A SUPPORTING SYSTEM FOR EVALUATION AND REVIEW OF BUSINESS PROCESS THROUGH ACTIVITY-BASED APPROACH

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Abstract - To keep up with global competition, there is a growing need for agile and flexible manufacturing. Calling particular attentions on two important phases in a generic model of business process management (BPM), *i.e.* selection phase and description, in this paper, we have proposed a general procedure for supporting quick and reconfigurable decision making. To develop the method, in practice, we used an activity-based model known as IDEF0 and a multi-objective optimization method like AHP. It is shown that the integration of these methods can provide a novel approach for the BPM's evaluation and review amenable to the post-analysis against a certain vagueness through λ-fuzzy measure method. After all, using the proposed approach, we can derive the best decision systematically and definitely for the business practice through total evaluation even in intangible circumstances. To demonstrate and validate the approach, a case study has been carried out for an automobile manufacturing.

Keywords: Integrated decision support aid, Business process management, IDEF0, AHP, λ-fuzzy measure

1. INTRODUCTION

Rapidly changing markets and rapid introduction of new products have created a growing need for agile and responsive manufacturing. Key technologies to reduce time for market and a highly diversified customer base are those of the flexible and reconfigurable decision process. To keep up with global competition, we need to develop a decision support aid providing valuable information in quick, accurate, and understandable manners.

With this point of view, in this paper, we will call attention on an evaluation and review in business process management (BPM). We are already familiar with several methods such like business process modeling, activity-based costing, benchmarking, work flow simulation, optimization, and much more. Though system engineers are becoming to use these recent progresses of the BPM for rational problem-solving, there still occur serious shortcomings that viewpoints and methods differ respectively depending on the engineers in charge. To work with such matters, the following aspects should be emphasized particularly: final goal is usually composed of multiple sub-goals characterized by incommensurable measures with each other; there are involved some sub-goals difficult to evaluate by numerical metrics; cooperative works among engineers with different disciplines and in charges are in nature; the recent dynamic decision environment makes the boundary conditions very unclear and changeable.

Below we present an integrated approach for supporting a rational decision making in the BPM. To demonstrate and validate the approach, we provide a case study regarding project planning in an automobile manufacturing.

2. OUTLINE OF THE WHOLE PROCEDURE

In a generic model of the BPM shown in **Fig.1** (Elzinga et al., 1995), the cycle of selection,

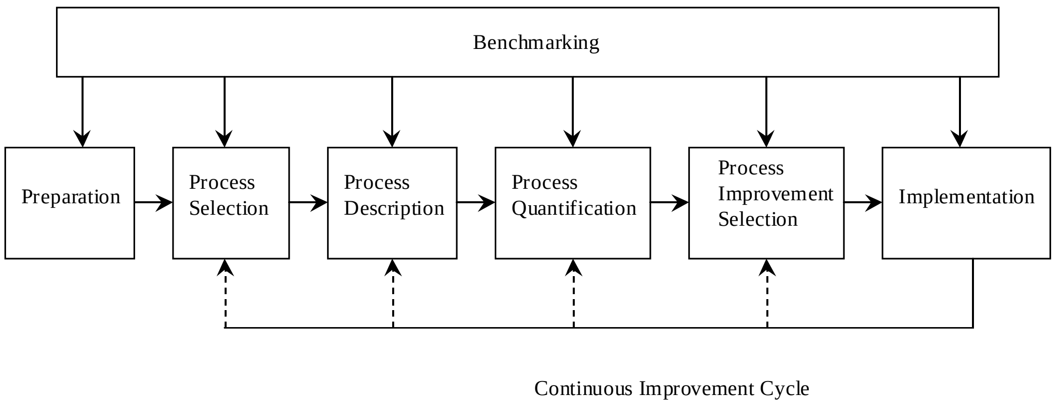

Fig. 1 Generic Model of the BPM

description, quantification, improvement selection and implementation is repeated to keep continuous improvement after goal setting for the enterprise. Among them, it should be recognized that the selection step can be a key to the success of the BPM, and considered to be a difficult decision-making process in itself. Being a multi-objective and group decision-making process in the BPM cycle, it must be carried out as in a structured form as is possible.

