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The voting analytic hierarchy process method for selecting supplier

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Abstract

Supplier selection has received extensive attention in supply chain management. Yahya et al. (J. Oper. Res. Soc. 50 (1999) 916–930) integrate a collaborative purchasing programme where one of the aims is to select suppliers. They illustrate a new approach based on the use of Saaty's analytic hierarchy process (AHP) method that was developed to assist in multi-criteria decision-making problems. In order to decide the total ranking of the suppliers, we compare the weighted sum of the selection number of rank vote, after determining the weights in a selected rank. This investigation presents a novel weighting procedure in place of AHP's paired comparison for selecting suppliers. It provides a simpler method than AHP that is called voting analytic hierarchy process, but which does not lose the systematic approach of deriving the weights to be used and for scoring the performance of suppliers.

Keywords: Data envelopment analysis (DEA); Analytic hierarchy process (AHP); Voting analytic hierarchy process (VAHP)

1. Introduction

In today's highly competitive environment, an effective supplier selection process is very important to the success of any manufacturing organization. Selecting the right supplier is always a difficult task for the purchasing manager. Suppliers have varied strengths and weaknesses which require careful assessment by the purchasers before ranking can be given to them. So, every decision needs to be integrated by trading off performances of different suppliers at each supply chain stage.

Yahya and Kingsman (1999) use Saaty's analytic hierarchy process (AHP) method to determine priority in selecting suppliers. The AHP has found widespread application in decision-making problems, involving multiple criteria in systems of many levels. The strongest features of the AHP are that it generates numerical priorities from the

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subjective knowledge expressed in the estimates of paired comparison matrices. The method is surely useful in evaluating suppliers' weights in marketing, or in ranking order, for instance. It is, however, difficult to determine suitable weight and order of each alternative. Noguchi et al. (2002) have shown that different weights among objects give rise to different results in ranking. And they propose a new ordering to solve the weights of ranks by considering feasible solutions' region of the constraint set in linear program.

The rest of this paper is organized as follows. Relevant literature on supplier selection criteria is reviewed, along with multiple-criteria decision-making methods. The six-step procedure for supplier selection is illustrated and a numerical example provided. Finally, the results of the various methodologies are compared and contrasted to AHP.

2. Literature review

2.1. Supplier selection criteria

One major aspect of the purchasing function is supplier selection, which includes the acquisition of required material, services and equipment for all types of business enterprises. The first step in any supplier rating procedure is to establish the criteria for supplier selection. Weber et al. (1991, 1993) reviewed and classified various articles related to vendor selection and discussed the impact of just-in-time (JIT) manufacturing strategy on vendor selection. They used Dickson's 23 criteria and indicated that net price, delivery, and quality were discussed in 80%, 59%, and 54% of the 74 articles, respectively. Yahya and Kingsman (1999) studied the particular Umbrella Scheme of Malaysia's furniture industry and used the criteria of supplier selection for Dickson's research (Dickson, 1996).

Fawcet et al. (1997) represented a measure of the firm's logistics performance concerning key factors such as cost, quality, delivery, flexibility and innovation. This is not an easy decision because there are many different criteria for a good partner. The criteria for developing a partnership with a supply chain member organization are typically driven by the expectation of quality, cost efficiency, delivery dependability, volume flexibility, information and customer service (Olhager and Selldin, 2004; Motwani et al., 1998; Li et al., 1997; Choi and Hartley, 1996). Different companies have different specific requirements concerning vendor evaluation. For instance, in the automotive industry (Europe), functions of supplier logistics performance measurement include strategy formulation and clarification, management information, communication, motivation of suppliers, coordination and alignment, decision making and priority, and learning (Schmitz and Platts, 2004).

2.2. Multiple-criteria methods for evaluation

The multi-criteria aspect of decision analysis appears because outcomes must be evaluated in terms of several objectives. These are stated in terms of properties, either desirable or undesirable, that determine the decision maker's preferences for the outcomes. The purpose of the value model is to take the outcomes of the system models, determine the degree to which they satisfy each of the objectives, and then make the necessary trade-offs to arrive at a ranking for the alternatives that correctly express the preferences of the decision maker.

