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BIDDING-MANUFACTURER USING FUZZY ANALYTIC NETWORK PROCESS AND VIKOR METHOD

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Abstract. *Selecting an appropriate and qualified manufacturer for the government projects is a very important issue. Recently, the ranking method is the most common approach by the government to select the appropriate one. However, a variety of necessary information cannot be exposed by this method. This study aims at providing a better approach to assist the government in selecting the appropriate bid manufacturer. The fuzzy analytical network process (FANP) with VIKOR method is proposed to select the bidding-manufacturer for government projects. A real project of the business district revitalization in a city is used to illustrate the applications of the proposed approach.*
Keywords: Bid manufacturer selection, Commercial area, Fuzzy theory, FANP, VIKOR

1. **Introduction.** Most research in the past focus on discussing problems in manufacturers including strategy application and market competition. Only a few research discussed about the problems in the procedure of selecting an appropriate bid manufacturer. The approach to select the supplier is different between the government and industrial manufacturers. Once the tenders are submitted, they must be evaluated in order to arrive at the selection of the preferred bidder. Selecting an appropriate manufacturer from government projects becomes an important issue. In terms of the government's strategy and long-term development, the aim of development of infrastructure is usually beneficial to people in the country. Policy can affect not only priority of the construction projects but also the distribution of resources [1-6].

Although there are many approaches to evaluate decision-making problems recently, most of conditions cannot be solved by only one approach. Thus, it is beneficial for the government to make a politic decision based on more than one approach with crossing analysis [7,8].

Apart from an approach to select the appropriate manufacturer with the lowest price, the ranking method is the most common approach. Although the ranking method is easy to implement, its result cannot disclose the problem in the relationship of the evaluation criteria. Analytic network process (ANP) introduced by Satty in 1996 is used to solve this problem [9]. ANP not only solves the above problem effectively but also quantifies the evaluation criteria in the government's construction project to simplify a complicated selection process with a high uncertainty [10,11]. Moreover, problems in subjective thought and fuzzy language from decision makers during the selection can be solved by fuzzy set theory introduced by Zadeh in 1965 [12]. As a result, the numbers of research to solve fuzzy phenomenon and fuzzy linguistic have been increased [13].

In this study, Fuzzy ANP with VIKOR method is applied to studying the part of selection of bid manufacturers. The suggestions from (decision makers) examiners and the consideration for the uncertainty in a situation and language were also involved. Furthermore, a project regarding bidding-manufacturer selection for commercial zone revitalization in New Taipei city in Taiwan was used to illustrate the practicality of the proposed method. The rest of this paper is arranged as follows. The relevant literature is presented in Section 2. The selection of a bid manufacturer by Fuzzy ANP with VIKOR is presented in Section 3. Section 4 discusses the application of a real case. Finally, we make a conclusion and suggest future studies.

2. **Related Work.** The most credited approach to select a manufacturer by the government is tendering. There are three subtypes of tendering: open tendering, selective tendering, and limited tendering. The final decision for the manufacturer is based on the lowest tender and the most advantageous tender, respectively. In the lowest tender, the successful manufacturer with the lowest price is selected from all the participants. On the other hand, in the most advantageous tender, experts in relevant fields will be involved as the examiners and decision makers. They will inspect the information regarding the manufacturers, score them based on the requirements of the tender, and rank them.

To select the appropriate manufacturer is the most important issue in the field of management of public policy for the government. The best efficiency and quality of infrastructure are able to be disclosed through the assistance from the appropriate manufacturer. Choi and Hartley mentioned that the importance of selecting appropriate suppliers is based on their capabilities in store management, production design, and product quality control, respectively [14]. An appropriate supplier can decrease the cost [15]. Furthermore, Tan et al. reported that supply base management (SBM) should involve the followings: 1) supplier evaluation; 2) supplier involvement; and 3) decentralization of purchasing [16].

There are many evaluation ways to select the appropriate manufacturer. However, it often makes decision makers confused about how to select the best one. Dickson [10] mentioned that it is necessary to select a supplier by evaluating and integrating various elements. The problem in selecting suppliers attracts the attention gradually in academics and industry after his statement. Some researches provided various factors for selecting suppliers based on different reasons, conditions, characteristics, strategies, and services [17-19].

In the ranking method, an examiner will rank the bid manufacturers based on the tenderer's information and the weight of the select criterion. After measuring the final ranking score by summing each ranking score from every examiner and criterion, the successful tenderer will be selected as one with the lowest ranking score. Furthermore, there are two different approaches of ranking method. At the first approach, the ranking score will be given by measuring a final score of criteria. At the second approach, ranking scores of the tenders will be measured by the criteria. The final ranking score will be calculated by considering the weight of the criteria and summing total ranking scores [20-22].

