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THE CONSTRUCTION OF THE FIRM'S PERFORMANCE EVALUATION MODEL ON OUTSOURCING ACTIVITIES - APPLICATION OF THE FUZZY SYNTHESIS

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Abstract: The purpose of this study is to apply Fuzzy Synthesis Judge to set up a model of performance evaluation criterion used to assess the quality of enterprise's outsourcing management. This study adopts means of literature review and expert-based interviews to contribute to an adequate evaluation criteria used to measure the performance of outsourcing activities. In terms of data collection and analysis, the participants consist of experts in aviation industry. By means of questionnaire distribution to experts, the data analysis is applied with fuzzy synthesis judge to examine the weight value. Consequently, this study utilizes fuzzy synthesis judge to qualify the performance evaluation and determine the optimal model used to examine the efficiency of outsourcing management. This study offers a model of evaluation criterion which makes it possible for enterprises to make the best outsourcing performance.

Keywords: Performance evaluation model, outsourcing activities, fuzzy synthesis judge.

1. INTRODUCTION

In terms of mass production, outsourcing is widely thought of as one of the effective methods to improve management performance. Further, outsourcing is defined as the purchase of value-creating activities in which enterprises can make long-term agreements with external suppliers. Outsourcing is of great significance to enterprise's strategic management and is referred to as a strategic concept which enables enterprises to add value to the business. However, enterprises without an evaluation criterion are likely to have difficulty in examining and monitoring outsourcing process [2, 3, 4, 5]. Accordingly, firms are in need of adequate evaluation criteria to manage outsourcing activities with efficiency and an effective measurement to evaluate the performance of their outsourcing activities. Thereupon, this study manages to make use of the technique of fuzzy synthesis judge to make it possible for firms to set up a decision model associated with outsourcing performance evaluation criteria.

When it comes to the concept of organizational fulfillment, outsourcing is widely regarded as one of the effective ways for enterprises to improve management performance. However, an enterprise could hardly examine and monitor its process of outsourcing activities without any evaluation criterion. [2, 3, 4, 5] Hence, the aim of current study is to construct a series of criteria based on the evaluation mechanism developed by Honeywell. Then, the next step is to determine the significant criterion/factors on a basis of a complete and detailed exploration with literatures and different perspectives, such as strategy, economics, technology, management and costs

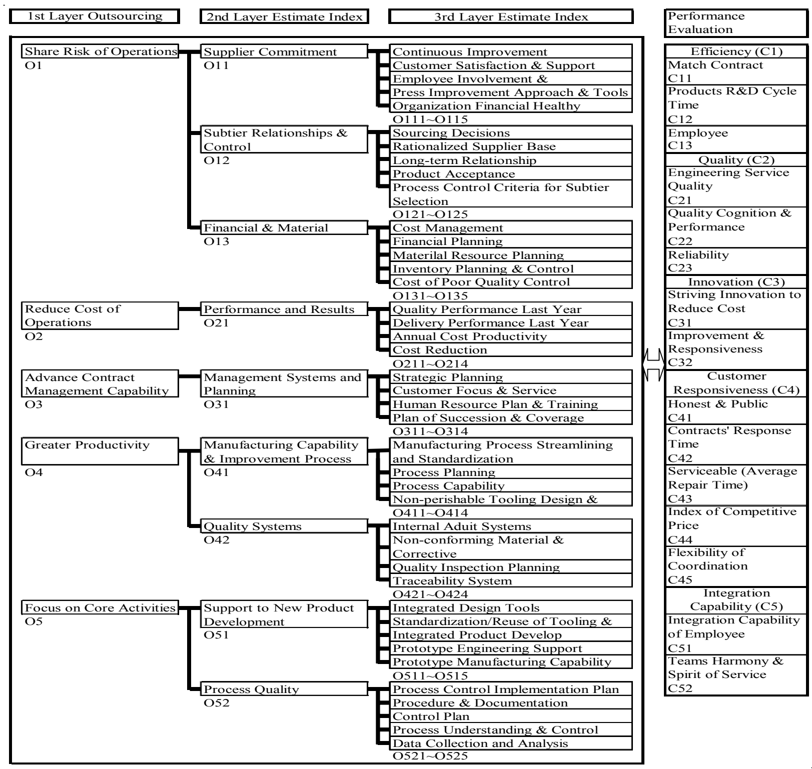


Figure 1. Multi-target and multi-criteria analysis of outsourcing frame for avionics test system [6]

