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Mathematical and Computer Modelling 39 (2004) 1397–1412

MATHEMATICAL AND COMPUTER MODELLING

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A Multiattribute GDSS for Aiding Problem-Solving

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(Received and accepted February 2003)

Abstract—This study proposes a group decision support system (GDSS) with multiattribute to help solve problems in the real world. The problems are usually characterized as a multiattribute decision making (MADM) for selections, and shall be the responsibility of an expert group. On a regular basis, experts within that group will meet and conduct discussions on the web. After each individual make efforts of judgments, comparisons, and rankings, they shall determine, collectively as a group, the final rankings of all possible alternatives. Furthermore, aimed at insuring the decision quality of the collective decisions, an integrated procedure will be applied to make any modifications as necessary. Based on the geometric aspects of decision quality, the disparity of each individual member's preferences on attribute can be filtered out by the suggested bounded indicators. And then the outliers related to attributes' weights will be identified through a different set of consensus indicators, thus, further improving the decision quality while maintaining a quantitative level of consensus. Finally, using a car-selection problem herein, the proposed integrated procedure is implemented on a network-based PC system with web interfaces. © 2004 Elsevier Ltd. All rights reserved.

Keywords—Decision support system, Decision quality, Consensus indicators, Attribute's weight, Problem-solving, MADM, GDM.

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The authors are very grateful to National Science Council, Taiwan, R.O.C., for the financial support under the Grant Numbers: NSC 90-2218-E-214-010, NSC 91-2213-E-032-035, and NSC 92-2213-E-032-032. And special thanks shall be given to Professor L.-C. Huang, Mr. T.-H. Chen, and Ms. Y.-I. Hsiao at I-Shou University, and Professor H.-J. Shyur at Tamkang University, Taiwan, for their valuable help.

 Typeset by $\mathcal{AMS}$-TEX
doi:10.1016/j.mcm.2004.06.014

1. INTRODUCTION

Multiattribute decision making (MADM) techniques have been widespread useful for problem-solving in selections or choices during the past few decades, and on a constant basis these techniques also deal with discrete alternatives [1]. These techniques focus on value evaluation, such as setting standards for evaluation criteria, assigning weight for each criterion, grading each alternative under individual criteria, synthesizing utilities, and ranking alternatives, e.g., [2]. These techniques usually assume that the set of criteria is predefined or there exists some kind of consent before the MADM routine starts. Generally, the prerequisite is obtained through a task group from more than one decision makers (DMs) or analysts in practice. Therefore, it is debatable concerning the MADM procedure from which clear definition is hard to obtain, least to say a consensus, thus forthcoming. In such a way, the decision quality of the MADM techniques is in doubt. Furthermore, the course of actions might be erroneous if the criteria or their weights are inappropriately assigned.

To overcome the drawbacks, one branch of research is dedicated to tackle model choice problem [3], a systematic analysis of decision procedures. In certain cases, one method of multicriteria decision aids hopefully will make more sense than others for a specific problem. The other branch's efforts involve with the development of an integrated group decision support system (GDSS) for the tasks of cooperative groups in decision environments characterized by the existence of multiple, conflicting criteria [4]. The latter is of great concern in this paper, which is common for a GDSS in a network-based computerized environment for an efficient decision aid [5].

To fulfill the mission of decision support, an integrated procedure of MADM and group decision making (GDM) is proposed to include TOPSIS (technique for order preference by similarity to ideal solution) [1], NGT (nominal group technique) [6], AHP (analytic hierarchy process) [7], Borda's function [8], concept of thresholds [9], and newly-development indicators for consensus facilitation. Each technique is assigned to a particular step according to its characteristic, such as identification of attributes, elicitation of weights, allocation of weights, screening of alternatives, evaluation of alternatives, and selection of an alternative. In the meantime, we modify the problem-solve procedure of [10] in the part of consensus facilitation. The procedure, categorized into a six steps, is illustrated in Figure 1.

In addition, the coordination and consensus facilitation have been realized through a couple of bounded indicators and consensus indicators, which are stimulated by [11]. And some referred levels are suggested for judgment. Moreover, some qualitative characters, which are described by linguistic variables, are simulated by several interval indices [12] through fuzzy concept and the vague conditions can be improved. Therefore, the suggested integrated procedure is more efficient and flexible for decision aid in the real world.

To demonstrate the feasibility of the proposed procedure, a network-based PC system with web interfaces is suggested as a tool for decision-making. All of the aforementioned techniques are identified as the elements of model bases, and are followed by the general procedure for solving problems [2] with some modifications. The procedures are executed through the techniques of active server page (ASP) to communicate with the chairman and other members, and to carry out through the model base and a database as well. Unlike other GDSSs, the coordination and consensus facilitation adopted herein, have a significant effort upon the improvement of the decision quality. And the details will be illustrated by a car-selection problem in the final example.

2. BACKGROUND INFORMATION

Several common techniques of MADM and GDM, and related consensus contents as well, are reviewed in this section as the background information for our development. Please check each technique and its designated step shown in Figure 1.