The value model is developed in terms of a hierarchy of objectives and sub-objectives, as shown in Fig. 1, for selecting suppliers. To quantify the model, a unit of measurement must be assigned to the lowest members of the hierarchy. When the analysis turns to such

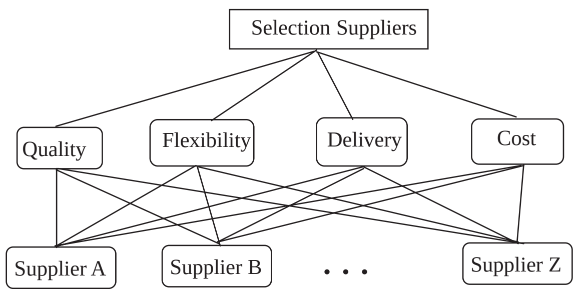

Fig. 1. Summary of three-level hierarchy for selecting suppliers.

intangible considerations as management, risk or quality, it is rarely possible to find a single variable whose direct measurement will provide a valid indicator. In fact, each of these measures is a composition of a multitude of elements, weighted and summed together in what many would view as an arbitrary approach.

The AHP provided a simple but theoretically sound multiple-criteria methodology for evaluating alternatives. The strength of the AHP lies in its ability to structure a complex, multi-person and multi-attribute problem hierarchically, and then to investigate each level of the hierarchy separately, combining the results as the analysis progresses. The levels of hierarchy describe a system from the lowest level (sets of alternatives), through the intermediate levels (subcriteria and criteria), to the highest level (general object). Using the AHP methodology, priorities of alternatives are estimated independently for every criterion at each level. The weight (or priority) of each criterion is defined by the same AHP procedure. Paired comparison of the factors (which, depending on the context, may be alternatives, criteria or object) are undertaken using a scale indicating the strength with which one factor dominates another with respect to a higher-level factor. This scaling process can then be translated into priority weights or scores for ranking the alternatives. It yields the overall priority of alternatives on each successively higher level as a linear combination of the subpriorities derived for the previous level. Such summing through the whole hierarchical structure produces a synthesized judgment for all alternatives under the stated goal (Saaty, 1983). An integrated AHP and preemptive goal programming based multi-criteria decision-making methodology was developed to take into account both qualitative and quantitative factors in supplier selection (Wang et al., 2004).

Data envelopment analysis (DEA) is an analytical procedure developed by Charnes et al. (1978) for measuring the relative efficiency of DMUs that perform the same type of functions and have identical goals and objectives. Using DEA, the relative efficiency of DMUs that use multiple inputs to produce multiple outputs may be calculated. The weights used for each DMU are those which maximize the ratio between the weighted output and weighted input. These weights are determined in such way that has no method of aggregating or pre-assigning weights of the inputs and outputs. DEA is a mathematical programming technique that calculates the relative efficiencies of multiple decision-making units (DMUs) based on multiple inputs and outputs. The mathematical programming approach known as DEA has proved to be a useful tool in evaluating the performance of DMUs. Weber (1996) applied DEA in supplier evaluation for an individual product and demonstrated the advantages of applying DEA to such a system. In Weber's study, six vendors supplying an item to a baby food manufacturer were evaluated. Significant reductions in costs, late deliveries and rejected materials can be achieved if inefficient vendors can become DEA efficient.

As for the ranking of alternatives, one of the most familiar methods compares the weighted sum of their votes after determining suitable weights of each alternative. It is, however, difficult to determine a suitable weight for each alternative a priori. Cook and Kress (1990) presented a procedure by applying DEA to the problem of rank ordering the candidates in a preferential election. In such an election, each voter selects a subset of the candidates and places them in rank order; the poll organizer then establishes for each candidate a standing of the number of first, second, third place votes, etc., received. Green et al. (1996) developed the procedure further by setting specific constraints to weights. In what follows, this procedure is referred to as "Green's method", which consists of the following two methods to set constraints: (1) the difference of weights between jth place and (j+1)th place for any j is allowed to be zero; (2) the above difference of weight must be strictly more than zero.