First, with the adoption of interviews with experts composed of senior managers in aviation industry, this study found the evaluation model feasible to measure such items as "*Outsourcing Objective*", "*Estimate Index*" and "*Performance Evaluation Criterion*" [2, 4, 5, 9]. Secondly, this study founds a structural evaluation to appraise whether it is appropriate to qualify multi-goal and multi-criteria by means of such an evaluation. Finally, the quantitative decision-making model with the application of Fuzzy Synthesis Judge is built to evaluate business's outsourcing performance.

1.1. Construction of Evaluation Model

Through literature review and in-depth expert interviews to analyze these outsourcing activities, the study defines five categories (C1~C5) of Performance Evaluation Criteria: efficiency (C1), quality (C2), innovation (C3), customer responsiveness (C4) and integration capability (C5); five objectives (O1~O5) of outsourcing management: share risk of operation (O1), reduce cost of operation (O2), advance contract management capability (O3), greater productivity (O4) and focus on core activities (O5); and night evaluation items(O11~O13, O21, O31, O41, O42, O51, O52) indices on outsourcing management: supplier commitment (O11), sub tier relationship & control (O12), financial & material control (O13), performance and results(O21), management systems and planning (O31), manufacturing capability & improvement process (O41), quality systems (O42), support to new product development (O51) and process quality management (O52). Then, 41 items (O111~O115, O121 ~O125, O131~O135, O211~O214, O311~O314, O411~O414, O421~O424, O511 ~O515, O521~O525) of sub-level evaluation are converted into indices such as: continuous improvement (O111), customer satisfaction & support (O112) etc.

The objective analysis shown as figure-1 for outsourcing management is accomplished on a basis of the index verification by experts. Consequently, the method of Fuzzy Synthesis Judge is utilized to evaluate these indices in order to develop an appropriate decision-making model attributed to performance evaluation criteria of outsourcing activities.

2. CASE STUDY

A firm, the benchmark manufacturer in the avionics industry in Taiwan [6], is recruited to be a case study in this article. The Fuzzy Theory proposed by Bellman and Zadeh[1] was applied in this study. Entirely 18 experts including senior managers, mid-level managers, consultants, project leaders and the chief employees in industries are requested to attend outsourcing activities. The data collection is based on the interviews with those members in the case study.

The procedures of the study are as follows:

1. To decide the evaluation criteria to the supplier
2. To establish the evaluation factors as the criteria to reach the outsourcing activities goal
3. To set up the evaluating goals based on the correlation among the evaluation factors, and establish a layer-evaluating target
4. To set up the weighting of each factor to calculate the mixed weighting of the lowest layer based on the important evaluating goals
5. To establish a single factor evaluation set to the lowest layer

6. To apply the method of fuzzy synthesis judge, compare and, then, find a suitable result

2.1. The Application of Fuzzy-based Comprehensive Assessment

According to the establishment of the evaluation model shown as Figure-1, the current study reveals the processes of Fuzzy-based Comprehensive Assessment, adopting Fuzzy Number and *Linguistic Variable* to measure each factor on five outsourcing activities goals: efficiency, quality, innovation, customer responsiveness and integration capability, finally comparing and arranging the criteria for each category by means of the application of defuzzification.

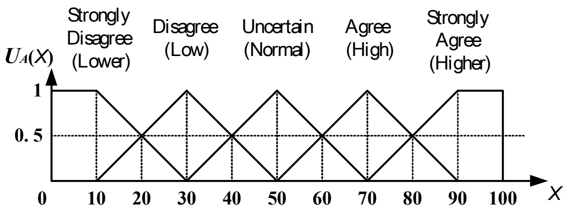


Figure 2. Five levels Linguistic Variable of membership function

Table 1. Triangular Fuzzy Number of Linguistic Variable

Membership Variable	Strongly (Lower)	Disagree (Low)	Uncertain (Normal)	Agree (High)	Strongly (Higher)
Expert Assume	0~30	10~50	30~70	50~90	70~100
l	0	10	30	50	70
m	10	30	50	70	90
u	30	50	70	90	100

