strongly connected fuzzy adjacent matrix M_f becomes a primitive one.
Suppose that μ is the maximum real eigen value of M_f, and y positive eigen vector corresponding to μ.
Then, from Frobenius's theorem, the following expression is held.

$$\lim_{k\to\infty} (M_f / \mu)^k \cdot e = y \tag{12}$$

where $y=(y_1, y_2, \dots, y_n)^t$ and the element y_i $(i=1,2,\dots,n)$ means the grade representing level of evaluation factor. We call it "contribution grade" after this.
Corresponding to the degree of the contribution grade, we call the fuzzy eigen vector y the contribution grade vector. And y can be expressed as a normalized relative contribution of factor to the structural model as follows:

$$\sum_{i=1}^{n} y_i = 1,\ 0 \le y_i \le 1 \tag{13}$$

Difference with respect to contribution grade between representative and individual evaluation factor structure

Let

$$H = (h_1, h_2, \dots, h_n),\ 0 \leqq h_j \leqq 1 \quad j=1,\dots,n \tag{14}$$

$$K_i = (k_{i1}, k_{i2}, \dots, k_{in}),\ 0 \leqq k_{ij} \leqq 1 \tag{15}$$

$$i=1,2,\dots,\ell \qquad j=1,2,\dots,n$$

where H is a contribution grade vector for the representative evaluation factor structure and K_i a contribution grade vector for the i-th individual evaluation factor structure.
Then we define two functions with respect to the difference of contribution grade for each corresponding term between H and K_i as follows:

a) $V_{1i} = \max | h_i - k_{ij} | \quad i=1,2,\dots,n$ (16)

b) $V_{1i} = (\sum_{j=1}^{n} | h_j - k_{ij} |)/2$ (17)

where a dominator "2" can be derived as follows:

$$\max(\sum_{j=1}^{n} | h_j - k_{ij} |) = 2 \tag{18}$$

It is clear that each of Defs.(16) and (17) satisfies $0 \le V_{1i} \le 1$.
Each V_{1i} is defined as an index to the degree of disagreement concerning with the structure between individual and the representaive evaluation factor structures.

Hence, it will be seen that the more the value of V_{1i} closes to zero, the more the disagreement grade with respect to the structure between individuals and a representative structure is small. Conversly, the more the disagreement between them closes to 1, the more the disagreement is large.

Difference with respect to the order of evaluation factors between representative and individual evaluation factor structure

We arrange the elements of H with respect to the representative structure in order of largeness. Then, corresponding to the above arrangement, the elements of K_i for the individual structure are also arranged at the same time.

Further, we get the number of transposition I_i (g) which occurs in the contribution grade vector for the individual structure.

A function as the index which shows the grade of disagreement of factors between H and K_i on the basis of the number of transpositions is given as follows:

$$V_{2i} = I_i(g) \sum_{j=1}^{n} j, \quad i=1,2,\ldots,n \tag{19}$$

where j is a maximum number of transposition in the contribution grade vector for the individual structure and it is clear to satisfy $0 \leqq V_{2i} \leqq 1$.

Disagreement of the subordination relation concerning factors of respresentative and individual evaluation factor structures

Now, let

$$A_H = \begin{pmatrix} a_{11}^h & a_{12}^h & \cdots & a_{1n}^h \\ a_{21}^h & a_{22}^h & \cdots & a_{2n}^h \\ \cdots & \cdots & \cdots & \cdots \\ a_{n1}^h & a_{n2}^h & \cdots & a_{nn}^h \end{pmatrix} \tag{20}$$

$$A_k = \begin{pmatrix} a_{11}^k & a_{12}^k & \cdots & a_{1n}^k \\ a_{21}^k & a_{22}^k & \cdots & a_{2n}^k \\ \cdots & \cdots & \cdots & \cdots \\ a_{n1}^k & a_{n2}^k & \cdots & a_{nn}^k \end{pmatrix}, \quad k=1,2,\ldots,\ell \tag{21}$$

where A_H is the fuzzy semi-reachability matrix yielding a representative structure and A_k the fuzzy semi-reachability matrix which is able to yield the individual structure.

An index ℓ in A_k shows ℓ-th appraisor.

Then the number of agreement, θ_i of individual structure against the representative one is given with the number of subordination relations such that

$a_{ij}{}^{h} \geqq p$ and $a_{ij}{}^{k} \geqq p$

or

$a_{ij}{}^{h} < p$ and $a_{ij}{}^{k} < p$

Moreover, the membership function Θ with respect to the agreement θ_i is given as follows:

$$\Theta_i = \theta_i / n^2 \qquad i=1,2,\ldots,\ell \qquad (22)$$

where "n^2" in eq.(22) shows the maximum number of subordination relations. It is clear that $0 \leqq \Theta_i \leqq 1$.

On the basis of eq.(22), an estrangement parameter representing how much grade the individual structural model disagrees to the representative one is defined as follows:

$$V_{3i} = 1 - \Theta_i \qquad i=1,2,\ldots,\ell \qquad (23)$$

A total estrangement parameter ε of individual structural model against the representative one is expressed by integrating the three factors V_{1i}, V_{2i} and V_{3i} described above as follows:

$$\varepsilon_i = \rho_1 V_{1i} + \rho_2 V_{2i} + \rho_3 V_{3i} \qquad i=1,2,\ldots,\ell \qquad (24)$$

where $\sum_{i=1}^{3} \rho_i = 1 \quad 0 \leqq \rho_i \leqq 1$.

In general, the weight ρ_i, $(i=1,2,3)$ should be subjectively given through the discussion about system characteristics.

SUB - SYSTEM M7 : This sub-system decides if agreed structure was formed, with the support of sub - systems M6 and C61

SUB - SYSTEM C8 : This sub-system defines the proportion of importance among evaluation factors of appraisors' evaluation factor structure. It is sub - program SUBWEI and works as follows.

We suppose that the consenting structure of evaluation factors with q levels for the appraisors is identified as shown in Fig.7 from the algorithm described in sub-system C5.