Analytic network process (ANP) was proposed by Saaty in 1996 [9]. ANP not only can solve complex multi-criteria decision problems but also can solve multi-criteria or hierarchy dependence relationships. In many cases, interdependence exists between criteria and alternatives. ANP provides an effective tool in cases that interactions among the elements of system form a network structure via a supermatrix approach. ANP is usually applied to solving conditions where the hierarchical structure cannot be enclosed such as designation of specific products, the best ranking order in purchasing important products, and selection of suppliers [23-26].

The concept of fuzzy theory was introduced by Zadeh in 1965. The uncertainty from subjective decision or language delivery can be quantified as mathematic format by fuzzy theory and the classic bisection method can be extended to fuzzy zone. After fuzzy theory was applied in ANP, the evaluation criteria in each hierarch can be analyzed and the relationship between goals and alternatives and weight of cluster and element can be identified. Fuzzy questions which cannot be explained completely by language from interviewers can also be solved [27-32].

VlseKriterijumska Optimizacija I Kompromisno Resenje (VIKOR) proposed by Opricovic in 1998 is used to solve multiple criteria decision making problem with conflicting or competitive criteria by compromising and ranking for finding the best solution [33]. Its basic concept is to identify positive-ideal solution and negative-ideal solution. Positive-ideal solution means that the best solution can be discovered from all alternatives after the processes of a variety of evaluations and negative-ideal solution means the worst solution [34-36]. In VIKOR, compromise ranking is received by Lp-metric in compromising programming method [37]. By this approach, the group benefit can be maximized and the opposing views individual regret can be minimized. Therefore, the compromising result will be accepted by decision makers.

3. **Proposed Procedure for Bidding-Manufacturer Selection.** During selecting the bid manufacturers, the meaning of evaluated elements may not match the correct scores to examiners. For avoiding the issue of selective error caused by fuzzy logic, fuzzy theory was applied in this study to solve this potential issue.

Fuzzy multi-criteria decision making (FMCDM) methods have already been developed due to the inaccurate in assessment of the relative importance of attributes and attribute alternatives relative performance level. Inaccuracy may have many kinds of reasons, such as unquantifiable information, incomplete information, unobtainable information, and partial ignorance. As traditional MCDM methods cannot effectively deal with the aforementioned issues, we propose a way based on the Fuzzy ANP with VIKOR to help in project selection and evaluation [38-41]. We develop the analytic and evaluation criteria first. Then we use the evaluation model and calculate the data in the following steps.

The steps of the Fuzzy ANP with VIKOR are provided as follows.

Step 1: Develop the ANP model based on the criteria and sub-criterion.

Step 2: Identify the appropriate linguistic variables. The appropriate linguistic variables for the importance weighted of criteria, and the fuzzy rating for alternatives with regard to each sub-criterion of these linguistic variables can be expressed in positive trapezoidal fuzzy numbers, where l, m and u represent the lowest, the most possible and the highest possible values, respectively, where $l < m < u$ [42]. Each fuzzy number can be represented by a membership function as follows:

$$\mu_A(x) = \begin{cases} \dfrac{x-l}{m-l}, & l \le x \le m \\ \dfrac{u-x}{u-m}, & m \le x \le u \\ 0, & \text{otherwise} \end{cases} \tag{1}$$

Step 3: Establish pairwise comparison matrices by decision committee using the linguistic scales for relative importance to get the aggregated fuzzy weight of criteria, and aggregated fuzzy rating of alternatives and construct a fuzzy decision matrix.

Step 4: Defuzzify the fuzzy decision matrix and fuzzy weight of each criterion into crisp values. This calculation is done by using the center of gravity method.

$$F = \frac{\Sigma g(x_i) \times u_A(x_i)}{\Sigma u_A(x_i)} \tag{2}$$

where $g(x_i)$ is the membership important measure in a weight and $u_A(x_i)$ is the membership functions in a fuzzy set.

Step 5: Develop a weighted supermatrix and add all weights to supermatrix.

Step 6: Obtain the limit supermatrix. The weighted supermatrix is in unstable state, and then makes a supermatrix to weight convergence of computing via the limit.