According to Zadeh[11], a quantitative fuzzy situation should be analyzed by means of an artificial *Linguistic Variable*. Therefore, the items are measured by Adopt Fuzzy Number. In other words, it examines the level of *strongly disagree*, *disagree*, *uncertain, agree* and *strongly agree.* For the individual factors and related measured methods to manufacturers, it is designed to divide the measurement into five levels—lower, low, normal, high and higher —from 1 to 100 scales. For example, if the individual factor weighting is *higher*, it may belong to the level of *strongly agree and higher,* and vice versa. As shown in Table-1, the subjective opinions of individual artificial *Linguistic Variable* are proposed by the experts in the A firm. In addition, the internal scale could be converted into a *Triangular Fuzzy Number (l, m, u)* [7].

2.2 Fuzzy Number Calculation

2.2.1 The Weighting Assessment between Layers

The Linguistic Variables, which represent the important weighting of outsourcing activities, are acquired from the 18 experts in the A firm. The $W_{ij} = (LW_{ij}, MW_{ij}, UW_{ij})$, where *i* represents the number of experts and *j* is used to evaluate the weighing factor. In this case, *Fuzzy Number Addition* and *Fuzzy Number Multiplication* are applied to get synthesize weighting (in Eq.4), where *n* = 18 (experts in the A firm). From *i* = 1 to18, the following formula represents the index of Fuzzy Weighting from the experts:

$$\begin{aligned}\overline{W_j} &= \frac{1}{n}\left(\sum_{i=1}^{n} LW_{ij}, \sum_{i=1}^{n} MW_{ij}, \sum_{i=1}^{n} UW_{ij}\right) \\ &= \left(\frac{1}{n}\sum_{i=1}^{n} LW_{ij}, \frac{1}{n}\sum_{i=1}^{n} MW_{ij}, \frac{1}{n}\sum_{i=1}^{n} UW_{ij}\right) \\ &= \left(\overline{LW_j}, \overline{MW_j}, \overline{UW_j}\right)\end{aligned} \quad \text{(Eq.4)}$$

2.2.2 The Defuzzification between Layers

Applied with *COA* (Center of Area) method in Figure-3, the defuzzification [7] is to get the weighting of each factor in the system. The equation is shown as.

$$DW_j(Zo) = \frac{\left[(\mu_c(Z_1) * Z_1 + \mu_c(Z_2) * Z_2\right]}{\mu_c(Z_1) + \mu_c(Z_2)} \quad \text{(Eq.5)}$$

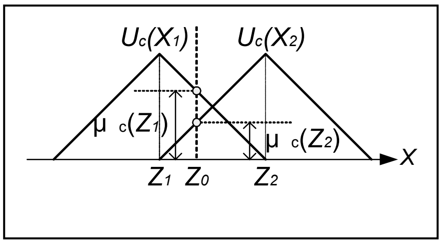


Figure 3. Defuzzification represented at the center of area method

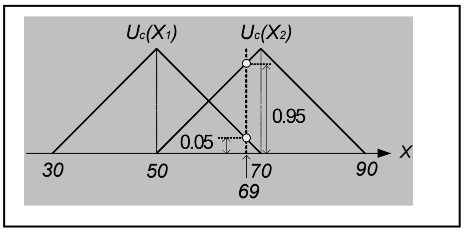
Table 2. Fuzzy weighting calculation

Outsourcing Target	Expert Rating	$U_c(X_1)$	$U_c(X_2)$	DW_j	$\overline{DW_j}$
O1	73.3	(50,70,90)	(70,90,100)	73.33	0.185
O2	83.3	(50,70,90)	(70,90,100)	83.33	0.21
O3	76.7	(50,70,90)	(70,90,100)	76.67	0.193
O4	80	(50,70,90)	(70,90,100)	80	0.202
O5	83.3	(50,70,90)	(70,90,100)	83.33	0.21

Table-2 explains the calculation process and result of outsourcing target in the first layer. For example, in the A firm, if an expert rates the weighting as 69, the results could be obtained as follows:

1. Transfer Linguistic Variable and change into Triangular Fuzzy Number, such as
2. $U_c(X_1)$=(30,50,70) and $U_c(X_2)$=(50,70,90),
3. $\mu_c(Z_1)$ = (69-70) / (50-70) = 0.05,
4. $\mu_c(Z_2)$ = (69-50) / (70-50) = 0.95,
5. With Eq.5, obtain the defuzzification weighting as:

$$Z_0 = 69,\quad DW_j(69) = \frac{(0.05\times 50 + 0.95\times 70)}{0.05+0.95} = 69$$



2.2.3 The Calculation Result for Each Weighting of Layer

In Eq. 5, DW_j is not a normalized weighting but a defuzzilized weighting. Hence, Eq.6 is used to normalize DW_j as:

$$\overline{DW_j} = DW_j \Big/ \sum_{j=1}^{m} DW_j ,\ \sum_{j=1}^{m} \overline{DW_j} = 1 \text{ and } 0 \le \overline{\mathrm{DW}}_j \le 1, \forall j \qquad \text{(Eq.6)}$$

$$\overline{DW_1} = \frac{73.33}{(73.33+83.3+76.7+80+83.3)} = 0.185^*$$

The final weighting is obtainable by means of the utilization of Eq.6 to calculate the results with each index weighting from the first to the third layers, individually. For example, in the 3^{rd} layer of *continuous improvement* (O111) index, weighting is 0.185(O1)*0.330(O11)*0.209(O111) = 0.0128**.

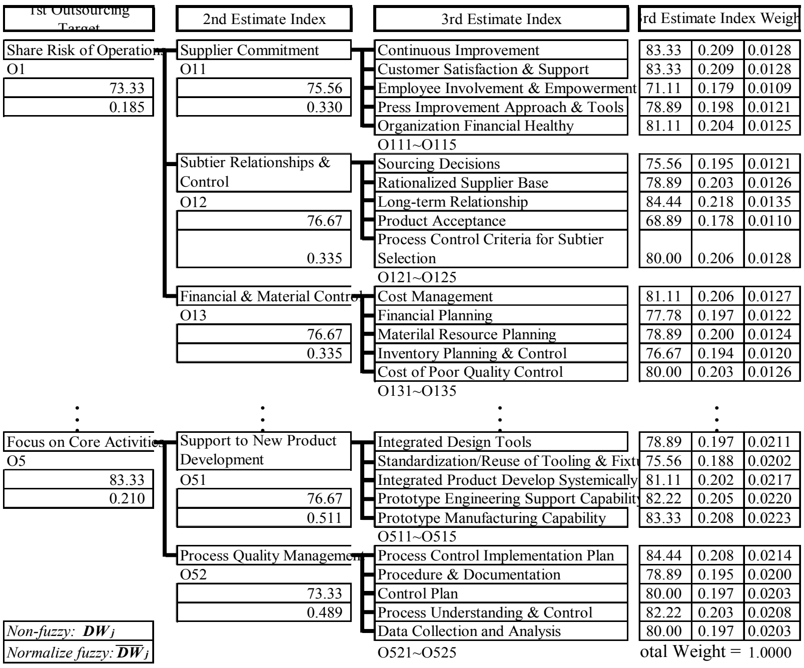


Figure 4. The results of weighted factor calculation with *1st* to *3rd* layer regarding outsourcing management in AB firm [6]

The rest results could be analogized by the same method as well as in Figure-4.

Table 3. Compare original with revised of Linguistic Variable

Original	Lower	Low	Normal	High	Higher
	(0,10,30)	(10,30,50)	(30,50,70)	(50,70,90)	(70,90,100)
	10	30	50	70	90
Revised	Higher	High	Normal	Low	Lower
	(70,90,100)	(50,70,90)	(30,50,70)	(10,30,50)	(0,10,30)
	90	70	50	30	10

2.3 The Evaluation on Performance of Each Factor

The performance in the present research refers to the Linguistic Variables: lower, low, normal, high and higher levels. Then, those experts' opinions are scaled into Fuzzy Numbers. In the situation of multi-criteria evaluation, the questionnaire is divided into "*increase operation risk*" and "*increase enterprise operation cost*". Then, the measurement of "*performance represent*" with the inverse evaluation is integrated.