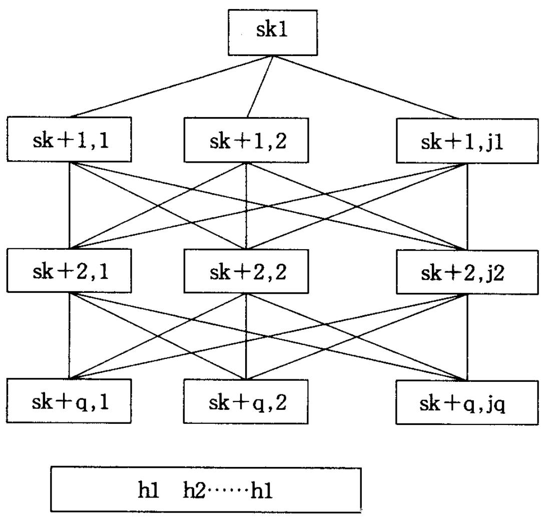

Fig.7 Consenting structure of evaluation factors with q ievels

where S is the set of personnel evaluation factors and it is shown as follows;

$$S=\{s_{k1}\ ,\ s_{k+1,1},\dots s_{k+1,j1}\ ,\ s_{k+2,1}\ ,\dots,s_{k+2,j2}\ ,\dots,s_{k+q,1},\dots s_{k+q,jq}\ \} \tag{25}$$

The set of subjects, H is as follows,

$$H=\{h_1\ ,h_2\ ,\dots,h_\ell\} \tag{26}$$

Let's Fr be the evaluation factor matrix to derive the structure of evaluation factors shown in Fig. 7. Then the degrees of importance (contribution degrees) of evaluation factors belonging to k-th level are yielded by eqns.(27),(28).

$$w_i^k=\sum_{j\in J^{k-1}} w_j^{k-1}\cdot f_{ij}^{k'} \tag{27}$$

$$f_{ij}^{k'}=f_{ij}^k\Big/\sum_{m\in K} f_{mj}^k\quad ,j\in J^{k-1} \tag{28}$$

where the symbol j^{k-1} is the set of subscripts for the evaluation factors of k-1th level to which the i-th evaluation factor of k-th level, si contributes.

w_j^{k-1} shows the degrees of importance contributing to the evaluation factors of k-1th level. f_{ij} shows the grade of which the i-th evaluation factor of k-th level, s_i^k contributes to s_j and is normalized. K is a set of subscripts for the evaluation factor of k-th level, From this, we can get the degrees of importance (contribution degrees) of evaluation factors in each level. Further we re-denote wi obtained by eq.(27) as follows.

$$wi=w_i^k\ \ (\ i=1,2,\dots,\ q\ ) \tag{29}$$

On the basis of the weights of evaluation factors in eq.(27).

SUB - SYSTEM MC9: Appraisors do appraisal according to evaluation factors and express the result in the form of matrixes. This system compiles the matrixes using the program SUBEVA and establishes appraisee's evaluation according to follows.

[Evaluation Methods]

(1) By applying theorem of Forbenius to performance evaluation factor matrixes, maximum real eigen value and its eigen vector are defined and hence appraisal point of an appraisee is defined. We evaluate the ℓ subjects. We formulate the personnel evaluation matrices $F_{k+i,l}$,$F_{k+i,2}$, . . . , $F_{k+i,ji}$ from the view point of evaluation factors ($s_{k+i,l}$,$s_{k+i,2}$, . . . ,$s_{k+i,ji}$) in i-th level of the structure of evaluation factors as follows.

$F_{k+i,1}$ =

$s_{k+i,1}$	h_1	h_2	$\cdots$	h_l
h_1	f_{11}^1	f_{12}^1	$\cdots$	f_{1l}^1
h_2	f_{21}^1	f_{22}^1	$\cdots$	f_{2l}^1
$\vdots$	$\vdots$	$\vdots$		$\vdots$
h_l	f_{l1}^1	f_{l2}^1	$\cdots$	f_{ll}^1

$$F_{k+i,2} = \begin{array}{c|cccc} s_{k+i,2} & h_1 & h_2 & \cdots & h_l \\ \hline h_1 & f_{11}^{2} & f_{12}^{2} & \cdots & f_{1l}^{2} \\ h_2 & f_{21}^{2} & f_{22}^{2} & \cdots & f_{2l}^{2} \\ \vdots & \vdots & \vdots & & \vdots \\ h_l & f_{l1}^{2} & f_{l2}^{2} & \cdots & f_{ll}^{2} \end{array}$$

$$\vdots$$

$$F_{k+i,ji} = \begin{array}{c|cccc} s_{k+i,ji} & h_1 & h_2 & \cdots & h_l \\ \hline h_1 & f_{11}^{ji} & f_{12}^{ji} & \cdots & f_{1l}^{ji} \\ h_2 & f_{21}^{ji} & f_{22}^{ji} & \cdots & f_{2l}^{ji} \\ \vdots & \vdots & \vdots & & \vdots \\ h_l & f_{l1}^{ji} & f_{l2}^{ji} & \cdots & f_{ll}^{ji} \end{array}$$

where the matrix $F_{k+i,ji}$ shows the evaluation among the subjects h_1 ,h_2 ,..., h_ℓ from the viewpoint of evaluation factor $s_{k+i,ji}$. The element f_{ij} of $F_{k+i,ji}$ is subjectively given by the fuzzy binary relation. It shows the grade which the h_i is prefered to h_j .

For the personnel evaluation matrix $F_{k+i,ji}$, the following operation is carried out.

$$W^{(n)}_{k+i,ji} = F^{(n)}_{k+i,ji} \cdot \mathbf{e} \tag{31}$$

where $\mathbf{e} = (1,1,....,1)^t$ and the t denotes transposition.