Step 7: Determine the best and worst values. The steps of its procedure of measurement are given as follows:

$$f_i^* = \left[\langle \max_j f_{ij} | i \in I_1 \rangle, \langle \min_j f_{ij} | i \in I_2 \rangle \right] \forall_i \tag{3}$$

$$f_i^- = \left[\langle \min_j f_{ij} | i \in I_1 \rangle, \langle \max_j f_{ij} | i \in I_2 \rangle \right] \forall_i \tag{4}$$

where j is the alternative; i is evaluation criterion; f_{ij} is the evaluation value of i evaluation criteria in the jth alternative, which is received by questionnaire; I_1 is the set of beneficial evaluation criteria; I_2 is the set of cost evaluation criteria; f_i^* is positive-ideal solution; f_i^- is negative-ideal solution.

Step 8: Compute the values of S_j and R_j.

$$S_j = \sum_{i=1}^{n} w_i \left(f_i^* - f_{ij} \right) / \left(f_i^* - f_i^- \right) \forall_j \tag{5}$$

$$R_j = \underset{i}{Max} \left[w_i \left(f_i^* - f_{ij} \right) / \left(f_i^* - f_i^- \right) \right] \forall_j \tag{6}$$

where w_i is the weights of the ith criterion which expresses the relative importance of criteria.

Step 9: Compute the values of Q_j.

$$Q_j = v(S_j - S^*)/(S^- - S^*) + (1 - v)(R_j - R^*)/(R^- - R^*)\forall_j \tag{7}$$

where $S^* = \min_j S_j$, $S^- = \max_j S_j$, $R^* = \min_j R_j$, and $R^- = \max_j R_j$. In Equation (7), v is the weights of the strategy of the majority of criteria, where $v > 0.5$ is used for most of the resolutions to decision making; $v \approx 0.5$ is used to agree situation to decision making; and $v < 0.5$ is used to reject situation to decision making. The value v is usually set as 0.5 for the VIKOR method.

Step 10: Rank the VIKOR element. The smaller the VIKOR value is, the better the solution is. After ranking the VIROK element, the given minimized value is indicated as the best solution.

4. **Case Study.** Commercial activity can reflect the life of city and the development of a city can determine whether the environment of business is good or not. Vitalizing commercial activity is one of ways to increase the city image. As a result, most governments in the world provide a variety of business vitalization projects to achieve this aim [43]. Commercial area is defined as follows: the central point of an area consists of a variety of stores and the range of the distribution of the customers who prefer to go to these stores is called the size of the commercial zone. The areas of the commercial activity by these stores usually have their boundary. Different stores can have different commercial areas based on the products, traffic, location, and commercial size. The size of the commercial area will be affected by duration or other reasons and its shape may perform as a polygon. Furthermore, commercial zone and business district can be identified by the size of the

commercial area. The business district has smaller affected range which belongs to the city. Commercial zone involves a wide area which is not limited in a city.

Currently, the development of commercial zone has been attended gradually. Traditional commercial zone has faced various challenges including 1) lack of competitiveness, 2) lag of equipment, and 3) lag of the management of merchandize. Moreover, the challenges from other types of stores such as large malls are also an issue to affect its development. "The project of commercial zone revitalization" is a strategy to improve its competiveness by rebuilding public space and activating local business activities. In this project, individual stores will be integrated and reconstructed based on their original advantages such as local culture, environment, and products. The traditional commercial zone will convert to a characterized modern commercial zone and its competitiveness will be increased by introducing modern management and improving basic equipment.

Although the ranking method is the most common approach by the government to cope with the bidding-manufacturer selection problem due to its simplicity, some results cannot be shown completely. Ranking method is defined as an approach to identify the ranks of the bid manufacturers based on their information and criteria of the tender which were determined by examiners. A score will be received by continuously measuring. The manufacturer with the lowest score represents rank first. Five manufacturers and five examiners were involved in this case. The weights of criterion are different based on their importance. The criteria were shown in Table 1 and the ranks were shown in Table 2.

Table 1. The criteria

Criterion	Sub-criterion
Completeness and innovation of the service proposal (C.1)	1. Plan concept of contents (C.1.1) 2. Expected effect targets (C.1.2) 3. Experience of manufacturer (C.1.3) 4. Working plan (C.1.4)
Tenderer's ability to execute (C.2)	1. Project director and staff's education background, experience and specialty (C.2.1) 2. The work team's reasonable personnel arrangements and main business project (C.2.2) 3. Work experience of the project director (C.2.3) 4. Professional skills of the project director and staffs (C.2.4)
Project strategies, methods and feasibility (C.3)	1. The level of understanding and mastery to work objectives (C.3.1) 2. Awareness and understanding of the program and main issues (C.3.2) 3. Constructive ideas and suggestions (C.3.3) 4. Completeness of project work plans and contents (C.3.4) 5. Justifiability of working methods and processes (C.3.5) 6. Appropriateness of work schedule and control of time efficiency (C.3.6)
Price (C.4)	
Creative or extra paid to the government departments (C.5)	
Briefing and answer (C.6)	

TABLE 2. The results of the ranking method

Alternatives	Expert A	Expert B	Expert C	Expert D	Expert E	Cumulative ranking	Winning ranking
Firm A	3	5	3	2	3	16	3
Firm B	2	1	1	1	2	7	1
Firm C	5	4	5	5	4	23	5
Firm D	1	2	2	3	1	9	2
Firm E	4	3	4	4	5	20	4

All examiners stated that the result of rank was easily to be affected by their professional and individual preference as bias through ranking method. The result might not be objective. In terms of the bias, the appropriate manufacturer with a high score in a major criterion might not be chosen due to his lower ranking.