Procedure	Technique used
Step 0. Problem definition.	General discussion
⇩	
Step 1. Identification of necessary attributes for the problem. 1.1) Silent generation of attributes in writing. 1.2) Round-robin recording of attributes. 1.3) Serial discussion of the list of attributes. 1.4) Voting for necessary attributes.	NGT
⇩	
Step 2. Elicitation of weights to attributes by individual. 2.1) Establishment of a reciprocal matrix for attributes' comparison. 2.2) Calculation of attributes' weights. 2.3) Check for consistency of priority of the matrix for himself/herself.	AHP
⇩	
Step 3. Allocation of weights on attributes through group consensus. 3.1) Derivation of indicators' values. 3.2) Test of the feasible range on each attribute. 3.3) Identification of problematic options. 3.4) Modification of group consensus.	Consensus facilitation
⇩	
Step 4. Screening of alternatives. 4.1) Elimination of the alternatives with lower achievement.	Attributes' thresholds
⇩	
Step 5. Evaluation of the alternatives by individual. 5.1) Construction of the normalized decision matrix. 5.2) Construction of the weighted normalized decision matrix. 5.3) Determination of PIS and NIS. 5.4) Calculation of the separation measure. 5.5) Calculation of the relative closeness to the PIS. 5.6) Ranking of the alternatives.	TOPSIS
⇩	
Step 6. Selection of an alternative. 6.1) Aggregation of the individual results 6.2) Ranking of the alternatives.	Borda's function

Figure 1. An integrated procedure for problem-solving (modification from [10]).

2.1. MADM Techniques

Functionally associated with problems of discrete alternatives, MADM techniques are practical tools for solving problems in the past. The DM is to select, prioritize, and rank a finite number of courses of action [1]. Among these techniques, the category of information on attribute from DM is convenient for making decisions due to an explicitly represented procedure. According to the simulation comparison from [13], TOPSIS is the fewest rank reversals among eight methods in the category. Thus, TOPSIS is chosen as the main body for individuals' selection. At the same time, the weight of each criterion in TOPSIS is obtained from AHP, a pair-wise comparison for attributes, because both have the similar behavior. Hence, in the following, only these two major techniques are discussed. It is noted that these two are classified as the cardinal information on attribute being provided by the DM [1].

2.1.1. TOPSIS

TOPSIS is one handy MADM technique to manage real-world problems [14]. It originates from the concept of displaced ideal [15,16], that the alternative acquired should have the shortest distance from the (positive) ideal solution (PIS) and the farthest from the negative-ideal solution (NIS) or nadir. TOPSIS considers simultaneously the distances to both ideal and negative-ideal solutions. And in the end, a satisfactory solution is adopted on account of relative closeness. The concept of distance has been popular for choosing alternatives, even in the area of multiobjective decision making [17]. Since the concept of displaced ideal is rather instinctive, it is easy to make extension to GDM and other related areas. Noted that the central part of this study is to utilize the concept of PIS/NIS to displace the disparate opinions or preferences of an expert group.

The process of TOPSIS includes six successive steps as follows [1]:

(i) construction of the normalized decision matrix;
(ii) construction of the weighted normalized decision matrix;
(iii) determination of PIS and NIS;
(iv) calculation of the separation measure;
(v) calculation of the relative closeness to the PIS;
(vi) ranking of the alternatives.

We can see that the above steps need a set of weights for attributes from the DM before the procedure starts. Furthermore, the number of attributes, as well as the number of alternatives, shall be fixed in the beginning. These prerequisites are generally obtained through a task group from more than one DM or analysts in practice. Therefore, the details of these prerequisites should be carefully acquired to ensure the decision quality.

2.1.2. AHP

Since not all attributes are likely to be counted equally important in evaluation, weighting techniques are used to reflex the relative importance of each attribute in DM's mind. Among the techniques [1], a ratio weighting process through pairwise comparison among attributes [7] is considered to be easy to handle. Therefore, AHP is selected to catch the weights of attributes. And a consistence check, i.e., CR (consistence ratio) < 0.1, is embedded in the process at the same time. Nevertheless, the whole routine of AHP for MADM is neglected in our operation.

Now that the weights play a key role in MADM, they should be carefully examined. In practice, the weight of each attribute is generally obtained through team work or a task group from more than one DM. Hence, it might need an extra process to determine the feasible weights for the group. And consensus indicators are recommended for this purpose. We will launch a set of indicators in Section 3.

Apart from the weight issues, there implicitly exists a screening process in MADM procedure. When the attributes and their weights of the model are observed, the effective alternatives will be judged through the screening operation. Based on the threshold values on each attribute [9], the undesirable alternatives with lower and/or over achievements are eliminated. Note that the number of alternatives, n, are usually kept at $n < 10$ for further manipulation in MADM process [18].

2.2. GDM Techniques

GDM techniques are frequently operated in a democratic society. The analysis is no longer based on one individual's preference structure, and is extended to account for the conflicts among different interest parties who have different objectives, goals, and so forth. Among the techniques, the taxonomy of expert judgment/group participation is valuable for idea stimulation and issue clarification in business applications [8]. These techniques are common to deal with unstructured or semistructured problems. In addition, a counting process, Borda's function, is selected for aggregating individual preference after the choices have been made through the previous MADM routine.

2.2.1. Nominal group technique

First, the techniques of GDM are most preferred approaches for management. And the above prerequisites have been obtained through the course of meeting for a long time. Brain storming, Delphi technique, and nominal group technique (NGT) are common in management. However, only NGT is chosen due to the advantage of its limited processing time and limited number of DMs [19]. And it has been proven good for idea building and issue clarification [20]. For solving problems, NGT helps to acquire the attribute set for MADM.

The process of NGT can be outlined as the following four steps [6]:

(i) silent generation of ideas in writing;
(ii) round-robin recording of ideas;
(iii) serial discussion of the list of ideas; and
(iv) voting.