That is,

$$F^1=F,\ F^2=F^1\times F^1,\ F^3=F^1\times F^2, ...,F^n=F^1\times F^{n-1} \tag{32}$$

Further, F^n is the personnel evaluation matrix of n degree. As it is known that the strongly connected matrix is the primitive one, the following operation can be carried out from Frobenius' theorem. Let μ be the greatest eigen value of $F_{k+i,ji}$, and $E_{k+i,ji}$ be the eigen vector of $F_{k+i,ji}$ corresponding to μ. Then the following expression holds.

$$\lim_{n\to\infty}(F_{k+i,ji}/\mu)^n \cdot \mathbf{e} = E_{k+i,ji} \tag{33}$$

Therefore, the degrees of importance can be represented for each subject with the eigen vector $E_{k+i,ji}$.

Here, we denote the evaluation value for the subjects as follows.

$$\begin{aligned} E_{k+i,1} &= (E^1_{h1}\ ,\ E^1_{h2}\ ,\ ....,E^1_{hl}\ ) \\ E_{k+i,2} &= (E^2_{h1}\ ,\ E^2_{h2}\ ,\ ....,E^2_{hl}\ ) \\ &\vdots \\ E_{k+i,ji} &= (E^{ji}_{h1}\ ,\ E^{ji}_{h2}\ ,\ ....,E^{ji}_{hl}\ ) \end{aligned} \tag{34}$$

Eq.(34) is also written as follows.

$$E=[E_{k+i,1}^{t}, E_{k+i,2}^{t}, \ldots, E_{k+i,ji}^{t}] \tag{35}$$

(2) Appraisee's evaluation point can be also defined by using ratio. For example, assume that performance appraisal matrix of factor $s_{k+i,j}$ is $F_{k+i,j}$.

In eq.(30), if we assume all of diagonal elements are zeros and compare the reminder that eq. (36) stands.

$$F_{k+i,j} = \begin{array}{c|cccccc} s_{k+i,j} & h_1 & h_2 & h_3 & \cdots & h_{\ell-1} & h_\ell \\ \hline h_1 & 0 & f_{12}^j & - & \cdots & - & - \\ h_2 & f_{21}^j & 0 & f_{23}^j & \cdots & - & - \\ \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots \\ h_{\ell-1} & - & - & - & \cdots & 0 & f_{\ell-1,\ell}^j \\ h_\ell & - & - & - & \cdots & f_{\ell,\ell-1}^j & 0 \end{array} \tag{36}$$

,where $0 \leqq f_{i,i+1}^j \leqq 1$ and corresponding symmetrical element can be expressed by

$$f_{i+1,i}^j = 1 - f_{i,i+1}^j \tag{37}$$

At this time, appraisor"h_i"'s appraisal point E_{hi}^j, (i=1,2,..., ℓ) can be expressed as follows:

$$\begin{aligned} E_{h1}^j &: E_{h2}^j = f_{12}^j : f_{21}^j \\ E_{h1}^j &: E_{h3}^j = f_{23}^j : f_{32}^j \\ &\vdots \\ E_{hk}^j &: E_{hk+1}^j = f_{k,k+1}^j : f_{k+1,k}^j \\ &\vdots \\ E_{h\ell-1}^j &: E_{h\ell}^j = f_{\ell-1,\ell}^j : f_{\ell,\ell-1}^j \end{aligned} \tag{38}$$

, where $f_{i+1,i}^j = 1 - f_{i,i+1}^j \quad (i=1, 2, \cdots, k, \cdots, \ell)$

The ratio among appraisors can be shown in eq. (39).

$$\begin{aligned} E_{h1}^j &= \prod_{i=1}^{\ell-1} f_{i,i+1}^j \\ E_{h2}^j &= \prod_{i=2}^{k-1} f_{i,i+1}^j - E_{h1}^j \\ &\vdots \\ E_{hk}^j &= \prod_{i=1}^{k-1}(1-f_{i,i+1}^j)\prod_{i=k}^{\ell-1} f_{i,i+1}^j \\ &\vdots \\ E_{h\ell}^j &= \prod_{i=1}^{\ell-1}(1-f_{i,i+1}^j) \end{aligned} \tag{39}$$

These figures are the evaluation points on $s_{k+i,j}$ of appraisees.

SUB - SYSTEM M10: This system summarizes a single appraisor's evaluation points on different elements. One method to do so is multi-attributes evaluation method. [10] The other is a method to apply fuzzy integral calculus. [12]

(1) Multi-attributes evaluation method

This method defines the points of different elements (that were calculated by sub-system MC 9) with multi-attributes evaluation.

Let $E_{k+i,ji}$ be the largest real eigen vector for $F_{k+i,ji}$, which shows the evaluation value of appraisee from the view point of $s_{k+i,ji}$.

$$\begin{aligned} E_{k+i,1} &= (E_{h1}^{1}, E_{h2}^{1}, \cdots, E_{h\ell}^{1}) \\ E_{k+i,2} &= (E_{h1}^{2}, E_{h2}^{2}, \cdots, E_{h\ell}^{2}) \\ &\vdots \\ E_{k+i,ji} &= (E_{h1}^{ji}, E_{h2}^{ji} \cdots, E_{h\ell}^{ji}) \end{aligned} \quad (40)$$

we express them by making use of vector notation as follows.

$$E=[E_{k+i,1}^{t}, E_{k+i,2}^{t} \cdots, E_{k+i,ji}^{t}] \quad (41)$$

Further we compute Hw for the sake of ordering the appraisee from the view point of evaluation factor in i - th level as follows.

$$Hw = E \cdot Wi \quad (42)$$

where $Hw = (h_w^1, h_w^2, \cdots, h_w^{\ell})^t$.