Let us assume that there is more than one criterion for ranking, say R (number). Next, let n be the number of voters, S be the number of places, and R the number of criteria. u_{rs} denotes the weight of the sth place with respect to the rth criteria. Every candidate wishes to assign each weight u_{rs} so as to maximize the weighted sum of votes to the rth criteria, that is, the score θ_{rr}

becomes the largest. "Green's weak ordering" is defined as follows:

$$\begin{aligned} &\theta_{rr} = \max \sum_{(s=1\sim S)} u_{rs}x_{rs} \\ \text{s.t.}\quad &\theta_{rp} = \sum_{(s=1\sim S)} u_{rs}x_{ps} \leqslant 1\ (p = 1,2,\ldots,R) \\ &u_{r1} - u_{r2} \geqslant u_{r2} - u_{r3} \geqslant u_{rs-1} - u_{rs} \\ &\quad \geqslant d(s-1,\varepsilon) = \varepsilon \geqslant 0, \\ &\quad u_{r1} \geqslant u_{r2} \geqslant \cdots \geqslant u_{rs} \geqslant 0. \end{aligned} \tag{1}$$

"Green's strong ordering" is defined as follows:

$$\begin{aligned} &\theta_{rr} = \max \sum_{(s=1\sim S)} u_{rs}x_{rs} \\ \text{s.t.}\quad &\theta_{rp} = \sum_{(s=1\sim S)} u_{rs}x_{ps} \leqslant 1\ (p = 1,2,\ldots,R) \\ &u_{r1} - u_{r2} > u_{r2} - u_{r3} > u_{rs} - u_{rs+1} > d(s,\varepsilon) \\ &\quad = \varepsilon > 0, \\ &u_{r1} > u_{r2} > \cdots > u_{rs} > \cdots \geqslant \varepsilon. \end{aligned} \tag{2}$$

Here, x_{rs} is the total votes of the rth criteria for the sth place by n voters. We will obtain some number x_{r1} of votes as first place, x_{r2} as second place,…, x_{rs} of sth place, $r = 1,2,\ldots,R$. $s = 1,2,\ldots,S$. $d(s,\varepsilon) = \varepsilon$ appearing in Eq. (2) constraint stands for the difference in weights between sth place and $(s+1)$th place.

The above-mentioned Green's method, however, has the following shortcomings:

(a) application to concrete examples and
(b) the change of ε influences the total ranking of objects.

Especially, they do not examine (b) at all. The influence of ε can be analyzed by considering the feasible region of solutions (weights) obtained by LP, which is influenced by the number of votes to the objects.

Noguchi et al. (2002) examine the application of Green's method and show that different weights among objects give rise to different results in ranking. Moreover, we apply Noguchi's strong ordering not only to single-purpose problems, but also to multi-purpose problems such as the supplier-selection problem in a business corporation. In the total ranking method using DEA, one wants to set weights a particular constraint, "strong ordering" can be employed, which is characterized by the following constraints:

(a′) $u_{rs} \geqslant \varepsilon = 1/((1+2+\cdots+S)*n) = 2/(n*S(S+1))$ and
(b′) $u_{r1} \geqslant 2u_{r2} \geqslant 3u_{r3} \geqslant \cdots \geqslant Su_{rs}$.

We will explain now inequalities (a′). First of all, u_{rs} should be positive in order not to lose information about last place. Therefore, we add the condition $u_{rs} \geqslant \varepsilon$. The difference in weights between the $(s-1)$th and sth places should become small step by step as changing to the last place. Weights should satisfy the following inequalities:

$$\begin{aligned} &u_{r1} - u_{r2} > \cdots > u_{rs-1} - u_{rs} > u_{rs} - u_{rs+1} \\ &\quad > \cdots > u_{rS-1} - u_{rS} > 0. \end{aligned}$$

Then, since

$$u_{rs} - u_{rs+1} < u_{rs} - [(s-2)/(s-1)]u_{rs+1},$$

in order to make the weight of "strong ordering", replace $>$ by $\geqslant$, i.e., we set

$$\begin{aligned} &u_{rs-1} - u_{rs} \geqslant u_{rs} - [(s-2)/(s-1)]u_{rs+1}, \\ &u_{rs-1} \geqslant 2u_{rs} - [(s-2)/(s-1)]u_{rs}\ (\because u_{rs} > u_{rs+1}), \\ &u_{rs-1} \geqslant [s/(s-1)]u_{rs}, \\ &(s-1)u_{rs-1} \geqslant s\,u_{rs}. \end{aligned}$$