The defined steps are thought to be especially beneficial in the field of solving unstructured problems.

Moreover, some qualitative characters and discrimination for the threshold values of agreement and disagreement will be simulated through fuzzy concept, and the vague conditions are expected to be decreased to certain extent. Obviously, our modified version of NGT process is clearer and more accessible than the original one. The techniques mentioned above then will be integrated into the system.

2.2.2. Borda's function

Borda's function or Borda's count is one common social choice function for order ranking among the group [7]. For a given set of priority vectors, an appropriate consensus is given by the average of the vectors [21]. Although the function is a general representation, we only utilize the Borda's function for accumulating the order on alternatives from each member in the final step of the proposed procedure. And the counting procedure is rather straightforward.

2.3. Decision Support Systems

After the above MADM and GDM techniques are discussed, these techniques can be included in a decision support system (DSS). A DSS is a computer-based information system that combines models and data in an attempt to solve unstructured problems with extensive user involvement through a friendly user interface. The components of the DSS can be composed of the following four subsystems:

(i) data management;
(ii) model management;
(iii) knowledge-based management; and
(iv) user interface [22].

However, an awareness of group collaboration has impact on organizational performance in decision-making, and hence, enables the physical implementation of a GDSS [23]. In such a way, the geographical restriction will be relieved when the system is installed. Furthermore, due to the existence of multiple, conflicting criteria for manipulating some practical problems, a multiple criteria GDSS is suggested to support complex decisions [4]. In this paper, we only discuss the problems with discrete alternatives, and a multiattribute GDSS is specified. Its major components contain data management, decision model, and user interfaces subsystems.

3. MEASURES OF DECISION QUALITY

Decision quality is most important to ensure an effective decision. Although techniques of MADM and GDM attempt to help people make a better decision in a complicated situation, the inherent difference among the members of the group needs to be investigated quantitatively to reach a generally accepted level. And then the decision quality can be kept to some standard. Among the measures of decision quality, we can roughly classify them into two types: statistical measures and geometric measures. The former tries to obtain an efficient decision based on a large-size sample, e.g., the quality of the group decisions in a laboratory experiment [24]. The latter utilizes geometric concepts to define an efficient decision, e.g., the estimation of the levels of agreement or disagreement [11]. In this study, we will focus on the geometric aspects measure of decision quality, i.e., proposing bounded indicators, for ease of having a sense to identify the outliers of the group. In addition, the disparity of the attribute weights is another main interest. After the attributes and their weights are indisputably prescribed, TOPSIS operation will start for the MADM process by all members.

It is noted that we have not studied the impacts of groupthink and decision power in organizations on decision quality in this paper. These two factors might not be represented through geometric aspects.

3.1. Agreement/Disagreement Indices

Consensus is one major topic in GDM. How to reach the consensus from individual opinions has drawn much attention in the past, and it would be more difficult to do so in a MADM environment. Saaty [25] suggests a geometric mean of all individual judgments as the group judgment for AHP. Basak and Saaty [26] further investigate the consensus of preference rankings of individuals among a large number of people through stochastic approach. Madu [27] then introduces a quality confidence process for applying AHP in the GDM environment, and outliers can, thus, be identified. Based on the concept of similarity measures of preference vectors, Bryson [28] points out that there are large disparities within comparison information that could result in inaccurate representation of the computed consensus matrix at the human level. With this in mind, he and Ngwenyama *et al.* [11] propose three indicators to estimate the level of group consensus related to the level of agreement and another three individual indicators related to the measure of the position of each individual to the group.

Because the relative location of two vectors with the same angle might generate different values, the threshold values for strong agreement and disagreement would be meaningless. Therefore, Lin [29] further suggests making use of the similarity function proposed by Chen [30] and combining with the above six indicators to evaluate agreement and disagreement of the group. To avoid the misunderstanding of the use of the indicators related to angles, we will propose the consensus indicators based on their locations in a Euclidean space.

Observe that the measure of disparity of the group preference or opinion can be on attributes, alternatives, attributes' weights, or other elements of decision-making. And we just post a general consideration in this section.

3.2. Geometric Aspects

A straightforward way to think of preference vectors would be to consider these vectors as separated points in a multidimensional or Euclidean space. We can place these points one by one, and measure the distance among any two of them. Since these points will be located in a multidimensional geometric shape or a polyhedron, we are always interested in the boundary of the shape to be formed so that we can figure out how large it is. In other words, the size of the shape represents the diversity of the individuals' preferences. For example, as the size of the shape increases, so does the diversity of opinions within the group. Thus, the consensus will be harder to reach. Based on the extreme points at two ends, we can, in a geometric aspect, imagine the shape to be a multidimensional sphere to encircle all points or their locations. Hence, the pseudo center of the sphere and their mean can be located, and a set of distance measures can be referred.

According to the locations of maximum and minimum points of the preference vector of the group, we can establish an approximate diameter of the pseudo sphere in a multidimensional space. However, the geometric mean (GM) seems less meaningful in the space due to a ratio scale among all points. Hence, the point of arithmetic mean (AM) will be adopted in place of the geometric mean to serve as the center of the sphere intuitively. Then, we can view the AM as the center of the group. Even though the pseudo center has been shifted from the middle point of maximum and minimum to the point of AM, the diameter of the sphere is still kept to enclose all points. By this arrangement, we can measure the distance between the point of AM and any other point of each voter. Therefore, the voter with longer distance will be deemed as an outlier of the group. And if the outliers are taken away or their opinions are changed, the consensus of the group can, thus, be enhanced.