(2) Fuzzy integral calculus method

When a set of evaluation factors is $S(=\{s_1, s_2, \ldots, s_n\})$ and appraisal point of appraisee "hi" on s_j, $(j=1,2,\ldots,n)$ is $E_{hi}(s_j)$,

then $E_{hi}^{j} = E_{hi}(s_j)$

Assuming that the appraisal point E_{hi}^{j} on S fulfills

$$E_{hi}^{1} \geqq E_{hi}^{2} \geqq \cdots \geqq E_{hi}^{n} \quad (43)$$

and that the importance of evaluation factor s_j is $g_j = g(s_j), (j=1,2,\ldots,n)$, then the total appraisal point of appraisee "hi"should be expressed with fuzzy integral calculus.

$$\int_S E_{hi}^{i} \circ g(s_j) = \bigvee_{j=1}^{n} [E_{hi}(s_j) \wedge g(s_j)] \quad (44)$$

, where $S_j = \{s_1, s_2, \cdots, s_j\}$

However, fuzzy measure for $\forall S' \subset S$ has to be identified in order to get the total point shown in eq. (44).

when the fuzzy distribution function is expressed as follows,

$$H(s_1) \leqq H(s_2) \leqq \cdots \leqq H(s_n) = 1 \tag{45}$$

and

$$g_\lambda(S_j) = H(s_j) \tag{46}$$

Assuming that

$$g_1 = H(s_1)$$
$$g_j = \{H(s_j) - H(s_{j-1})\} / (1 + \lambda H(s_{j-1})), 2 \leqq j \leqq n \tag{47}$$

$g_\lambda(s')$ for $S' \subset S$ is given by

$$g_\lambda(s') = \frac{1}{\lambda}[\prod_{sj \in S'}(1 + \lambda g_j) - 1] \tag{48}$$

From this,we can get the $g_\lambda(s')$ for any subset S′of S from the g_λ defined on $S_1 \subset S_2 \subset \cdots \subset S_n = S$ that is $H(s_j)$.

Algorithm to determine the total evaluation value by Fuzzy Integral

Step 1. Reorganize performance appraisal points E^j_{hi} ,$(j=1,2,\cdots,n)$ from smallest to largest.
Step 2. Get the fuzzy distribution function from following equations

$$H(s_j) = g_j + H(s_{j-1}) + \lambda g_j\ H(s_{j-1}),\ H(s_1) = g_1$$

Step 3. Get the integrated evaluation point h^i_w from the following equation.

$$h^i_w = \bigvee_{j=1}^{n}[E^j_{hi} \wedge H(s_j)]$$

By the algorithm mentioned above, total performance appraisal point of appraisee that consists of evaluation on all elements are defined.

4. Process to Apply Fuzzy Appraisal System

With cooperation of company A, we actually introduced the system. Following shows the procedure to introduction.

(1) Deciding the department and appraisors

Four employees at personnel department were chosen as appraisees and four managers of the same department were chosen as appraisors.

(2) Explanation of the system

We had a meeting to explain the structure and method of application of the system with the would be appraisors. We also had time for questions and answers. In the meeting, explanation on the outline of the system, and particulary on its difference from the current appraisal system was made.

(3) Deciding Evaluation Factor Structure

Two different approaches were made. One was to use the current evaluation factor of the company A and the other was to construct new evaluation factor structure upon agreement among appraisors.

The different evaluation factor structure is shown in Fig. 7.