In this case study, level zero indicated the participants. There were five manufacturers and the best solution was to select one from five. Level one indicated major evaluation criteria. There were six criteria including the creativity and completion of their service proposals (C.1), the ability of administration of the manufacturer (C.2), executive strategy, method and possibility of the plan (C.3), price (C.4), creativity or extra service (C.5), and the skills of presentation and answering (C.6), respectively. Level two indicates 14 sub-major evaluation criteria from C.1.1 to C.3.6.

The weight of each major criterion was quantified by FANP method. An appropriate manufacturer was selected by analyzing the criteria with their weights. The evaluation result from each examiner was computed by Step 1 to Step 10 and analyzed by FANP which was driven by the software – Microsoft Excel 2007.

The result indicates that the most important criterion for examiners is C.1 with weights 0.301. The followings are C.3 with 0.241, C.2 with 0.148, C.4 with 0.116, C.5 with 0.105, and C.6 with 0.089, respectively. If integration of level one and level two is considered, the result of aim expectancy is the weightiest with 0.089. The followings are comprehension of aim with 0.085, conception of proposal with 0.075, and experience explanation by the manufacturer with 0.074, respectively.

According to the weights from FANP, the final scores and ranks of the manufacturers are shown in Table 3.

TABLE 3. Fuzzy ANP aggregate pair-wise comparison matrix

Whole	C.1	C.2	C.3
C.1	(1,1,1)	(1,1,1)	(1,1.149,1.246)
C.2	(1,1,1)	(1,1,1)	(0.265,0.361,0.574)
C.3	(1,0.871,0.803)	(3.776,2.766,1.741)	(1,1,1)
C.4	(0.574,0.361,0.265)	(1.246,1.149,1)	(0.871,0.461,0.315)
C.5	(0.361,0.265,0.209)	(1,0.871,0.803)	(1,0.5,0.333)
C.6	(0.2,0.1667,0.143)	(0.660,0.392,0.280)	(0.871,0.461,0.315)
Whole	C.4	C.5	C.6
C.1	(1.741,2.766,3.776)	(2.766,3.776,4.782)	(5,6,7)
C.2	(0.803,0.871,1)	(1,1.149,1.246)	(1.516,2.551,3.565)
C.3	(1.149,2.169,3.178)	(1,2,3)	(1.149,2.169,3.177)
C.4	(1,1,1)	(1,1,1)	(1,1,1)
C.5	(1,1,1)	(1,1,1)	(0.803,0.871,1)
C.6	(1,1,1)	(1.246,1.149,1)	(1,1,1)

TABLE 4. Fuzzy ANP pair-wise comparison matrix for C.1

C.1	C.1.1	C.1.2	C.1.3	C.1.4
C.1.1	(1,1,1)	(0.803,0.871,1)	(1,1,1)	(1,1.149,1.246)
C.1.2	(1.246,1.149,1)	(1,1,1)	(1,1,1)	(1,2,3)
C.1.3	(1,1,1)	(1,1,1)	(1,1,1)	(1,1,1)
C.1.4	(1,0.871,0.803)	(1,0.5,0.333)	(1,1,1)	(1,1,1)

TABLE 5. Fuzzy ANP pair-wise comparison matrix for C.2

C.2	C.2.1	C.2.2	C.2.3	C.2.4
C.2.1	(1,1,1)	(0.265,0.362,0.575)	(0.362,0.574,1.149)	(2.169,3.178,4.183)
C.2.2	(3.776,2.766,1.741)	(1,1,1)	(1,1,1)	(2.766,3.777,4.782)
C.2.3	(2.766,1.741,0.871)	(1,1,1)	(1,1,1)	(1,2,3)
C.2.4	(0.462,0.315,0.239)	(0.362,0.265,0.209)	(1,0.5,0.333)	(1,1,1)