3.3. Bounded Indicators

Before the consensus facilitation is treated, we need to know if the disparity of members' opinions is good enough or not. Consequently, we bring up two bounded indicators, AM_upper and AM_lower as the upper bound and the lower bound, respectively, of the group. These two create a feasible range for each preference. If any value is beyond the range, we will further check their consensus indicators, which are illustrated below, to find the outliers of the group. Otherwise, no action will be taken on this account. Noted that the upper bound and lower bound can be set as +30% and -30% of the AM value, respectively, for a reference.

3.4. Consensus Indicators

To realize the above geometric regards, three classes of indicators, e.g., max_dist, min_dist, and AM_dist, are aided to measure the disparity of the members' preferences. And we can identify outliers of the group through an operation of these three indicators.

3.4.1. Max-related indicators

Analogous to NIS, maximum point is a pseudo point that represents the maximum value in each dimension among all preference vectors of the group. Max_dist is an indicator to measure the distance between each member's and the maximum point, and it represents how far a preference is away from one extreme. And the small value is undesirable. After max_dist is defined, the indicator of max_rat is to measure max_dist as the percentage of the pseudo diameter in a multidimensional space. And the distance of all members' can be ranked in an increasing order, i.e., max_rank.

3.4.2. Min-related indicators

Analogous to NIS, minimum point is also a pseudo point that indicates the minimum value in each dimension among all preference vectors of the group. Min_dist is a measure of the distance between each member's and the minimum point, and it depicts how far a preference is away from another extreme. And the small value is also undesirable. After min_dist is prescribed, the indicator of min_rat is to measure min_dist as the percentage of the pseudo diameter. And the distance, that all members' represent, can also be ranked from the smallest to the largest, i.e., min_rank. As a matter of fact, the largest distance is the most preferable for consensus facilitation.

3.4.3. AM-related indicators

Because arithmetic mean is defined as the center of the group preference, analogical distance measures can be established. AM_dist is an indicator to measure the distance between each member and the AM, and it pictures how far a preference is away from the group mean. After AM_dist is specified, the indicator of AM_rat is to measure AM_dist as the percentage of the pseudo diameter. However, the distance that all individuals' represent can be ranked in a decreasing order here, i.e., AM_rank. Analogous to PIS, the smallest distance is most desirable.

Since these distance relevant indicators are valuable information to show the disparity of the group preference, the above three ranking indicators can be further applied as the tool for consensus facilitation.

3.5. Consensus Facilitation

After interpreting the consensus related indicators cited above, we see that the preference vectors of a couple of members or voters are significantly close to the maximum point or the minimum point, or away from the center, which means the members to be the outliers of the group. Mathematically, we will introduce another indicator Min_all_rank = Min{max_rank, min_rank, AM_rank} to distinguish the outliers. Utilizing the minimum operator, we can obtain at least one of the three with the minimum rank to catch the disparity in all aspects. Thus, the outliers will be identified and their preference vectors should be revised to reach some degree of consensus.

However, we can further translate this consideration into a quantitative judgment. The voter that obtains the first rank on Min_all_rank will be the first one to be modified. This means the largest disparity should be first considered to change so that a better degree of consensus can be attained. If the modified preference is still not satisfactory by the group standard, an elaboration of process will be followed, i.e., the second rank and third rank are then forced to modify their preference and check the result afterwards. The process will be continued until a general agreement is achieved. Moreover, we can also delete the preferences of outliers if the size of the group is large enough. And the degree of consensus would be strengthened.

Table 1. Basic data of the preference of the group.

Voter	Preference Vector					Summation	Note
1	0.2310	0.1430	0.2180	0.2020	0.2060	1.000	
2	0.2680	0.1180	0.2060	0.2400	0.1680	1.000	
3	0.2570	0.1560	0.1560	0.2410	0.1890	0.999	
4	0.2650	0.1360	0.2150	0.2260	0.1580	1.000	
5	0.2020	0.1690	0.1790	0.2270	0.2230	1.000	
6	0.2310	0.1540	0.1900	0.2590	0.1670	1.001	
7	0.2780	0.0990	0.2150	0.2440	0.1650	1.001	
8	0.2060	0.1500	0.1720	0.2420	0.2290	0.999	
9	0.2080	0.1640	0.1790	0.2220	0.2270	1.000	
10	0.2170	0.1710	0.2120	0.2330	0.1680	1.001	
11	0.2430	0.1670	0.2230	0.2280	0.1490	1.001	
12	0.2240	0.1600	0.2030	0.2390	0.1740	1.000	
GM	0.2338	0.1472	0.1962	0.2332	0.1833		Reference
AM	0.2351	0.1489	0.1973	0.2336	0.1853		
Minimization	0.2020	0.0990	0.1560	0.2020	0.1490		
Maximization	0.2780	0.1710	0.2230	0.2590	0.2290		

Note: GM—geometric mean; AM—arithmetic mean.

Table 2. Calculation of some distance related indicators.

Voter	max_dist	max_rat	max_rank	min_dist	min_rat	min_rank
1	0.0824	52.04%	1	0.0993	62.71%	7
2	0.0853	53.86%	4	0.0950	59.96%	3
3	0.0841	53.11%	3	0.0969	61.18%	4
4	0.0871	54.98%	6	0.0973	61.45%	5
5	0.0937	59.13%	10	0.1074	67.78%	12
6	0.0862	54.41%	5	0.0927	58.52%	2
7	0.0978	61.75%	12	0.1062	67.03%	11
8	0.0923	58.25%	9	0.1043	65.82%	9
9	0.0909	57.36%	8	0.1062	67.02%	10
10	0.0908	57.30%	7	0.0993	62.70%	6
11	0.0965	60.92%	11	0.1040	65.64%	8
12	0.0828	52.29%	2	0.0917	57.88%	1
Total	1.0700	675.39%		1.2004	757.69%	

Table 2. (cont.)