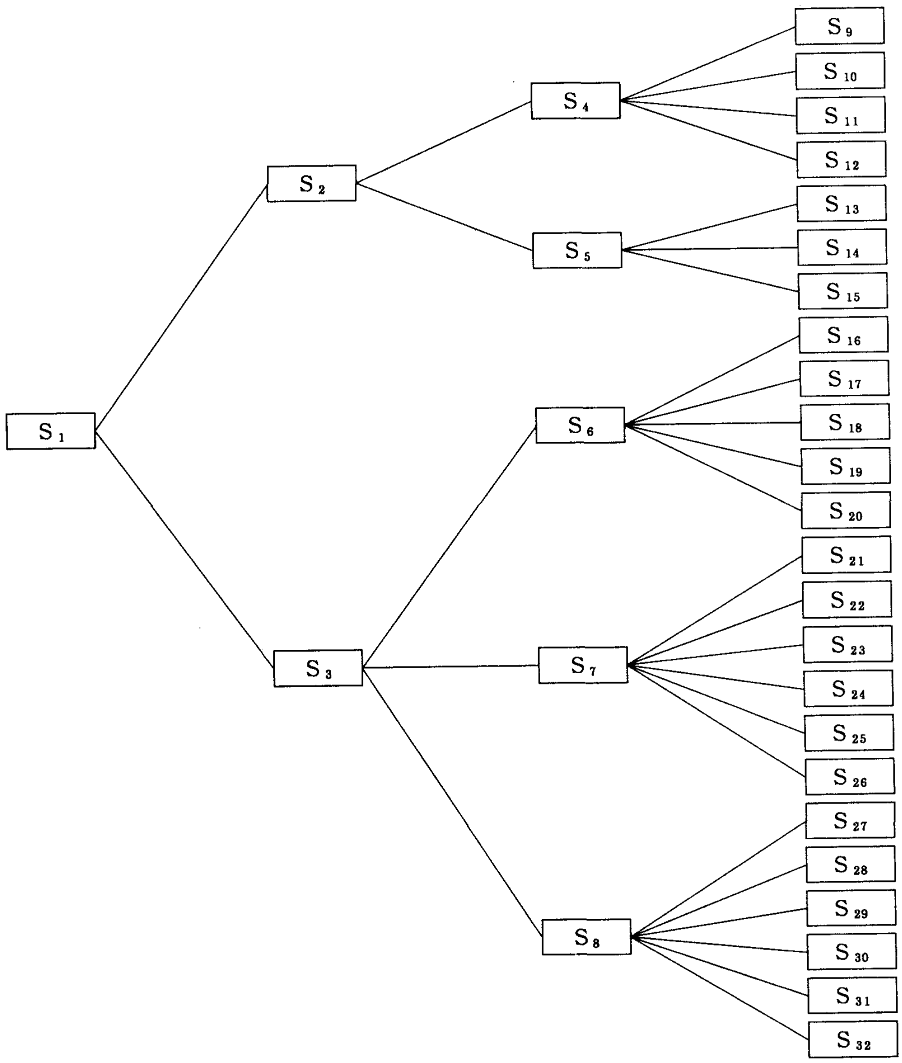

Fig.7 Evaluation Factor Structure

Evaluation factors

S 1	Performance Appraisal
S 2	Grade of job
S 3	Attitude Toward Job
S 4	Quality of work
S 5	Quality of job
S 6	Voluntariness
S 7	Cooperation
S 8	Responsibility
S 9	Quality of work in comparison with objectives. If it was executed efficiently
S10	If instructions were followed. Accuracy of work and process
S11	Cost consciousness and suggestions for improvement
S12	Contribution to better environment
S13	If the job was done in time
S14	If the job was performed without delay
S15	If the quantity of job was adequate in comparison with the objective
S16	Voluntariness to challenge difficult task
S17	Was there enough will to take responsibility to assigned job
S18	Was there eagerness to learn
S19	Suggestion for more efficient way of doing jobs
S20	Improvement on skills
S21	Fair attitude and cooperation
S22	If order was followed
S23	If corporate rules was followed and tried to stabilize the human relations
S24	Recognition and execution of own role
S25	Listen to other's ideas followed the concensus
S26	Cooperation with other departments
S27	Straight forward attitude
S28	If asked what did not understand
S29	Determination
S30	If avoided responsibility
S31	If words and action was met
S32	Report to manager

Construction of new evaluation factor structure was done in following order.

a. Realization of appraisors' individual mental structure model

Appraisors relearn about the current performance appraisal structure and decide what modification, if any, is needed on individual basis.

b. Decide on optimum evaluation factor

All appraisors discuss about their own evaluation factor structures, which are the result of examining current system.

The method used was brain-storming and the agreed representative evaluation factor matrix was decided as optimum evaluation factor. The consenting structure model can also be decided by using Nominal Group Techniques (*5).

(4) Deciding Proportion of Weight

After agreeing on evaluation factor structure (Chart 2), it is necessarily to decide the weight (importance) of each factor. The proportion should be decided as follows.

a. Summarizing appraisors' opinion on weight

Collect opinions of appraisors on weight balance and feed the result to the following formula.

$$w_i^k = \sum_{i \in J^{k-1}} w_j^{k-1} \cdot a_{ij}^{k'}$$

$$a_{ij}^{k'} = a_{ij}^k \Big/ \sum_{m \in K} a_{mj}^k \quad j \in J^{k-1} \qquad (49)$$

b. Deciding the weight

The proportion of weight (weighting) was calculated on each appraisor's basis (example chart - 3) and on the average. The average weighting was shown to all appraisors who agreed to adopt the average as the final and agreed weighting.

Chart - 3 Weight List

Evaluation factor	Mr. A	Mr. B	Mr. C	Mr. D	average	MAX	MIN	range
S_1	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.000
S_2	0.385	0.400	0.270	0.167	0.304	0.400	0.167	0.233
S_3	0.615	0.600	0.730	0.833	0.696	0.833	0.600	0.233
S_4	0.070	0.050	0.047	0.029	0.049	0.070	0.029	0.041
S_5	0.088	0.050	0.023	0.022	0.047	0.088	0.022	0.066
S_6	0.105	0.125	0.059	0.029	0.078	0.125	0.029	0.096
S_7	0.070	0.125	0.059	0.051	0.075	0.125	0.051	0.074
S_8	0.053	0.050	0.082	0.036	0.056	0.082	0.036	0.046
S_9	0.185	0.180	0.243	0.298	0.223	0.298	0.180	0.118
S_{10}	0.431	0.420	0.487	0.536	0.473	0.536	0.420	0.136
S_{11}	0.192	0.252	0.229	0.214	0.217	0.252	0.192	0.060
S_{12}	0.239	0.168	0.258	0.322	0.256	0.322	0.168	0.154

where

	Evaluation factor
S_1	Performance appaisal
S_2	Attitude toward job
S_3	Quality of work
S_4	Cooperativeness
S_5	Discipline
S_6	Responsibility
S_7	Positive attitude
S_8	Self reliance
S_9	Effort
S_{10}	Achievement
S_{11}	Quality achievement
S_{12}	Quantity achievement

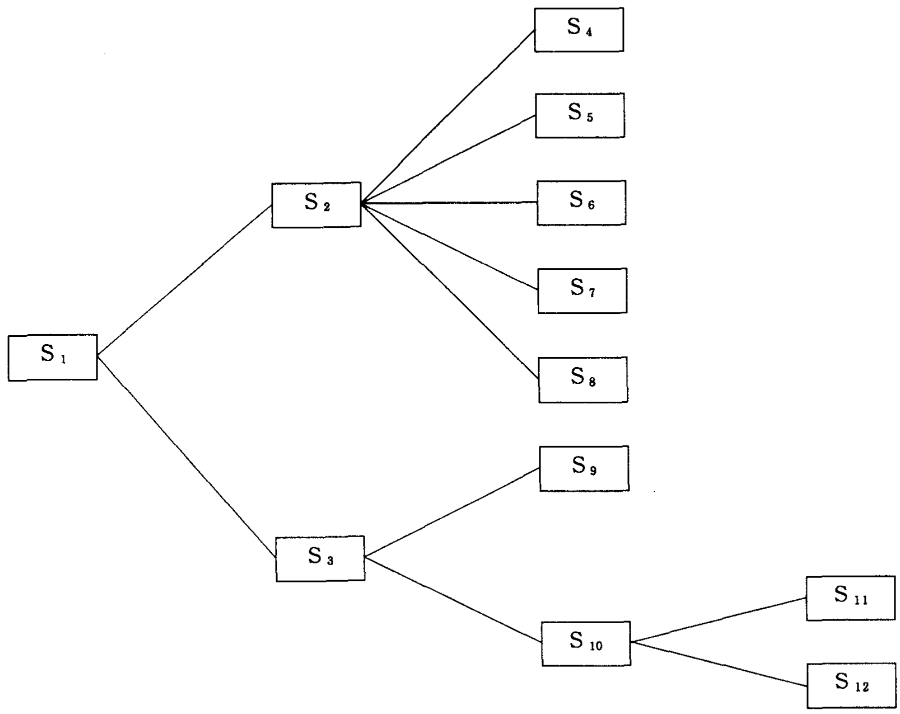

Fig.8 New Evaluation Factor Structure

(5) Designing of Appraisal Sheet

The elements to be included on the appraisal sheet decide the effectiveness of the sheet. Human resource development, qualification for the job and other aspects should be covered. However, since this is not the topic of this paper, only the method to process evaluation points is explained here. The appraisal sheet used in the introduction is shown below.