TABLE 6. Fuzzy ANP pair-wise comparison matrix for C.3

C.3	C.3.1	C.3.2	C.3.3
C.3.1	(1,1,1)	(1,1.320,1.933)	(1.888,2.930,3.949)
C.3.2	(1,0.758,0.517)	(1,1,1)	(1.320,2.048,2.702)
C.3.3	(0.530,0.341,0.253)	(0.758,0.488,0.370)	(1,1,1)
C.3.4	(0.461,0.315,0.239)	(0.379,0.266,0.208)	(1,0.660,0.517)
C.3.5	(0.219,0.179,0.152)	(0.239,0.193,0.162)	(0.660,0.392,0.280)
C.3.6	(0.163,0.140,0.123)	(0.157,0.136,0.120)	(0.287,0.222,0.181)
C.3	C.3.4	C.3.5	C.3.6
C.3.1	(2.169,3.178,4.183)	(4.573,5.578,6.581)	(6.128,7.137,8.145)
C.3.2	(2.639,3.758,4.816)	(4.183,5.186,6.188)	(6.355,7.361,8.365)
C.3.3	(1,1.516,1.933)	(1.516,2.551,3.565)	(3.482,4.514,5.533)
C.3.4	(1,1,1)	(1,1.741,2.408)	(1.741,2.408,3.031)
C.3.5	(1,0.574,0.415)	(1,1,1)	(0.415,0.574,1)
C.3.6	(0.574,0.415,0.330)	(2.408,1.741,1)	(1,1,1)

To avoid conflicts between elements of the assessment, and can find the best solution, here we use the characteristics of the VIKOR as an evaluation tool. After five experts evaluated and calculated in accordance with the case given six criterions and fourteen sub-criterions, Q_j with the lowest score is the best manufacturer selected by experts. In this case, Firm D is the best with 0.296 and Firm C is the worst with 0.368. Firm C scores batter than the other firms in service proposals and completeness of the content of an innovation (0.091) and project implementation strategies, method and feasibility (0.584). We find that the two criterions are valued by experts and it is the reason why Firm C can win. All results are listed in Table 11.

Through ranking method, the rank of the bid manufacturers is listed based on the given scores from the examiners. The importance and interaction of criteria cannot be indicated.

Furthermore, according to both ranking method and FANP, the creativity and completion of their service proposals is shown as the most important evaluation criterion at level one. At level two, the result of aim expectancy is the most important criterion which is followed by comprehension of aim.

TABLE 7. Fuzzy ANP eigenvectors for levels 1 and 2

Level 1 ($n = 6$)		Level 2 ($n = 14$)	
Criterion	Weights	Sub-criterion	Weights
Completeness and innovation of the service proposal (C.1)	(0.273,0.306,0.326)	Plan concept of contents (C.1.1)	(0.237,0.245,0.253)
		Expected effect targets (C.1.2)	(0.264,0.305,0.323)
		Experience of manufacturer (C.1.3)	(0.250,0.247,0.243)
		Working plan (C.1.4)	(0.250,0.202,0.180)
Tender' s ability to execute (C.2)	(0.133,0.151,0.171)	Project director and staff's education background, experience and specialty (C.2.1)	(0.162,0.204,0.280)
		The work team's reasonable personnel arrangements and main business project (C.2.2)	(0.387,0.390,0.367)
		Work experience of the project director (C.2.3)	(0.292,0.302,0.276)
		Professional skills of the project director and staffs (C.2.4)	(0.159,0.104,0.078)
Project strategies, methods and feasibility (C.3)	(0.214,0.247,0.255)	The level of understanding and mastery to work objectives (C.3.1)	(0.296,0.348,0.392)
		Awareness and understanding of the program and main issues (C.3.2)	(0.288,0.304,0.298)
		Constructive ideas and suggestions (C.3.3)	(0.156,0.149,0.142)
		Completeness of project work plans and contents (C.3.4)	(0.114,0.097,0.088)
		Justifiability of working methods and processes (C.3.5)	(0.075,0.052,0.043)
		Appropriateness of work schedule and control of time efficiency (C.3.6)	(0.070,0.050,0.036)
Price (C.4)	(0.138,0.110,0.094)		
Creative or extra paid to the government departments (C.5)	(0.126,0.099,0.087)		
Briefing and answer (C.6)	(0.116,0.086,0.068)		