Therefore, before the conversion of Linguistic Variable into Triangular Fuzzy Number, it is necessary to reverse the direction for the continuing calculation as in Table-3.

2.4 The Synthesize Judge by Each Factor

According to the above method, one could acquire the Triangular Fuzzy Number, R_{ij} which represents the factor performance. To finalize the contribution weighting of each factor to the whole judge $\boldsymbol{E_{ij}}$ **:**

$$E_{ij} = \overline{DW_j} \otimes R_{ij} = (LE_{ij}, ME_{ij}, UE_{ij}) \quad \text{(Eq.7)}$$

where the mark "$\otimes$" is a fuzzy multiplication operation, i is the i^{th} expert and j is the j^{th} factor

The questionnaires are summated by these 18 experts, and each expert has different criteria in the same factor item. As a result, different points of view may arise among different experts. Thus, the mean value should be used to calculate the judge result.

$$E_{mj} = \frac{1}{n}(E_{1j} \oplus E_{2j} \oplus ...E_{ij} \oplus ...E_{nj}), \forall j \quad \text{(Eq.8)}$$

where the mark "$\oplus$" indicates fuzzy addition operation, m is m^{th} expert and j is j^{th} factor.

Table-4 is referred to as the judge result of *efficiency* performance for each factor. Referring in Figure-3, the results from the experts are analyzed and transformed into $\boldsymbol{Z_o}$. To acquire the contribution of total evaluation, researchers compare $\mu_c(Z_1)$ and $\mu_c(Z_2)$ to acquire the largest weighting as the representative value, which was transformed into Triangular Fuzzy Numbers ((LR_j, MR_j, UR_j). After calculations, the results are shown in Table-4.

Table 4. Performance Evaluation Criterion of Efficiency with *Share Risk of Operations* (O1) factors for fuzzy Synthesis Judge

Estimate Idex		Revised	LR_{ij}	MR_{ij}	UR_{ij}	$\overline{DW}_j$	LE_{ij}	ME_{ij}	UE_{ij}	E_{mj}
O11	O111	26.67	10	30	50	0.013	0.13	0.38	0.64	
	O112	26.67	10	30	50	0.013	0.13	0.38	0.64	
	O113	27.78	10	30	50	0.011	0.11	0.33	0.55	
	O114	17.78	0	10	30	0.012	0	0.12	0.36	
	O115	38.89	10	30	50	0.012	0.12	0.37	0.62	1.628*
O12	O121	28.89	10	30	50	0.012	0.12	0.36	0.61	
	O122	31.11	10	30	50	0.013	0.13	0.38	0.63	
	O123	21.11	10	30	50	0.014	0.14	0.41	0.68	
	O124	35.56	10	30	50	0.011	0.11	0.33	0.55	
	O125	27.78	10	30	50	0.013	0.13	0.38	0.64	1.86
O13	O131	33.33	10	30	50	0.013	0.13	0.38	0.64	
	O132	36.67	10	30	50	0.012	0.12	0.37	0.61	
	O133	27.78	10	30	50	0.012	0.12	0.37	0.62	
	O134	32.22	10	30	50	0.012	0.12	0.36	0.60	
	O135	33.33	10	30	50	0.013	0.13	0.38	0.63	1.857

For example, we used Eq.7 to calculate

$\boldsymbol{LE_{11}}$= 10 × 0.128= 0.128, $\boldsymbol{ME_{11}}$= 30 × 0.0128= 0.384, and $\boldsymbol{UE_{11}}$= 50 × 0.0128= 0.64

$\boldsymbol{\Sigma LE_{11}}$ = 0.128 + 0.128 + 0.109+0+0.124=0.489,

$\boldsymbol{\Sigma ME_{11}}$ = 0.384 + 0.384 + 0.327+0.121+0.372=1.588, and

$\boldsymbol{\Sigma UE_{11}}$ = 0.64 + 0.64 + 0.545 + 0.363+0.62=2.808,

And then we used Eq.8 to get

$$E_{11} = \frac{1}{3}(\sum LE_{11} + \sum ME_{11} + \sum UE_{11}) = \frac{1}{3}(0.489 + 1.588 + 2.808) = 1.628^*$$