PERFORMANCE APPRAISAL SHEET

Check your evaluation in points from 0 to 1.

(Sample) In view of s_9, h_1 grades 0.75 in comparison with h_2.

0.0 ——— 0.5 ——— 0.75 (×) ——— 1.0

Inferior ——— Can't tell ——— Superior

Appraisal of s_{10}

(1) I see that h_1 is ( ) in comparison with h_2
(2) I see that h_2 is ( ) in comparison with h_3
(3) I see that h_3 is ( ) in comparison with h_4
(4) I see that h_4 is ( ) in comparison with h_5
(5) I see that h_5 is ( ) in comparison with h_6
(6) I see that h_6 is ( ) in comparison with h_7
(7) I see that h_7 is ( ) in comparison with h_8
(8) I see that h_8 is ( ) in comparison with h_9
(9) I see that h_9 is ( ) in comparison with h_{10}

(n) I see that h_n is ( ) in comparison with h_1

* h_n is the last appraisee

---

(6) Performing Appraisal

a. Explanation

Explained about how to fill the appraisal sheet and had a time for question and answer.

b. Writing in the appraisal point

Appraisors filled in the sheets, which were collected. Appraisors did not find it difficult to fill the form.

c. Data Processing

The data on collected sheets were fed to computer.

5. Analysis of the Result

The analysis on the actual trial is as follows.

(1) Analysis on Evaluation Factors

The structure of evaluation factor was agreed after considerable amount of time was invested by appraisors. Usually, the evaluation factor structure is designed by personnel staffs or outside experts and do not necessary reflect the requisits at each department or divisions. The optimum set of evaluation factors differs by departments but to documentize those evaluation factors is often too tedious and thus abandoned. Yet, if one is to pursue fairer and more appropriate appraisal, fuzzy system should provide itself as one of the promising and practical answer.

(2) Analysis on Weight

At the moment appraisors agree on evaluation factor structure, they already have their own idea of what the weight balance should be. We defined their individual and average weighting. The difference could be seen in Chart 4 and 5.

h_1 to h_4 symbolizes appraisees. Appraisors are Messrs. I,A, H and M.

On Chart - 4, S04 to S12 represents factors related to "cooperation" and "qualitative output" (see Chart - 2) the 0.029 of Mr. I in S04 is his weight on the factor. However, on chart - 5 the figure becomes 0.049. This means that initially Mr. I gave 0.029 for evaluation factor S04 but that in average the factor was weighted as 0.049 which means higher importance.

H1=0.27, H2=0.18, H3=0.27, H4=0.27 of Mr. I mean that he gave the same evaluation to H1, H3, H4 but a lower evaluation to H2. On the lowest line of the same chart, Mr. I gave evaluation of H1=0.318.... This means that the overall evaluation by Mr. I has been best for H1 and worst for H4. H1=0.318 is calculated by multiplying the evaluation of each factor with the weight assigned to each factor and adding up all the resulting figures.

On the trial, both the evaluation utilizing the individual weight (chart - 4) and average weight (chart - 5) were calculated. It so happened that the order of appraisal (who is the best, second, third and fourth) was the same in both charts. Depending on the difference between individual weight balance and average one, however, the order can be different. Using individual weight means to emphasize the individual set of value or philosophy. Yet, this method always accompanies the danger that certain appraisors' evaluation becomes so unique that the attempt to adjust or to compare his/her evaluation with others is not adequate. In such a case, utilization of average weight is suggested.

Chart - 4 Appraisal by Individual Weight Based on New Evaluation Factor Structure.

＊＊＊＊ Mr. I ＊＊＊＊
＊＊＊S04(0.029)＊＊＊ (H1= 0.27 H2= 0.18 H3= 0.27 H4= 0.27)
＊＊＊S05(0.022)＊＊＊ (H1= 0.27 H2= 0.27 H3= 0.27 H4= 0.18)
＊＊＊S06(0.029)＊＊＊ (H1= 0.27 H2= 0.27 H3= 0.27 H4= 0.18)
＊＊＊S07(0.051)＊＊＊ (H1= 0.36 H2= 0.24 H3= 0.24 H4= 0.16)
＊＊＊S08(0.036)＊＊＊ (H1= 0.27 H2= 0.18 H3= 0.27 H4= 0.27)
＊＊＊S09(0.298)＊＊＊ (H1= 0.22 H2= 0.22 H3= 0.22 H4= 0.33)
＊＊＊S11(0.214)＊＊＊ (H1= 0.32 H2= 0.32 H3= 0.21 H4= 0.14)
＊＊＊S12(0.322)＊＊＊ (H1= 0.42 H2= 0.28 H3= 0.18 H4= 0.12)

＊＊＊＊ Mr. A ＊＊＊＊
＊＊＊S04(0.070)＊＊＊ (H1= 0.53 H2= 0.13 H3= 0.13 H4= 0.20)
＊＊＊S05(0.088)＊＊＊ (H1= 0.20 H2= 0.20 H3= 0.30 H4= 0.30)
＊＊＊S06(0.105)＊＊＊ (H1= 0.62 H2= 0.16 H3= 0.16 H4= 0.07)
＊＊＊S07(0.070)＊＊＊ (H1= 0.72 H2= 0.08 H3= 0.08 H4= 0.12)
＊＊＊S08(0.053)＊＊＊ (H1= 0.57 H2= 0.14 H3= 0.14 H4= 0.14)
＊＊＊S09(0.185)＊＊＊ (H1= 0.79 H2= 0.09 H3= 0.09 H4= 0.04)
＊＊＊S11(0.192)＊＊＊ (H1= 0.47 H2= 0.20 H3= 0.20 H4= 0.13)
＊＊＊S12(0.239)＊＊＊ (H1= 0.49 H2= 0.21 H3= 0.21 H4= 0.09)