Table 8. The weighted supermatrix

Super-matrix	C.1	C.2	C.3	C.4	C.5	C.6	C.1.1	C.1.2	C.1.3	C.1.4	C.2.1	C.2.2	C.2.3	C.2.4	C.3.1	C.3.2	C.3.3	C.3.4	C.3.5	C.3.6
C.1	0	0	0	0	0	0	0.167	0.163	0.167	0.172	0.189	0.154	0.172	0.154	0.168	0.172	0.166	0.157	0.155	0.160
C.2	0	0	0	0	0	0	0.167	0.183	0.163	0.147	0.185	0.164	0.151	0.184	0.150	0.170	0.184	0.200	0.158	0.167
C.3	0	0	0	0	0	0	0.167	0.163	0.167	0.172	0.153	0.172	0.170	0.165	0.179	0.156	0.157	0.149	0.199	0.177
C.4	0	0	0	0	0	0	0.167	0.163	0.167	0.172	0.153	0.172	0.170	0.165	0.170	0.164	0.162	0.171	0.167	0.170
C.5	0	0	0	0	0	0	0.167	0.163	0.167	0.172	0.153	0.172	0.170	0.165	0.168	0.172	0.166	0.157	0.155	0.160
C.6	0	0	0	0	0	0	0.166	0.167	0.167	0.167	0.167	0.167	0.167	0.167	0.167	0.167	0.167	0.166	0.167	0.167
C.1.1	0.083	0.083	0.083	0.083	0.083	0.082	0	0	0	0	0	0	0	0	0	0	0	0	0	0
C.1.2	0.097	0.109	0.097	0.097	0.097	0.099	0	0	0	0	0	0	0	0	0	0	0	0	0	0
C.1.3	0.083	0.081	0.083	0.083	0.083	0.082	0	0	0	0	0	0	0	0	0	0	0	0	0	0
C.1.4	0.072	0.061	0.072	0.072	0.072	0.070	0	0	0	0	0	0	0	0	0	0	0	0	0	0
C.2.1	0.080	0.078	0.065	0.065	0.065	0.071	0	0	0	0	0	0	0	0	0	0	0	0	0	0
C.2.2	0.121	0.128	0.134	0.134	0.134	0.130	0	0	0	0	0	0	0	0	0	0	0	0	0	0
C.2.3	0.100	0.088	0.099	0.099	0.099	0.097	0	0	0	0	0	0	0	0	0	0	0	0	0	0
C.2.4	0.033	0.039	0.035	0.035	0.035	0.036	0	0	0	0	0	0	0	0	0	0	0	0	0	0
C.3.1	0.118	0.105	0.126	0.120	0.118	0.117	0	0	0	0	0	0	0	0	0	0	0	0	0	0
C.3.2	0.103	0.102	0.094	0.098	0.103	0.100	0	0	0	0	0	0	0	0	0	0	0	0	0	0
C.3.3	0.049	0.054	0.046	0.048	0.049	0.049	0	0	0	0	0	0	0	0	0	0	0	0	0	0
C.3.4	0.031	0.039	0.029	0.034	0.031	0.033	0	0	0	0	0	0	0	0	0	0	0	0	0	0
C.3.5	0.016	0.017	0.021	0.018	0.016	0.018	0	0	0	0	0	0	0	0	0	0	0	0	0	0
C.3.6	0.015	0.016	0.017	0.016	0.015	0.016	0	0	0	0	0	0	0	0	0	0	0	0	0	0