To work with intangible decision problems, the AHP has been widely used to establish and prioritize goals, objectives, and alternatives, and rank the alternatives (Hanratty & Joseph, 1992). However, its separated application from the description step in the BPM is insufficient to deal with all aspects emphasized earlier. We can expect a more reliable establishment by synchronizing it with the description step. For this purpose, we propose a procedure integrating the methods available in two important steps of the BPM cycle, *e.g.*, the AHP as a value system design and a ranking method in the selection step, and IDEF0 (Marca & McGowan, 1988) as a functional structure modeling in the description step. Furthermore, we will try to extend the evaluation process of the AHP through λ-fuzzy measure to deal with unclear and changeable decision environment associated with a certain human factor.

Though the IDEF0 seems to describe only a functional structure of the BPM in itself, we can analyze the system quantitatively after transforming it into an appropriate simulation model. For this purpose, we can utilize certain commercial software. After all, the proposed integral procedure can be described as shown in **Fig.2.** Below we will give a brief explanation of each element method employed there.

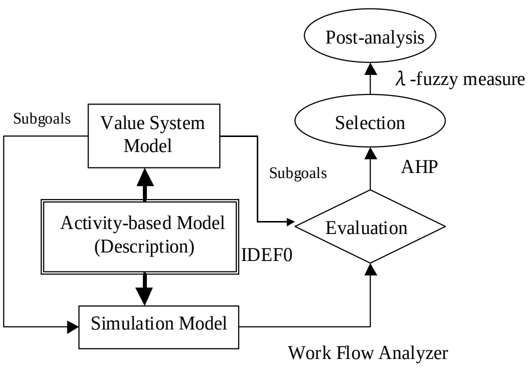

Fig. 2 Proposed Integrated Procedure

2.1. Analytic Hierarchy Process (AHP)

The AHP (Saaty, 1980) is a multi-objective optimization method in terms of hierarchy that structures the value system of decision-maker (DM). Just carrying out simple subjective judgements, DM can choose the most preferred solution among a finite number of decision alternatives. It begins with constructing an objective tree through breaking down successively goals into their respective sub-goals until value system of the problem has been clearly defined. In the objective tree thus constructed, the top level represents a final goal, and the bottom level contains alternatives. Then preference data collected through the pair comparisons is used to compute the relative weights of the sub-goals by the eigen value method. Finally by using aggregated weights over the hierarchy, rating of each alternative is derived for the final decision

At the data-gathering step of the AHP, DM is asked to express his/her relative preference for a pair of sub-goals. Such responses are usually taken place by using linguistic statements, and then transformed into the numeric score. After doing such pair comparisons repeatedly, we can obtain a pair comparison matrix $\boldsymbol{A}$ whose i-j element a_{ij} represents degree of importance for the j-th sub-goal $\boldsymbol{f}^j$ to the i-th one $\boldsymbol{f}^i$. Assuming the rate of relative weight represents the degree between the two, *i.e.*, $a_{ij}=w_i/w_j$, we can derive two apparent relations like $a_{ii}=1$ and $a_{ji}=1/a_{ij}$. This mean that we need only $n(n-1)/2$ numbers of pair comparison over n sub-goals. After all, the relative weights vector $\boldsymbol{w}$ can be calculated as the normalized eigen vector corresponding to the maximum eigen value λ_{max} of $\boldsymbol{A}$ following Eqs.(1) and (2). (In Eq.(1), $\mathbf{I}$ denotes a unit matrix.)

$$(\boldsymbol{A}-\lambda\mathbf{I})\boldsymbol{w}^{+}=\mathbf{0} \quad (1)$$

$$w_i=w_i^{+}(\lambda_{max})/\Sigma^{n}_{i=1} w_i^{+}(\lambda_{max}), \quad (i=1,\ldots,n) \quad (2)$$

Thus calculated weights are used to derive the aggregated ones which serve for calculating the ratings of the decision alternatives. That is, the largest rating represents the best choice. We are also easy to examine the consistency of such pair comparisons based on the consistency index defined by $(\lambda_{max} - n)/(n - 1)$. The advantage of the AHP refers to the fact such that: we can carry out the multi-objective optimization with both qualitative and quantitative factors only by repeating the simple subjective pair comparisons.