＊＊＊＊ Mr. H ＊＊＊＊
＊＊＊S04(0.050)＊＊＊ (H1= 0.20 H2= 0.20 H3= 0.30 H4= 0.30)
＊＊＊S05(0.050)＊＊＊ (H1= 0.30 H2= 0.30 H3= 0.20 H4= 0.20)
＊＊＊S06(0.125)＊＊＊ (H1= 0.25 H2= 0.38 H3= 0.25 H4= 0.11)
＊＊＊S07(0.125)＊＊＊ (H1= 0.37 H2= 0.37 H3= 0.16 H4= 0.11)
＊＊＊S08(0.050)＊＊＊ (H1= 0.25 H2= 0.25 H3= 0.25 H4= 0.25)
＊＊＊S09(0.180)＊＊＊ (H1= 0.32 H2= 0.32 H3= 0.21 H4= 0.14)
＊＊＊S11(0.252)＊＊＊ (H1= 0.28 H2= 0.42 H3= 0.18 H4= 0.12)
＊＊＊S12(0.168)＊＊＊ (H1= 0.38 H2= 0.38 H3= 0.16 H4= 0.07)

＊＊＊＊ Mr. M ＊＊＊＊
＊＊＊S04(0.047)＊＊＊ (H1= 0.15 H2= 0.15 H3= 0.35 H4= 0.35)
＊＊＊S05(0.023)＊＊＊ (H1= 0.27 H2= 0.18 H3= 0.27 H4= 0.27)
＊＊＊S06(0.059)＊＊＊ (H1= 0.25 H2= 0.25 H3= 0.25 H4= 0.25)
＊＊＊S07(0.059)＊＊＊ (H1= 0.30 H2= 0.20 H3= 0.20 H4= 0.30)
＊＊＊S08(0.082)＊＊＊ (H1= 0.22 H2= 0.22 H3= 0.22 H4= 0.33)
＊＊＊S09(0.243)＊＊＊ (H1= 0.14 H2= 0.21 H3= 0.32 H4= 0.32)
＊＊＊S11(0.229)＊＊＊ (H1= 0.42 H2= 0.28 H3= 0.18 H4= 0.12)
＊＊＊S12(0.258)＊＊＊ (H1= 0.25 H2= 0.25 H3= 0.25 H4= 0.25)

**** EVALUATION RESULT ****
**** Mr. I **** (H1= 0.318 H2= 0.262 H3= 0.215 H4= 0.204)
**** Mr. A **** (H1= 0.552 H2= 0.161 H3= 0.170 H4= 0.117)
**** Mr. H **** (H1= 0.308 H2= 0.359 H3= 0.201 H4= 0.132)
**** Mr.M **** (H1= 0.258 H2= 0.236 H3= 0.252 H4= 0.253)

Chart - 5 Appraisal by Average Weighting Based on New Evaluation Factor Structure

**** Mr. I ****
S04(0.049) (H1= 0.27 H2= 0.18 H3= 0.27 H4= 0.27)
S05(0.047) (H1= 0.27 H2= 0.27 H3= 0.27 H4= 0.18)
S06(0.078) (H1= 0.27 H2= 0.27 H3= 0.27 H4= 0.18)
S07(0.075) (H1= 0.36 H2= 0.24 H3= 0.24 H4= 0.16)
S08(0.056) (H1= 0.27 H2= 0.18 H3= 0.27 H4= 0.27)
S09(0.223) (H1= 0.22 H2= 0.22 H3= 0.22 H4= 0.33)
S11(0.217) (H1= 0.32 H2= 0.32 H3= 0.21 H4= 0.14)
S12(0.256) (H1= 0.42 H2= 0.28 H3= 0.18 H4= 0.12)

**** Mr. A ****
S04(0.070) (H1= 0.53 H2= 0.13 H3= 0.13 H4= 0.20)
S05(0.088) (H1= 0.20 H2= 0.20 H3= 0.30 H4= 0.30)
S06(0.105) (H1= 0.62 H2= 0.16 H3= 0.16 H4= 0.07)
S07(0.070) (H1= 0.72 H2= 0.08 H3= 0.08 H4= 0.12)
S08(0.053) (H1= 0.57 H2= 0.147H3= 0.14 H4= 0.14)
S09(0.185) (H1= 0.79 H2= 0.09 H3= 0.09 H4= 0.04)
S11(0.192) (H1= 0.47 H2= 0.20 H3= 0.20 H4= 0.13)
S12(0.239) (H1= 0.49 H2= 0.21 H3= 0.21 H4= 0.09)

**** Mr. H ****
S04(0.049) (H1= 0.20 H2= 0.20 H3= 0.30 H4= 0.30)
S05(0.047) (H1= 0.30 H2= 0.30 H3= 0.20 H4= 0.20)
S06(0.078) (H1= 0.25 H2= 0.38 H3= 0.25 H4= 0.11)
S07(0.075) (H1= 0.37 H2= 0.37 H3= 0.16 H4= 0.11)
S08(0.056) (H1= 0.25 H2= 0.25 H3= 0.25 H4= 0.25)
S09(0.223) (H1= 0.32 H2= 0.32 H3= 0.21 H4= 0.14)
S11(0.217) (H1= 0.28 H2= 0.42 H3= 0.18 H4= 0.12)
S12(0.256) (H1= 0.38 H2= 0.38 H3= 0.16 H4= 0.07)