TABLE 9. The limit supermatrix

Super-matrix	C.1	C.2	C.3	C.4	C.5	C.6	C.1.1	C.1.2	C.1.3	C.1.4	C.2.1	C.2.2	C.2.3	C.2.4	C.3.1	C.3.2	C.3.3	C.3.4	C.3.5	C.3.6
C.1	0	0	0	0	0	0	0.167	0.167	0.167	0.167	0.167	0.167	0.167	0.167	0.167	0.167	0.167	0.167	0.167	0.167
C.2	0	0	0	0	0	0	0.167	0.167	0.167	0.167	0.167	0.167	0.167	0.167	0.167	0.167	0.167	0.167	0.167	0.167
C.3	0	0	0	0	0	0	0.167	0.167	0.167	0.167	0.167	0.167	0.167	0.167	0.167	0.167	0.167	0.167	0.167	0.167
C.4	0	0	0	0	0	0	0.167	0.167	0.167	0.167	0.167	0.167	0.167	0.167	0.167	0.167	0.167	0.167	0.167	0.167
C.5	0	0	0	0	0	0	0.167	0.167	0.167	0.167	0.167	0.167	0.167	0.167	0.167	0.167	0.167	0.167	0.167	0.167
C.6	0	0	0	0	0	0	0.167	0.167	0.167	0.167	0.167	0.167	0.167	0.167	0.167	0.167	0.167	0.167	0.167	0.167
C.1.1	0.083	0.083	0.083	0.083	0.083	0.083	0	0	0	0	0	0	0	0	0	0	0	0	0	0
C.1.2	0.099	0.099	0.099	0.099	0.099	0.099	0	0	0	0	0	0	0	0	0	0	0	0	0	0
C.1.3	0.082	0.082	0.082	0.082	0.082	0.082	0	0	0	0	0	0	0	0	0	0	0	0	0	0
C.1.4	0.070	0.070	0.070	0.070	0.070	0.070	0	0	0	0	0	0	0	0	0	0	0	0	0	0
C.2.1	0.071	0.071	0.071	0.071	0.071	0.071	0	0	0	0	0	0	0	0	0	0	0	0	0	0
C.2.2	0.130	0.130	0.130	0.130	0.130	0.130	0	0	0	0	0	0	0	0	0	0	0	0	0	0
C.2.3	0.097	0.097	0.097	0.097	0.097	0.097	0	0	0	0	0	0	0	0	0	0	0	0	0	0
C.2.4	0.036	0.036	0.036	0.036	0.036	0.036	0	0	0	0	0	0	0	0	0	0	0	0	0	0
C.3.1	0.117	0.117	0.117	0.117	0.117	0.117	0	0	0	0	0	0	0	0	0	0	0	0	0	0
C.3.2	0.100	0.100	0.100	0.100	0.100	0.100	0	0	0	0	0	0	0	0	0	0	0	0	0	0
C.3.3	0.049	0.049	0.049	0.049	0.049	0.049	0	0	0	0	0	0	0	0	0	0	0	0	0	0
C.3.4	0.033	0.033	0.033	0.033	0.033	0.033	0	0	0	0	0	0	0	0	0	0	0	0	0	0
C.3.5	0.018	0.018	0.018	0.018	0.018	0.018	0	0	0	0	0	0	0	0	0	0	0	0	0	0
C.3.6	0.016	0.016	0.016	0.016	0.016	0.016	0	0	0	0	0	0	0	0	0	0	0	0	0	0

TABLE 10. Fuzzy ANP weights comparison for levels 1 and 2

Level 1 ($n = 6$)			Level 2 ($n = 14$)		Overall weights	Overall ranking
Criterion	Weights	Ranking	Sub-criterion	Weights		
Completeness and innovation of the service proposal (C.1)	0.301	1	Plan concept of contents (C.1.1)	0.247	0.075	3
			Expected effect targets (C.1.2)	0.297	0.089	1
			Experience of manufacturer (C.1.3)	0.246	0.074	4
			Working plan (C.1.4)	0.209	0.063	6
Tenderer's ability to execute (C.2)	0.148	3	Project director and staff's education background, experience and specialty (C.2.1)	0.212	0.031	10
			The work team's reasonable personnel arrangements and main business project (C.2.2)	0.391	0.058	7
			Work experience of the project director (C.2.3)	0.290	0.043	8
			Professional skills of the project director and staffs (C.2.4)	0.107	0.016	12
Project strategies, methods and feasibility (C.3)	0.241	2	The level of understanding and mastery to work objectives (C.3.1)	0.352	0.085	2
			Awareness and understanding of the program and main issues (C.3.2)	0.301	0.073	5
			Constructive ideas and suggestions (C.3.3)	0.148	0.036	9
			Completeness of project work plans and contents (C.3.4)	0.098	0.024	11
			Justifiability of working methods and processes (C.3.5)	0.053	0.013	13
			Appropriateness of work schedule and control of time efficiency (C.3.6)	0.048	0.012	14
Price (C.4)	0.116	4				
Creative or extra paid to the government departments (C.5)	0.105	5				
Briefing and answer (C.6)	0.089	6				