Voter	AM_dist	AM_rat	AM_rank	Min_all_rank
1	0.0437	27.56%	9	1
2	0.0495	31.26%	5	3
3	0.0480	30.33%	7	3
4	0.0466	29.43%	8	5
5	0.0575	36.27%	3	3
6	0.0328	20.70%	11	2
7	0.0719	45.36%	1	1
8	0.0589	37.20%	2	2
9	0.0563	35.56%	4	4
10	0.0364	23.00%	10	6
11	0.0483	30.48%	6	6
12	0.0208	13.15%	12	1
Total	0.5708	360.31%		

Let us consider the following example in dealing with the preference on alternatives.

EXAMPLE 1. Twelve committee members anonymously ranked the five candidates and provided data on the relative strengths of their preference as the following (from [28]).

Based on the given data, we can calculate the arithmetic mean, maximum value, and minimum value of the group preference as shown in Table 1. In addition, the geometric mean (GM) is computed as a reference here.

Shortly after the previous step, the pseudo diameter in a Euclidean space can be estimated as the distance of 0.1584, and the AM is located at (0.2351, 0.1489, 0.1973, 0.2336, 0.1853). Then, we will check the feasible range on each preference vector, which are between +30% and −30% of the AM value. Unfortunately, the second one of the vector is beyond the given feasible range, and we will identify outliers through further operation.

Their max_dist, max_rat, and max_rank will be manipulated as one class, so is the class of min_dist, min_rat, and min_rank. The third class, AM_dist, AM_rat, and AM_rank are calculated accordingly. The final indicator, Min_all_rank, is applied to search for voters with the higher rank (i.e., minimum value), meaning their preference is away from the group. In this case, their preference should be modified or deleted to decrease the disparity. In Table 2, Voters 1, 7, and 12 have the highest rank, i.e., number 1, and are forced to conduct an action.

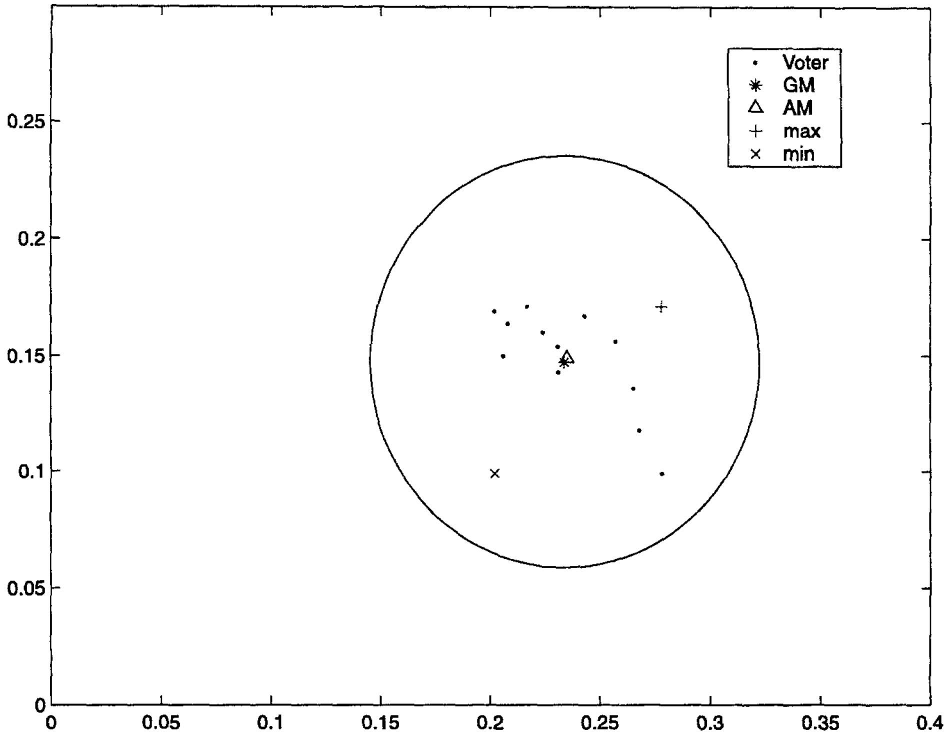


Figure 2. Preference vectors of Example 1 in a two-dimensional spaces.

Note:

(1) The data is taken from Table 1 with 12 voters.

(2) GM—geometric mean; AM—arithmetic mean.