The value of ε is adjusted by both the number of votes and place. Consequently, we derive inequalities (a′) from the value of ε and inequalities (b′). In this multiple criteria case, "Noguchi's strong ordering" is defined as follows:

$$\begin{aligned} &\theta_{rr} = \max \sum_{(s=1\sim S)} u_{rs}x_{rs}, \\ \text{s.t.}\quad &\theta_{rp} = \sum_{(s=1\sim S)} u_{rs}x_{ps} \leqslant 1\ (p = 1,2,\ldots,R), \\ &u_{r1} \geqslant 2u_{r2} \geqslant 3u_{r3} \geqslant \cdots \geqslant Su_{rs}, \\ &u_{rs} \geqslant \varepsilon = 1/((1+2+\cdots+S)*n) \\ &\quad = 2/(n*S(S+1)). \end{aligned} \tag{3}$$

3. Six-step procedure

We proposed the six-step procedure for selecting ten suppliers with a numerical example for the Umbrella Scheme of Malaysia's furniture industry, that is, from the paper of Yahya and Kingsman

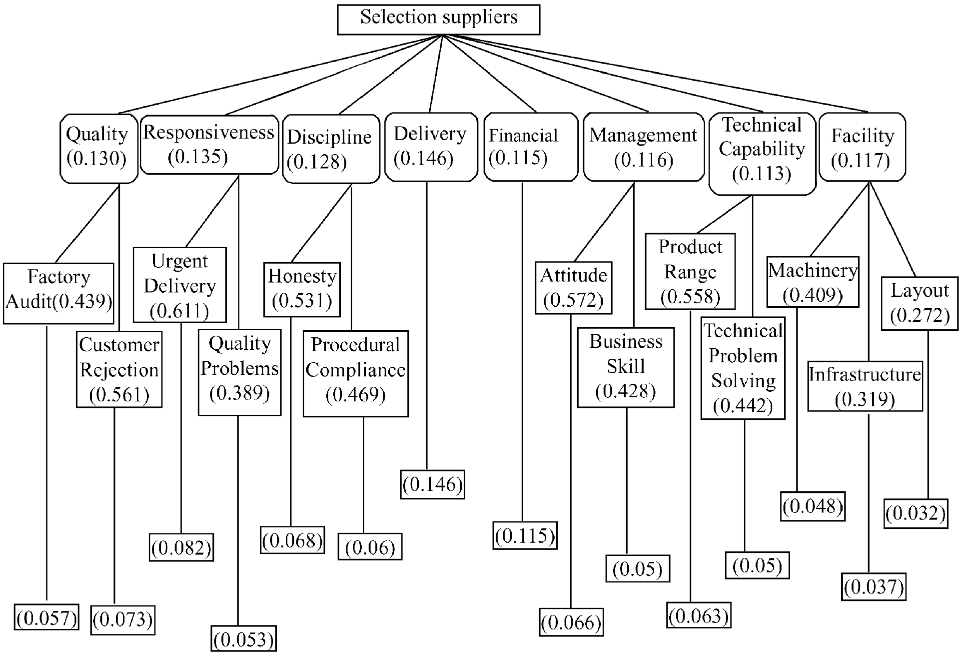

Fig. 2. Hierarchy of selection suppliers.

(1999). The problem is to select one of ten candidate suppliers. The first step is the structuring of the problem into a hierarchy (see Fig. 2). On the top level is the overall goal of selection suppliers. On the second level are eight criteria that contribute to the goal. On the third level are eight criteria that are decomposed into 13 subcriteria, and on the bottom (or fourth) level are ten candidate suppliers that are to be evaluated in terms of the subcriteria of the third level.

3.1. Step 1: Select suppliers' criteria

We use an example case of 60 respondents who participated in this study, who were all managers and supervisors of a company. They were first briefed about the overall objective of the study then specifically on supplier rating of Dickson's 23 criteria. The criteria obtained from group decision fall into two categories, objective and subjective criteria. The objective criteria are those that can be evaluated using factual data, and include *Quality*, *Delivery*, *Responsiveness*, *Technical Capability*, *Facility* and *Financial*. Subjective criteria are those that are difficult to quantify and thus have to be evaluated qualitatively, and include *Discipline* and *Management*. We will use the above eight criteria that must be satisfied in order to fulfill the goals of the selecting suppliers.