2.2. Activity-based modeling method, IDEF0

IDEF0 is a hierarchical activity-based modeling method developed for modeling functions of complex and interrelated system. It was derived from a well-established graphical language known as the structural analysis and design technique. Recently, it becomes viewed as an effective tool for the BPM together with the several methods in IDEF family.

Its basic structure is simple but definite enough as shown in **Fig.3**. It is just composed of one box and four kinds of arrow. The box represents a certain activity such like "produce A" or "consume B", and the arrows both material and information flows. There control stands for certain conditions, recipes, manuals, *etc*. imposed to carry out the activity, and mechanism for resources, facilities, personnel, *etc*. required by the activity. In another words, relation between input and output represents what is done through the activity while control describes why it is done, and mechanism how it is done.

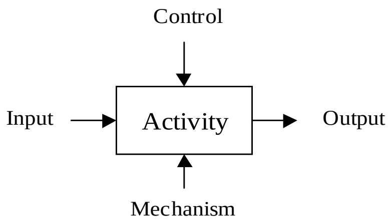

Fig.3 Basic Structure of IDEF0

The essential principle of the IDEF0 is that complex systems can be described by a set of activities to be performed in the BPM. These activities are decomposed progressively to express further detail until the required definition of the system will be reached. Under a definite modeling purpose and a clear viewpoint, the IDEF0 can describe even actual large complex systems due to its hierarchical decomposition. In addition, its simple modeling rules are very helpful for easy application, and the plain scheme at each level to grasp a whole idea quickly without trapping into too precise details (Shimizu *et.al.*, 1999).

Applying this hierarchical activity-based modeling method, we can achieve the following points essential for the integration of the selection and description steps of the BPM.

1) Explicit description about information in terms of the control and the mechanism in each activity is helpful to set up some sub-goals for the evaluation.

2) We can use appropriate commercial software having various links with simulation tools to evaluate certain important features of the BPM virtually.

3) Since the BPM belongs naturally to a cooperative work in multi-disciplinary nature, the IDEF0 provides a good environment to share common recognition among them.

4) Having a structure to facilitate modular design, the IDEF0 is easy to modify and/or correct the standard model corresponding to the particular concerns.

2.3. λ-Fuzzy measure method

Due to the dependencies among the sub-goals, evaluation of DM is likely to be influenced by the particular decision environment. Below we will show how to analyze such effect based on the λ-fuzzy measure g_λ which represents a relative importance of the sub-goal (Tanaka, 1990). First let suppose two sets of sub-goal A and B such that $A \cap B = \phi$ where the symbols $\cap$ and ϕ represent respectively the interaction and empty of the set. Then the following relation holds generally in terms of g_λ.

$$g_\lambda(A \cup B) = g_\lambda(A) + g_\lambda(B) + \lambda g_\lambda(A) g_\lambda(B), \quad (3)$$

where λ is a scaling factor to adjust the tendency, that is, negative λ describes the decelerated evaluation case, and non-negative λ the accelerated one.

Representing the rating of the j-th alternative for the i-th sub-goal x_i as $\mu_j(x_i)$, we can define λ-fuzzy integral by

$$\int \mu_A(x_i) \cdot g_\lambda = \mathrm{SUP}\,[h \wedge g_\lambda(A_h)], \text{ for } h \in [0,1], \quad (4)$$

where the operator $\wedge$ denotes MIN(h, $g_\lambda(A_h)$), and A_h is defined as $A_h=\{x | \mu_A(x) \geqq h\}$. Assuming the set $X=\{x_1, x_2, \ldots, x_n\}$ is finite, and $\mu_i=\mu_A(x_i)$ is ordered so that

$\mu_1 \geqq \mu_2 \geqq \ldots \geqq \mu_n$, the above integral can be rewritten as follows.

$$\int \mu_A(x_i) \cdot g_\lambda = \vee^n_{i=1} [\mu_i \wedge g_\lambda(X_i)], \quad (5)$$

where $X_i=\{x_1, x_2, \ldots, x_i\}$, and $\vee$ denotes max-operator.