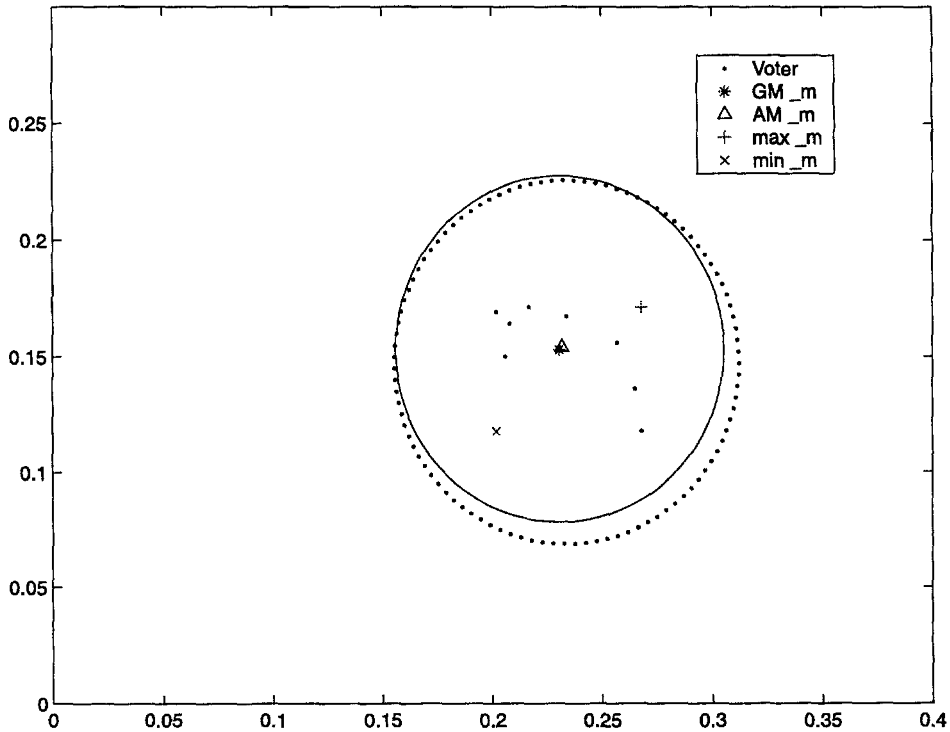


Figure 3. Preference vectors of Example 1 with modification.

Note:

(1) The data is obtained from Table 1 with nine voters.

(2) GM_m—modified geometric mean; AM_m—modified arithmetic mean.

(3) The dashed circle here is the same as the circle shown in Figure 2.

To demonstrate the effect of exclusion of extreme preferences, we have made a further calculation exclusive of the three voters or outliers. Its pseudo diameter has reduced to 0.1394, and the location of AM is at (0.2320, 0.1539, 0.1924, 0.2353, 0.1864). In addition, we now see that the distances of AM to maximization point and to minimization point are decreased significantly, from 0.0745 and 0.0872 to 0.0.0700 and 0.0714, respectively. Figures 2 and 3 illustrate individually the separation of the original preferences and the modified preference. Two different circles are shown the effect of exclusion in Figure 3. The same process can be executed until a satisfactory result is obtained.

For this example, the revised preference of the group is within the feasible range. The adapted result is acceptable so that the progress stops there. However, these three voters can still modify their preferences and present them to the group later. It all depends on which strategy is taken in the beginning.

It is noted that the above process can be applied to any target in decision-making, e.g., an alternative set, an attribute set, or a weight set [31]. However, we do not intend to involve the former two in our system.

The described steps are valuable for establishing an efficient GDSS, and through the given indicators and their referred values, the value of consensus of group decision can be measured and increased quantitatively.

4. IMPLEMENTATION OF THE INTEGRATED PROCEDURE

Being equipped with a broad range of decision analysis tools, we shall realize an integrated procedure combining these techniques for solving problems. And the procedure involved is classified as a multicriteria group decision support for discrete alternative problems. In fact, the procedure is the same as the procedure of decision analysis [32] with consensus-reaching intensified. Furthermore, to begin with an electronic meeting system, the procedure heavily relies on information technique to connect with the necessary techniques in each step.

4.1. Problem-Solving Procedure

After the problem-solving procedure has been defined in Figure 1, the designated activity flow will be realized on a GDSS.

4.2. Implementation of the GDSS

The procedure has been performed in an environment of network-based PCs with web interfaces. In the beginning, the communication among DMs of an organization, including a chairman and other members, will be controlled through a chat room or Microsoft Netmeeting for understanding the background of the project and exchanging opinions throughout the task group (Step 0). After the NGT process is conducted for obtaining the necessary attributes (Step 1), each DM will elicit the attributes' weights individually by Microsoft Excel (Step 2). Then, the individual's preference will be collected by the chairman, and much calculation will be made to group consensus on attribute's weight via Excel and ASP (Step 3). At this time, a series of discussions and modifications would have been done provided that the value of any consensus indicator is shown dissatisfactory. In addition, based on the thresholds of each attribute, unfavorable alternatives shall be eliminated from a presetup database (Step 4). Afterwards, the alternatives will be evaluated individually through TOPSIS process (Step 5). Finally, all members' rankings will be aggregated by Borda's function (Step 6). Therefore, the preferred alternative or the suggested options will be offered in the end.