3.2. Step 2: Structure the hierarchy of the criteria

The AHP was developed to provide a simple but theoretically multiple-criteria methodology for evaluating alternatives. We use the AHP to identify subcriteria under each criterion, and to investigate each level of the hierarchy separately. The 13 subcriteria are *Factory Audit*, *Customer Rejection*, *Urgent Delivery*, *Quality Problem*, *Honesty*, *Procedural Compliance*, *Attitude*, *Business Skill*, *Product Range*, *Technical Problem Solving*, *Machinery*, *Infrastructure*, *Layout*.

3.3. Step 3: Prioritize the order of criteria or subcriteria

3.3.1. The first stage

Let us suppose that there are 60 managers (or voters) in the study, and they will select different orders of criteria or subcriteria for the candidates.

Table 1
Priority votes of 8 criteria from 60 respondents in the first stage

Criteria	1st	2nd	3rd	4th	5th	6th	7th	8th	Total
Quality	15	5	5	9	12	4	0	10	60
Responsiveness	12	11	15	6	4	1	4	7	60
Discipline	7	10	8	10	9	6	3	7	60
Delivery	20	16	10	11	3	0	0	0	60
Financial	1	6	1	9	12	9	11	11	60
Management	1	5	7	7	5	13	15	7	60
Technical Capability	2	5	2	3	7	16	20	5	60
Facility	2	2	12	5	8	11	7	13	60
Total	60	60	60	60	60	60	60	60	

Table 2
Priority votes of some criteria from 60 respondents in the second stage

Criteria	1st	2nd	Criteria	1st	2nd	Criteria	1st	2nd	
Factory Audit	25	17	Urgent Delivery	42	16	Honesty	44	16	
Customer Reject	31	28	Quality Problem	6	37	Procedural Compliance	16	44	
Criteria	1st	2nd	Criteria	1st	2nd	Criteria	1st	2nd	3rd
Attitude	53	2	Product Range	55	5	Machinery	40	11	9
						Infrastructure	20	20	10
Business Skill	6	45	Technical Problem Solving	5	55	Layout	0	19	31

Every manager votes 1 to S ($S \leqslant R$), R is the number of criteria. For this purpose, let us assume eight criteria including (1) Quality, (2) Responsiveness, (3) Discipline, (4) Delivery, (5) Financial, (6) Management, (7) Technical Capability and (8) Facility. These criteria will be regarded as candidates. We will get eight orders from 1 to 8 and sum every vote in Table 1. It commonly happens that, when one has to select among many objects, a particular object is rated as the best in one evaluation, while others are selected by other evaluation methods. The managers get the order of criteria but not the weights. The weight of each ranking is determined automatically by the total votes each candidate obtains.

3.3.2. The second stage

We use the same methodology to find the orders of these subcriteria, presented in Table 2.

3.4. Step 4: Calculate the weights of criteria or subcriteria

In this paper, we use Noguchi's voting and ranking to develop criteria varied level from hierarchy analysis process. So, this methodology is called *Voting Analytic Hierarchy Process* (VAHP).

3.4.1. The first stage

We use the data of Table 1 and find the weights of eight criteria by Eqs. (3). Fig. 2 shows that weight for Quality, Responsiveness, Discipline, Delivery, Financial, Management, Technical Capability and Facility are 0.896, 0.924, 0.877, 1.000, 0.790, 0.796, 0.780, 0.803, respectively. After normalizing these data, the results are 0.130, 0.135, 0.128, 0.146, 0.115, 0.116, 0.113, 0.117.