**** Mr. M ****
S04(0.049) (H1= 0.15 H2= 0.15 H3= 0.35 H4= 0.35)
S05(0.047) (H1= 0.27 H2= 0.18 H3= 0.27 H4= 0.27)
S06(0.078) (H1= 0.25 H2= 0.25 H3= 0.25 H4= 0.25)

```
***S07(0.075)***  (H1= 0.30 H2= 0.20 H3= 0.20 H4= 0.30)
***S08(0.056)***  (H1= 0.22 H2= 0.22 H3= 0.22 H4= 0.33)
***S09(0.223)***  (H1= 0.14 H2= 0.21 H3= 0.32 H4= 0.32)
***S11(0.217)***  (H1= 0.42 H2= 0.28 H3= 0.18 H4= 0.12)
***S12(0.256)***  (H1= 0.25 H2= 0.25 H3= 0.25 H4= 0.25)

**** EVALUATION RESULT ****
**** Mr. I ****  (H1= 0.315  H2= 0.261  H3= 0.224  H4= 0.200)
**** Mr. A ****  (H1= 0.572  H2= 0.159  H3= 0.163  H4= 0.106)
**** Mr. H ****  (H1= 0.316  H2= 0.356  H3= 0.198  H4= 0.130)
**** Mr. M ****  (H1= 0.260  H2= 0.234  H3= 0.252  H4= 0.253)
```

7. Fuzzy Appraisal System and Other Systems

In this chapter, we describe how our fuzzy appraisal (system) relates to sub - systems of performance appraisal.

(1) Relation with Human Resource Development System

a. Development of appraisor performance

Most appraisors are managers and how much information on subordinates are gathered through performance appraisal is one measure of the manager's performance. Under fuzzy appraisal, the evaluation points are decided on the basis of factors and aggregate evaluation is not decided instantaneously. Thus, the capaciy to analyze subordinates' performance / attitude according to each evaluation factor is expected to improve dramatically. This kind of analytical mind tends to break up subordinates' behaviour into factors and helps appraisor himself in finding out what kind of training is required and why.

As mentioned before, the process of deciding evaluation factor structure and weight increases the appraisors' interest and understanding in appraisal system. As the result, appraisors' appraisal performance will be also improved.

b. Development of Appraisee Performance

The system clarifies what factor should be developed with certain appraisee. After appraisor and appraisee agrees which factor should be improved, planning of actual training has to be executed. The content of performance development program has to be built in the fuzzy performance appraisal sheet.

(2) Relation with Rotation and C.D.P. (Career Development Program)

Appraisee's evaluation point for each different evaluation factor represents the characteristics of his/her performance and can be used as data to decide rotation. Evaluation point of each evaluation factor can also be utilized as data for C.D.P. and should be fed to the plan's data base.

8. Practical Advantages and Disadvantages

Fuzzy appraisal is an attempt to apply fuzzy theory to performance appraisal and it contains several new problems in practical application. This chapter describes about advantages and disadvantages of fuzzy appraisal as well as issues that may arise in the future.

(1) Advantages

a. Grouping of appraisees can be reasonable and appropriate

It is possible to divide the group of appraisees to small groups of 5 to 6, depending on the purpose of appraisal or nature of appraisees. The system enables the designing of optimum performance appraisal for each group.

b. Flexible evaluation factor

The designing of evaluation factor structure is done for every type of appraisee groups. The structure can be revised every time. Thus evaluation factor is always up to date and adequate.

c. Optimum weighting

The weight of each evaluation factor is redefined every time a new evaluation factor structure is defined enabling itself to fit the moving target.

d. Enough leeway in deciding evaluation points

Evaluation points can be anywhere between 0 to 10, enabling appraisors to express precise evaluation.

e. Appraisor training not necessarily

While appraisor training is a requisite with most personnel management system, many corporations are doing without it according to our survey [5]. With fuzzy appraisal system, the first step of implementation requires cooperation of appraisors which makes up the training. As the result, the establishment and management of advanced level appraisal system becomes possible.

(2) Disadvantages

a. Understanding and accepting fuzzy theory difficult

It is difficult for appraisors to understand the nature, mathematic mechanism and design algorithm of fuzzy theory. Thus, persuading appraisors on the advantages of the system and to have the appraisors support the system is equally difficult.

b. Deciding evaluation factor structure and weighting takes time

The time to design and develop the system is substantial and people tend to regard the process as waste. This is especially evident when appraisors are using appraisal system designed by personnel department without appraisor training.

REFERENCES

[1] Masao HANAOKA, *LABOR MANAGEMENT IN JAPAN*, Hakutou Shobō Publishing, pp.81/82,1983

[2] Masao *HANAOKA, LABOR MANAGEMENT IN JAPAN revised version,* Hakutou Shobō Publishing, pp.130/135,1987

[3] Masao HANAOKA, "JAPANESE PERFORMANCE APPRAISAL AND SENIORITY SYSTEM",
Daito Bunka Univ. Paper Vol. 44, December1987.

[4] HANAOKA, AMAGASA & MROCZKOWSKI, "DESIGNING OF PERFORMANCE APPRAIS AL SYSTEM BY FUZZY THEORY part I", Daito Bunka Unv. Paper Vol. 46, February 1990

[5] Tadashi *FUJITA, PERFORMANCE APPRAISAL AND LABOR MANAGEMENT,* Hakuto Shobō Publishing, p195,1962.

[6] Michio AMAGASA, SYSTEM SYNTHESIS THEORY, Daito Bunka Univ. Business Institute Publishing, pp.49/63, 1987.

[7] AMAGASA, HANAOKA & MROCZKOWSKI, "DESIGNING OF PERFORMANCE APPRAISAL SYSTEM BY FUZZY THEORY part II", Daito Bunka Univ. Business Institute, Research Paper No. 10, March 1989

[8] Delbecq, A. L. et al, *GROUP PROCESS FOR THE PROGRAM PLANNING*, Scott Foresman and Co., 1975.

[9] Zadeh, L. A., "FUZZY SETS", Information and control, Vol 8, pp. 338/353, 1963.

[10] Hwang Yoon, Multiple Attribute Decision Making,Springer - Verlag, Heidelberg, New York, pp.92/115, 1970.

[11] AMAGASA, HANAOKA & MROCZKOWSKI, "PERFORMANCE APPRAISAL SYSTEM BY FUZZY THEORY", Proceedings of the Xth International Conference on Production Research, Nottingham, 1989.

[12] Michio SUGENO, Fuzzy Measure and Fuzzy Integral, SICE Vol.8 No.2 pp.218/226,1972.