The system includes three major parts: user's interfaces, database, and model base; and the first one is the most sophisticated work among these three. All user's interfaces of the system can be classified into two different types, chairman and members; the function of which depends on their respective requirements. The main structure also includes three parts: function list, input, and output interfaces. The functions list, designed by the suggested decision-making procedure, not only builds an invisible list to simplify pictures through visual basic (VB) but also provides online operational guide. Input interface sends user's inquiry or required operations to the server end by ASP. After the process is handled in model base or database, the valuable processed

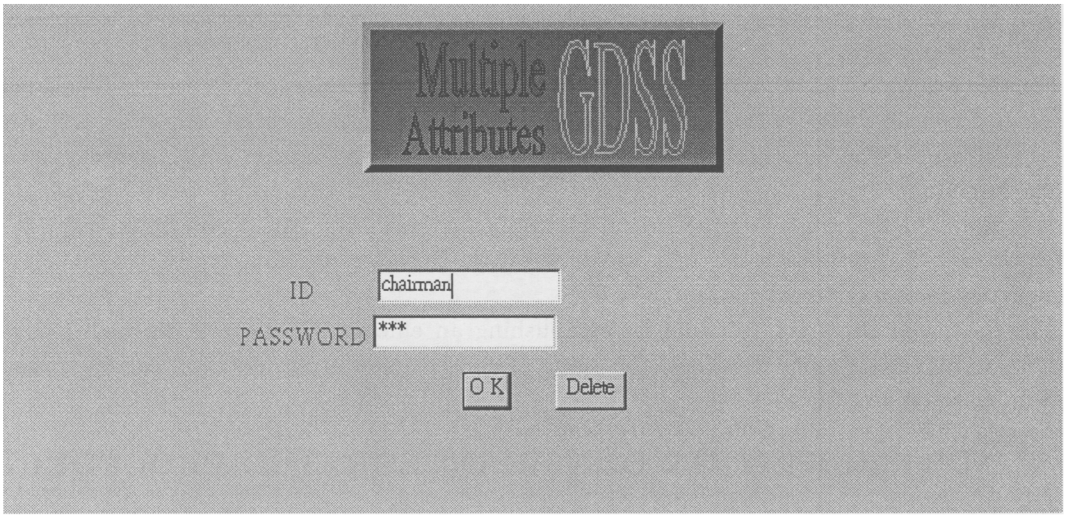


Figure 4. Login of the designed GDSS.

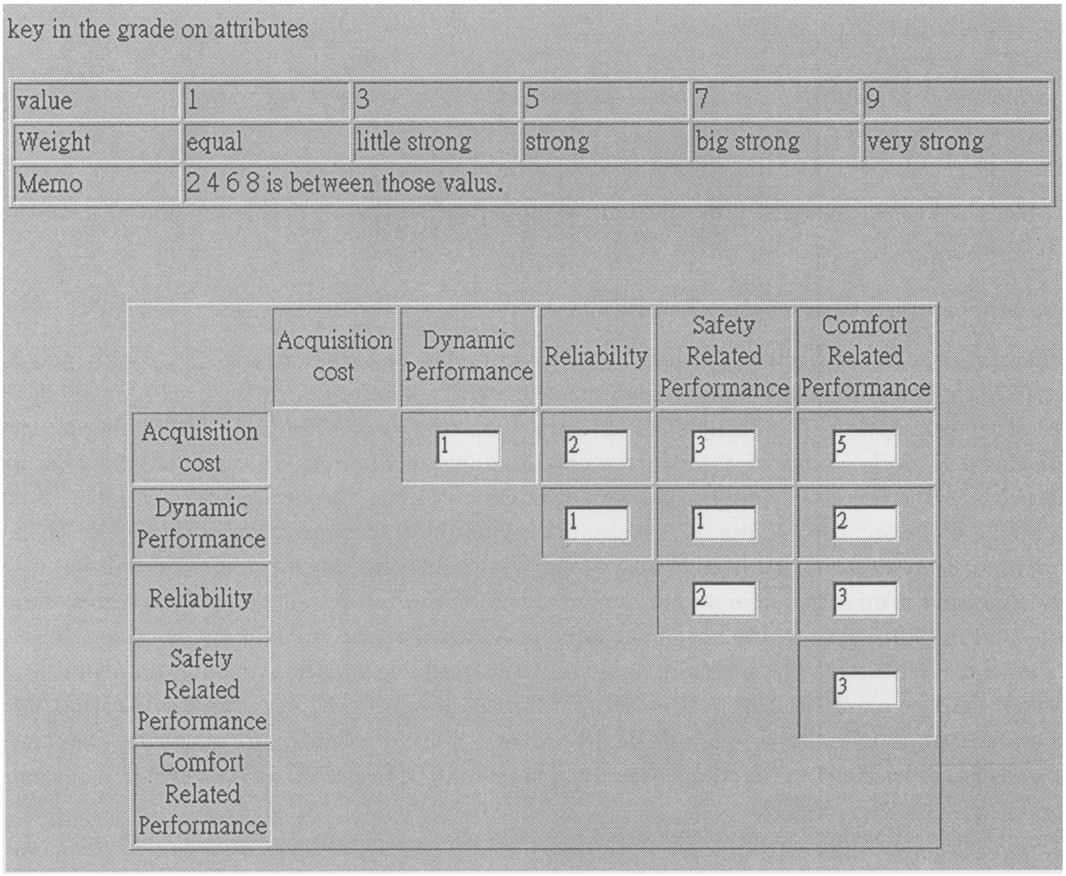


Figure 5. Pairwise comparison of car's attributes.