3.4.2. The second stage

We use the data of Table 2 and the same method. Fig. 2 shows the weights of the second

Table 3
Weights of the 13 subcriteria in the second stage

Criteria	θ_{rr} (normal)	Criteria	θ_{rr} (normal)	Criteria	θ_{rr} (normal)
Factory Audit	0.783 (*0.439*)	Urgent Delivery	1.000 (*0.611*)	Honesty	1.000 (*0.531*)
Customer Reject	1.000 (*0.561*)	Quality Problem	0.637 (*0.389*)	Procedural Compliance	0.883 (*0.469*)
Attitude	1.000 (*0.572*)	Product Range	1.000 (*0.558*)	Machinery	1.000 (*0.409*)
				Infrastructure	0.779 (*0.319*)
Business Skill	0.747 (*0.428*)	Technical Problem Solving	0.792 (*0.442*)	Layout	0.666 (*0.272*)

Table 4
Supplier criteria score guideline

Grade	Very dissatisfied	Poor	Acceptable	Good	Very satisfied
	←				→
Scores	0/1	2/3	5	7/8	9/10

level criteria. The second level gives the normalized values for all the 13 factors. The sum of weights for the factors of criteria must add up to one. So the quality criteria performance will be made up from weighting Customer Reject by 0.561 and the Factory Audit performance by 0.439. Finally, we will use the same methodology to find the weights of these subcriteria, presented in Table 3.

3.4.3. The third stage

The values in the bottom level are the global weight for each of the 13 factors; they are the factor weight multiplied by the criterion weight, so for Customer Reject factor the value is 0.561 times 0.130. As the actual performance data is collected for the factor value, these weights in the bottom level of Fig. 2 can be used directly to calculate the overall rating of the suppliers and to provide a performance 'score' that can be derived for each factor.

3.5. Step 5: Measure supplier performance

This step requires the managers to assess the performance of all suppliers on the 13 factors identified as important for supplier scores. A major problem was thus to ensure consistency between the managers and avoid any bias creeping in. A set of standard guidelines was set up after discussions with the managers (or voters) of the company. It is agreed that all performance scores would be based on an 11-point grade scale. Each grade would have an adjective descriptor and an associated point score or range of point scores. The managers preferred, in the first instance, to make their judgment on the qualitative scale of adjectival descriptors. The general performance score guidelines are given in Table 4. Therefore each supplier can be awarded a 'score' from 0 to 10 on each subcriterion.

3.6. Step 6: Identify supplier priority

Simple score sheets were provided to assist the manager to record the scores for each supplier on each of the 15 factors. Once the scores for each factor have been determined, then it is relatively easy to calculate the resulting supplier rating scores. An example of this is shown in Table 5. Mathematically, the supplier rating is equivalent to the sum of the product of each factor weight and the supplier performance score on that factor. The supplier rating value for supplier-1 is obtained by summing up the products of the respective elements in columns 3 and 4 for each row and given in the final column, to give a value of '8.057' over all the rows. The rating method used in supplier-1 can also be used to find the total scores

Table 5
Rating of supplier-1

Criteria	Sub-criteria	Weight	Scores	Sub-total
Quality	Customer Reject	0.057	8	0.456
	Factory Audit	0.073	7	0.511
Responsive	Urgent Delivery	0.082	9	0.738
	Quality Problem	0.053	9	0.477
Discipline	Honesty	0.068	7	0.476
	Procedural Compliance	0.060	6	0.360
Delivery	Delivery	0.146	7	1.022
Financial	Financial	0.115	9	1.035
Management	Attitude	0.066	7	0.462
	Business Skill	0.050	9	0.450
Technical Capability	Technical Problem Solving	0.063	9	0.567
	Product Range	0.050	9	0.450
Facility	Machinery	0.048	9	0.432
	Infrastructure	0.037	9	0.333
	Layout	0.032	9	0.288
Total scores				8.057

of the other nine suppliers. The supplier with the highest supplier rating value should be regarded as the best performing supplier and the rest can be ranked accordingly.

4. Discussion

Like AHP, the VAHP assessment method for selecting suppliers starts a hierarchy of objectives. The top of the hierarchy provides the analytic focus in terms of a problem statement. At the next level, the major considerations are defined in broad terms. This is usually followed by a list of the criteria for each of the foregoing considerations. Depending on how much detail is called for in the model, each criterion may then be broken down into individual parameters whose values are either estimated or determined by measurement or experimentation. The bottom level of the hierarchy contains the alternatives or scenarios underlying the problem.