Actually, the above computation can be carried out as follows.

1) Arrange μ_i into an descending order.

2) Calculate the fuzzy distribution function $H(x_i)$ by

$$H(x_i)=g_i+ H(x_{i-1})+ \lambda g_i H(x_{i-1}), \quad H(x_1)=g_1 \quad (6)$$

3) Then λ-fuzzy integral is obtained from $\vee^n_{i=1}[\mu_i \wedge H(x_i)]$.

Using this measure, we can concern with the decision environment reflecting the fluctuation of DM's tendency**.**

2.4. Proposed procedure in the integrated process

The IDEF0 model contains various valuable information necessary for the BPM. That is, by thinking about "what", "why" and "how" of each activity, we cannot dismiss the important objectives for the BPM under concern. Therefore, the IDEF0 is not only agreeable to cooperative work in the description step, but also is very helpful for the construction of the objective tree in the selection step. Reminding of Fig.2, we can understand each role and mutual standpoint of the element methods in the present study.

Table 1 Classification of Sub-goals

Property	Evaluation method	Examples
Quantitative	Deterministic metric	Various costs, Profit, Efficiency
	Simulation-base	Productivity, Operability, Flexibility
	Stochastic metric	Reliability/Risk, Disorder rate
Qualitative	Experienced-base	Working conditions/environment
	Sensitive metric	Esthetics, Psychological factors

After all, the objective tree is to be composed of many sub-goals with a variety of properties for evaluation as classified in **Table 1**. The subjective judgement required for the AHP is suitable to any properties of the sub-goals if certain operational procedures would be provided for supporting such judgements. Therefore multi-objective evaluation is easy and straightforward even in this manifold case. For example, simulation linked with the activity model like the IDEF0 is possible to reveal some features such as productivity, flexibility, and/or operability without constructing actual plants. In addition, some statistical aspects may evaluate certain reliability and risk of the production process, and the sensitive measure is amenable to the evaluation of sub-goals like aesthetics, comforts, empirical issues, etc..

Now we summarize the proposed procedure for evaluation and review below.

1) Among the DMs in charge, make a consensus on the final goal for the decision problem, and describe it as a top-level model of the IDEF0.

2) Establish the IDEF0 model while constructing partly the objective tree through careful assessment of each activity of the BPM in a concurrent manner.

3) By applying the AHP, calculate the relative weights, and aggregate them.

4) Decide the evaluation method of each sub-goal at the bottom level depending on their properties, and gather the metric for each alternative. At this point, depending on the evaluation methods, we might prepare systematic procedures one of which general idea is shown in **Fig.4**. (In the case where the evaluation method is simulation)

5) To compare each evaluation in common scale, normalize the metrics using the equation like $S_{ij}=5(s_{ij}-\underline{s}_i)/(s^+_i - \underline{s}_i)$. Here s_{ij} is the metric of the *j*-th alternative from the *i*-th sub-goal, and s^+_i and $\underline{s}_i$ denote the upper and lower values of the *i*-th evaluation respectively. Hence the best value of S_{ij} takes five, and the worst zero presently.

6) Choose the alternative with the largest ratings as the best choice, *i.e.* $\mathrm{Max}_j \ \Sigma^n_{i=1} w_{ij} S_{ij}$

7) If necessary, carry out the post-analysis based on the λ-fuzzy measure method described earlier to examine the effect of the tendency of the DM.