TABLE 11. The results using the FANP-VIKOR method

Dimensions/Criteria	Local Weights (base on FANP)	Overall Weights (base on FANP)	Performance					Gap of aspired level				
			Firm A	Firm B	Firm C	Firm D	Firm E	Firm A	Firm B	Firm C	Firm D	Firm E
Completeness and innovation of the service proposal (C.1)	**0.301**		**6.525**	**6.951**	**5.942**	**7.276**	**6.195**	**0.184**	**0.131**	**0.257**	**0.091**	**0.226**
Plan concept of contents (C.1.1)	0.249	0.075	7.000	7.200	6.200	7.800	6.000	0.125	0.100	0.225	0.025	0.250
Expected effect targets (C.1.2)	0.296	0.089	6.600	7.400	5.800	7.400	6.800	0.175	0.075	0.275	0.075	0.150
Experience of manufacturer (C.1.3)	0.246	0.074	6.400	6.800	5.800	7.000	6.000	0.200	0.150	0.275	0.125	0.250
Working plan (C.1.4)	0.209	0.063	6.000	6.200	6.000	6.800	5.800	0.250	0.225	0.250	0.150	0.275
Tenderer's ability to execute (C.2)	**0.148**		**2.857**	**3.166**	**3.142**	**2.947**	**3.068**	**0.643**	**0.604**	**0.607**	**0.632**	**0.617**
Project director and staff's education background, experience and specialty (C.2.1)	0.209	0.031	2.800	4.000	3.400	3.600	3.600	0.650	0.500	0.575	0.550	0.550
The work team's reasonable personnel arrangements and main business project (C.2.2)	0.392	0.058	3.000	3.000	3.000	2.600	3.000	0.625	0.625	0.625	0.675	0.625
Work experience of the project director (C.2.3)	0.291	0.043	2.800	3.000	3.200	3.000	2.800	0.650	0.625	0.600	0.625	0.650
Professional skills of the project director and staffs (C.2.4)	0.108	0.016	2.600	2.600	3.000	2.800	3.000	0.675	0.675	0.625	0.650	0.625
Project strategies, methods and feasibility (C.3)	**0.243**		**2.819**	**3.291**	**2.990**	**3.329**	**3.190**	**0.648**	**0.589**	**0.626**	**0.584**	**0.601**
The level of understanding and mastery to work objectives (C.3.1)	0.350	0.085	3.000	3.600	3.200	3.800	3.600	0.625	0.550	0.600	0.525	0.550
Awareness and understanding of the program and main issues (C.3.2)	0.300	0.073	2.600	3.000	3.000	3.000	3.000	0.675	0.625	0.625	0.625	0.625
Constructive ideas and suggestions (C.3.3)	0.148	0.036	2.800	2.800	2.600	3.000	2.400	0.650	0.650	0.675	0.625	0.700
Completeness of project work plans and contents (C.3.4)	0.099	0.024	2.800	3.800	2.800	3.400	3.400	0.650	0.525	0.650	0.575	0.575
Justifiability of working methods and processes (C.3.5)	0.053	0.013	2.600	3.400	2.800	3.000	3.000	0.675	0.575	0.650	0.625	0.625
Appropriateness of work schedule and control of time efficiency (C.3.6)	0.049	0.012	3.200	3.200	3.200	3.200	3.600	0.600	0.600	0.600	0.600	0.550
Price (C.4)	**0.116**		**7.400**	**7.400**	**7.200**	**7.200**	**6.600**	**0.075**	**0.075**	**0.100**	**0.100**	**0.175**
Creative or extra paid to the government departments (C.5)	**0.105**		**7.200**	**7.200**	**6.200**	**7.000**	**6.200**	**0.100**	**0.100**	**0.225**	**0.125**	**0.225**
Briefing and answer (C.6)	**0.089**		**7.000**	**7.400**	**6.800**	**7.200**	**6.400**	**0.125**	**0.075**	**0.150**	**0.100**	**0.200**
Total performance			**5.302**	**5.626**	**5.065**	**5.639**	**5.074**					
Total gap								**0.338(3)**	**0.298(2)**	**0.368(5)**	**0.296(1)**	**0.367(4)**

Table 12. Comparison results using different methods

Method	Firm A	Firm B	Firm C	Firm D	Firm E
Ranking (score)	3 (16)	1 (7)	5 (23)	2 (9)	4 (20)
FANP-VIKOR (score)	3 (0.338)	2 (0.298)	5 (0.368)	1 (0.296)	4 (0.367)

The relative weights between criteria and levels were determined by FANP. However, the conflicts between the criteria cannot be solved. Thus, VIKOR was used to avoid this problem and the result showed that Firm D was the best manufacturer which was followed by Firm B. Firm C was the worst one.

The solutions in Firm B and Firm D by ranking method were different with the above because the weights of criteria were not considered. As a result, ranking method has its deficit. All results are shown in Table 12.

Although the importance of VIKOR cannot be displayed due to absence of the conflict situation between the criteria in this case, VIKOR is still recommended for the government in the future to avoid similar situations. In this paper, VIKOR was still applied to ranking the manufacturers. We wish to improve the quality of decision-making by the government during tender and avoid the problems from ranking method and FANP by VIKOR.

5. **Conclusion.** There were a few studies to discuss the procedure of selecting manufacturers by the government in the past and the criteria for bid manufacturers were different with the differences of working requirements. Although ranking method is easy to use for manufacturer's selection, the relative interaction of criteria cannot be shown and discussed further. As a result, several problems may occur after the selection. In this paper, integrating FANP and VIKOR to avoid the deficits from ranking method in the selection procedure was studied and discussed. We wish that the study could be a reference for the government to build a better approach to evaluate the bidding-manufacturers in the future.

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