Fig. 2 shows a four-level hierarchy developed for evaluating the weights of suppliers. The focus of the problem is ''Suppliers ranking and selecting'' and the eight major criteria are Quality, Delivery, Responsiveness, Technical Capability, Facility, Financial, Discipline and Management. In fact, in the full analysis, each of the criteria at level 2 was significantly expanded to capture the detail necessary to make accurate comparisons. With regard to Quality, it will be divided into Customer Rejection and Factory Audit factors in level 3.

Before the assessment meeting, the committee was introduced to AHP methodology and examined the objective hierarchy developed previously by an analyst. Eventually, a consensus grew around the attribute definitions, and each member began to assign values to the individual matrix elements. A bottom-up approach was found to work best. Here the alternatives are first compared with respect to each attribute; next, a comparison is made among the attributes with respect to criteria; finally, the 13 criteria at the third level are compared among themselves. After the data sheets had been filled out for each criterion, individual responses were read aloud to ascertain the level of agreement. In light of the ensuing discussion, the participants were asked to revise their entries to better reflect their renewed understanding of the issues.

Once the hierarchy has been structured, local priority must be established for each factor on a given level with respect to each factor on the level immediately above it. In AHP, the step is carried

Table 6
Differences between VAHP and AHP

Step	AHP	VAHP
1	Select suppliers' criteria	Select suppliers' criteria
2	Structure the hierarchy of the criteria	Structure the hierarchy of the criteria
3	Determining the comparison matrix	Prioritize the order of criteria or subcriteria
4	Calculate the weights (eigenvalue)	Calculate the weights (Noguchi's ordering)
5	Measure supplier performance	Measure supplier performance
6	Identify supplier priority	Identify supplier priority

out by using paired comparisons between the factors to develop the relative weights. The following are some of its associated difficulties. The scale is supposedly "fundamental" in the mind, yet there are no rules for how a transformation to such a scale occurs. A person's transformation of a set of weights to fundamental scale could change over time. The approach is basically qualitative and difficult to judge and it is arguably more burdensome to implement from both the data requirement and validation point of view than the approach using the voting ranking. Saaty (1983) suggests that a 1:9 ratio scale be used to quantify the decision maker's strength of feeling between any two alternatives with respect to a given criterion.

The final step in the analysis is to develop the priorities for the factors on the fourth level with respect to those on the second and the third level. In our case, we compare the alternatives for selecting suppliers previously mentioned with each of the major criteria. For the moment, assume that the appropriate data have been elicited and that the calculations have been done for each of the fifth rows in Table 5. From this process, we would get the global priorities of every supplier.

In summary, comparing the benefits of the VAHP to AHP we find that:

1. The VAHP method is simple to understand and use for getting priority or weights. All experts were given the opportunity to examine the priority weights calculated from their initial responses and to assess the reasonableness of the ranking. When their result seemed counter-intuitive, they were encouraged to reevaluate their input data, determine the source of the inconsistency and make the appropriate changes.
2. The construction of the objective hierarchy of criteria, attributes and alternatives facilitates communication of the problem and solution recommendation.
3. It provides "vote ranking" rather than "paired comparison" quantifying and measuring consistence.
4. The paired comparison used to weight the criteria in the AHP is more difficult than the vote ranking which is used in the VAHP.
5. The strongest features of the AHP are that it generates numerical priorities from the subjective knowledge expressed in the estimates of paired comparison matrices. In this study we use the vote ranking to determine the weights in the selected rank, in place of the paired comparison method. In the six-step procedure, the difference of VAHP and AHP is Steps 3 and 4 in Table 6.

5. Conclusion

The VAHP approaches AHP, it allows the purchasing manager to generate non-inferior purchasing options and systematically analyze the inherent trade-offs among the relevant criteria. We discussed so far the applicability of the ranking method initiated by Noguchi et al. and by using DEA, we determined the weights from rank voting data. And then we showed that the total ordinal rank of objects may produce a different result according to the difference of the weights between ranks.

Finally, we extended these ordering methods to multi-purpose evaluation, e.g. employee selection, appraising performance of individual or department, etc. It is expected that in the near future this method will be applied effectively to various issues such as policy making, business strategies and performance assessment.

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