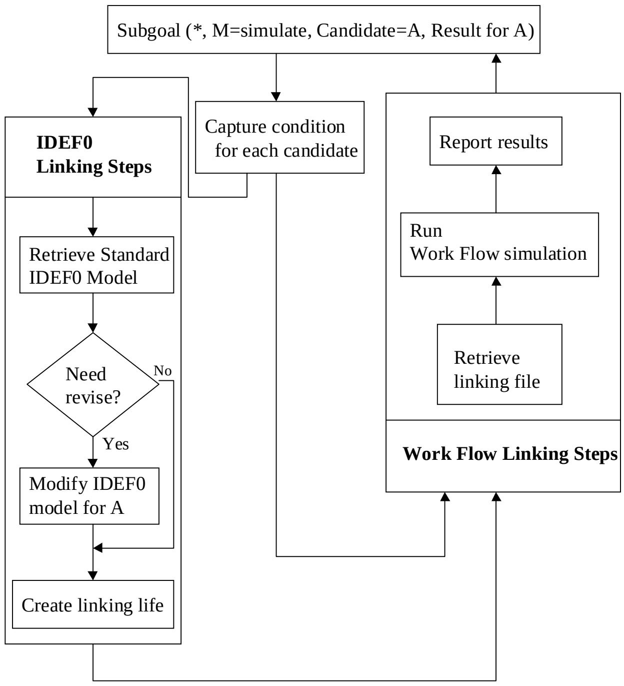

Fig. 4 Procedure of Simulation-based Evaluation

3. A CASE STUDY

The problem concerned here is stated as follows: according to the estimated increasing demands, production expansion of automobile engine is planned, and the following three alternatives are supposed to be selected for the further considerations. Then chose the best one among them through total evaluation.

Project 1 : Expanded production at the already installed line 1

Project 2 : Expanded production at the already installed line 2

Project 3 : Expanded production at the line 1 after moving it somewhere and modified it.

We have concerned with the above problem through the cooperation of three engineers (DMs) mainly.

First, we have built the IDEF0 model while noting about the sub-goals concurrently. Actually we used commercial software (DESIGN/IDEF, 1997) to build the IDEF0 model. The developed model is composed of 4 layers involving totally 38 activities whose upper diagrams present a general description for the assembling line of the engines. While we can reuse these diagrams for analyses in different circumstances with slight modifications if necessary, we need to prepare respective ones for describing the peculiar activities of the alternatives in the lower levels. (It happened at activity A11 presently.)

On the other hand, referring to the questionnaire to the engineers who know well about the production line, the objective tree was decided through careful discussions among the DMs. As shown in **Table 2**, the objective tree was made of 29 sub-goals arranged into 3 layers under the final goal.

Three sub-goals noted by "N/Sim" in the method column of the table are those that are to be evaluated through simulation under appropriate scenarios. Such analyses have not any serious difficulties since we can use the software tool linked to the IDEF0 model. Actually, the productivity was evaluated as the rate of number of productions per unit man-hour, the flexibility for production as the rate of the maximally possible productions without changing the situated conditions, and the flexibility for load balance as the number of workers whose idle time exceeds 50%. Here we should emphasize such an advantage that these important aspects can be evaluated virtually prior to the construction of the actual plants.

The pair comparisons to decide the weight and the rating of each alternative plan were performed by each DM. Though every DM weighs on the productivity and the cost, their individualities cause a variety of aspects regarding other sub-goals. There

Table 2 Objective Tree attached with Ratings of Alternatives (for DM-1)

Evaluation				Rating of Alternatives		
Level 1	Level 2	Level 3	Method*	Project 1	Project 2	Project 3
Cost	Initial		N/Num	2.03	2.51	1.17
	Maintenance		N/Num	2.78	2.6	2.75
Productivity			N/Sim	3.12	3.23	3.20
Flexibility	for production rate		N/Sim	1.69	2.66	1.65
	for plant break down		N/Sto	2.9	3.24	2.9
	for load balance		N/Sim	1.5	2.75	1.5
	for multi-products		L/Emp	4.0	5.0	4.0
	for logistics		L/Emp	3.0	5.0	5.0
Operability	Working Environment	Brightness	N/Num	3.0	5.0	5.0
		Vibration	L/Sen	3.0	3.0	3.0
		Noise	N/Num	2.0	4.0	4.0
		Temperature	L/Sen	2.0	4.0	4.0
		Esthetics/Sanitary	L/Sen	3.0	3.0	3.0
		Psychological factor	L/Sen	4.2	4.27	4.2
	Working Conditions	Working style	L/Emp	4.38	4.37	4.38
		Hard physical work	N/Num	3.0	2.87	3.0
		Fixed working position	N/Num	2.96	2.66	2.96
		Substitution by girls	L/Emp	4.0	3.0	4.0
	Working loads	Difficult mounting	L/Emp	3.22	3.16	4.06
		Numbers of mounting	N/Emp	3.03	3.03	3.03
		Other loads	N/Emp	2.96	2.66	2.96
	Automation rate		L/Emp	4.0	4.0	4.0
	Maintenance work	Operationality	L/Emp	1.64	2.36	1.64
		Usability of standard stores	L/Emp	3.0	3.0	3.0
Safety	at steady state		L/Emp	3.77	3.88	3.77
	at transient state		L/Emp	3.93	4.09	3.93
	Dangerous work		L/Emp	4.25	4.23	4.25
Risk (Loss)	against parts supplier		L/Emp	3.25	3.25	3.25
	against customers		L/Emp	3.0	3.0	3.0