2.5 Evaluation of Outsourcing Performance

If there are m factors, the evaluation performance of integration will be:

$$T_m = \sum_{j=1}^{m} E_{m\,j} \qquad \text{(Eq.9)}$$

The mark "T_m" represents the judge result of all experts. In other words, a better performance is equal to a better appropriation of integral suitability. The right side in Table-4 is referred to as the total amount of all Triangular Fuzzy Numbers. For example, the result of *sharing risk of operation* (O1) and the *efficiency* performance refers to the 2^{nd} layer of integral judge weighting = 1.628(O11) + 1.86(O12) +1.857(O13) =

5.345*(the 1^{st} layer of integral judge weighting $\boldsymbol{E}_{11}$). With the application of Eq.9 to calculate $T_1 = 5.345 + 5.361 + 14.33 + 15.464 + 16.129 = 56.629^{**}$, researchers obtain the other results with the similar method shown in Table-5.

With the utilization of Triangular Fuzzy Number R_{ij}, through defuzzification shown as table 5, this study has made it possible to get the performance weighting on each layer.

2.6 The Ranking of Each Program

By repeating the procedures mentioned in the previous section, researchers could get a ranking list as table 5.

Table 5. The factors of the 1^{st} and 2^{nd} layers indices and the ranking in AB firm

Target	O1	O2	O3	O4	O5	$\boldsymbol{T_m}$	Ranking
C1	5.345*	5.361	14.33	15.464	16.129	56.629**	**3**
C2	4.919	5.421	13.52	16.622	16.772	57.254	**2**
C3	7.503	7.433	13.52	14.119	15.42	57.995	**1**
C4	5.334	6.303	13.52	14.119	15.425	54.701	**5**
C5	5.332	6.303	13.52	14.577	15.069	54.791	**4**

3. CONCLUSION

The results of decision model associated with performance of evaluation criteria for the outsourcing management are shown as table 5. Based on the research procedure, the findings of this study are listed as follows.

In terms of integral suitability, the ranking sequences of supplier's performance evaluation criteria, which can be considered as suitable targets for outsourcing activities are as follows: The criteria of innovation (C3: 57.995) are the first ranking ; quality (C2: 57.254), the second; efficiency (C1:56.629), the third; customer responsiveness (C5: 54.791), the fourth; and integration capability (C4: 57.995), the fifth. In addition, it is helpful for enterprises to achieve the optimal objective on outsourcing activities when their control targets focus on the indices of striving innovation of reduce cost (C31), improvement & responsiveness (C32) (this item belongs to innovation evaluation criteria), and engineering service quality (C21), quality cognition & performance (C22), and reliability (C23) (this item belongs to quality evaluation criteria).

The calculation and analysis on the five performance evaluation criteria (efficiency (C1), quality (C2), innovation (C3), customer responsiveness (C4), and integration capability (C5)) by means of fuzzy synthesis judge indicate that the discrepancy of calculated values among these criteria are thought of as little significance. Furthermore, this study reveals that enterprises should take these five criteria into account while dealing with outsourcing activities. Most important of all, the adoption of fuzzy synthesis judge has made it feasible to get access to an adequate and quantitative performance evaluation model used to examine enterprise's outsourcing activities. In addition, enterprises may carry out an effective outsourcing management by means of evaluation model and make much progress in firm's competency.

For the criterion of *integral suitability* of outsourcing activities, the research indicates that the *innovation* (C3) ranks first and the *quality* (C2) ranks second. Meanwhile, if an enterprise tends to emphasizes *striving innovation to reduce cost* (C31), *improvement & responsiveness* (C32), *engineering service quality* (C21), *quality cognition and performance* (C22) and *reliability* (C23), the outsourcing system is likely to reach a situation of better *integral suitability*. These five factors are thought of as indispensable, even though the grades among these categories are close to one another. Besides, a wide range of objectives among different categories may lead to different directions. Thus, this study advises that business should adjust outsourcing activities criteria according to its organization resources and developing environments.

Eventually, although enterprises often face the problem of proposing an appropriate project under the situation without ample resources while seeking outsourcing, they would take advantage of their characteristics to establish a set of outsourcing evaluation criteria in an effective way. Based on its restrained resources, the current study provides enterprises with valuable suggestions which are worth taking into account while doing the outsourcing activities.

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