* {L,N}/{Num,Emp,Sim,Sto,Sen} where L= Qualitative, N= Quantitative
Num= Numerical, Emp= Empirical, Sim= Simulation-base, Sto= Stochastic, Sen= Sensitive

Table.3 Final Result for the Selection of each DM

	DM 1		DM 2		DM 3		Average	
	Rating	Rank	Rating	Rank	Rating	Rank	Rating	Rank
Project 1	3.063	2	2.975	3	3.142	3	3.035	3
Project 2	**3.184**	**1**	**3.182**	**1**	**3.316**	**1**	**3.198**	**1**
Project 3	3.044	3	2.989	2	3.178	2	3.046	2

it is interesting to know that weights regarding the safety and flexibility have pretty differences depending on the DMs. We summarize the final result in **Table 3** where every DM chooses the second project as the best choice. Though the first and third projects reversed in order depending on the DMs, we may consider they are substantially equal since its difference is slight.

Moreover, we have analyzed the above result based on the λ –fuzzy measure to reveal some dependency of ranking on the preference tendency. In the present consideration, we focus specially on the first level since it has proper number of goals that will play a major role to evaluate the alternatives. First to apply the foregoing algorithm, ratings on the first level were calculated by multiplying the aggregate weights till the second level with the rating of each alternatives. Then they were normalized so that they should range between 0.0 and 1.0.

As known from the relation depicted in **Fig.5**, the project No.2 becomes again the best selection in terms of the robustness. That is, it is the best not only in the standard case (λ=0.0) but also over whole range, from –1.0 (ultimate decelerate evaluation) to 1000.0 (accelerate evaluation). On the other hand, there are observed a tradeoff between the projects No.1 and No.3 along the range of λ though its difference is small.

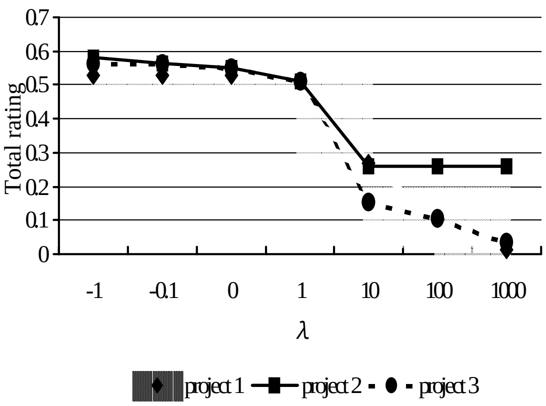

Fig. 5 Evaluation based on λ –fuzzy Measure Method for DM 1

4. CONCLUSION

We have proposed a general procedure for evaluation and review of the BPM in an integrated manner. By that, we can make systematically and also definitely the best decision through total evaluation, and post-analyze the effect regarding the human factor based on λ –fuzzy measure. The hierarchical structures both in the value system model and the activity functional model are revealed to be complementary with each other, and also very suitable for the modular design. Eventually, we can realize continuous improvement against the dynamically changing environment, perform decision more quickly and easily, and increase reusability of the both models. Effectiveness has been examined through a case study in an automobile manufacturing company.

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