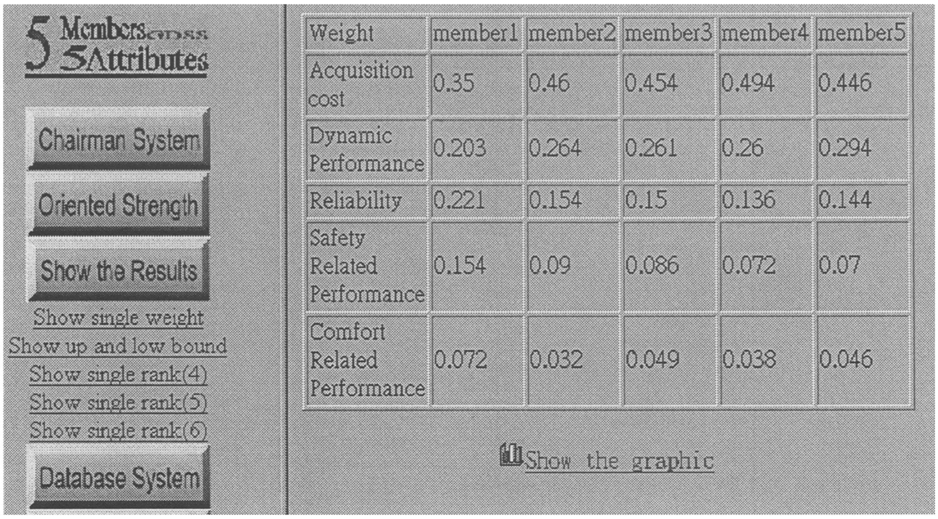
Note:
Five attributes are chosen in the process.

information is sent back to output interface via ASP. And the results can be illustrated in the forms of sheets, tables, or charts, to adequately assist DMs in making an optimal judgment. Because of the characteristics of constant data refreshing and less load to ASP, sound interactions between the users and the system can be maintained.

Let us demonstrate the insides of the system through a car-selection case.

EXAMPLE 2. A CAR-SELECTION PROBLEM. A small company is looking for a general-purpose car for office use, and a body of five members has been charged with the responsibility. They collect a substantial amount of technical and consumer information of cars available on the markets, and then they create a car database. All steps of decision making are to be executed through a prototype system. After exchanging information among members and some substantial computations, certain result can be obtained.

Following the procedure listed in Figure 1, a GDSS for the car selection is presented. While making use of the system, we first decide how many members (including the chairman of the group) to be included in the scheme. General discussion and NGT are processed through a chat room on the web. At the same time, the chairman and other members can log in to the system as shown in Figure 4. In general, the rest of the members are responsible for providing basic preferred data before Step 5, and the chairman (end) will take over the remaining computation until to the final choice. Figure 5 shows the pairwise comparison of car's attributes of Step 2



Weight	member1	member2	member3	member4	member5
Acquisition cost	0.35	0.46	0.454	0.494	0.446
Dynamic Performance	0.203	0.264	0.261	0.26	0.294
Reliability	0.221	0.154	0.15	0.136	0.144
Safety Related Performance	0.154	0.09	0.086	0.072	0.07
Comfort Related Performance	0.072	0.032	0.049	0.038	0.046

Figure 6. The weights of all five members.

Note:

Member 5 is designated as the chairman of the team.

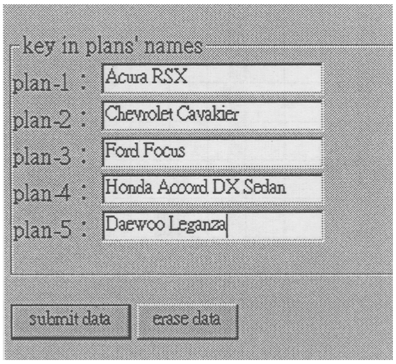
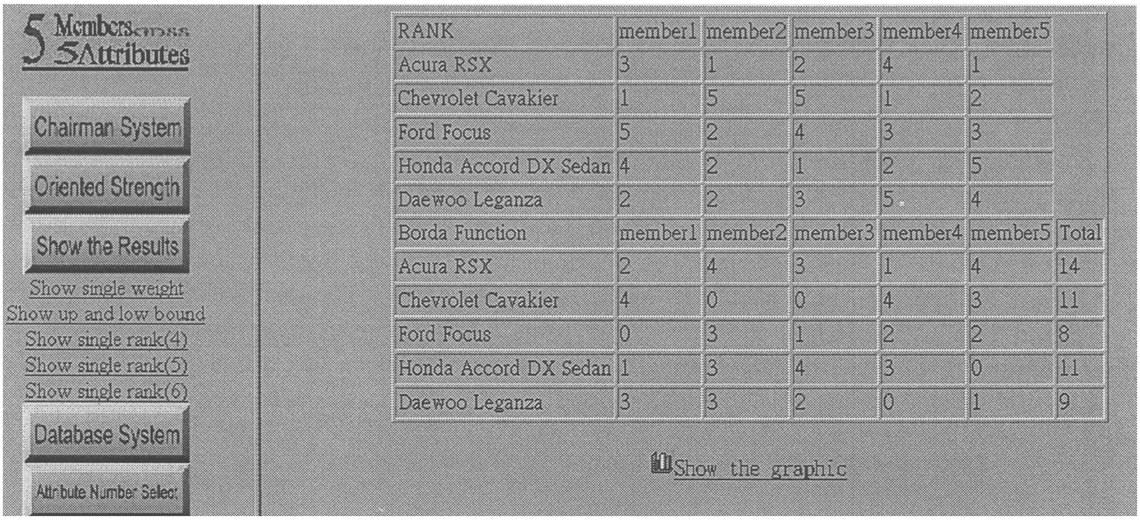


Figure 7. The five alternatives to be evaluated after screened out from the datebase.

(five attributes to be selected in Step 1). Figure 6 demonstrates the weights of all members after the consistency check. After the consensus on attributes' weights are reached, Figure 7 illustrates five alternatives, e.g., Acura RSX, Chevrolet Cavalier, Ford Focus, Honda Accord DX Sedan, and Daewoo Leganza, to be further evaluated after screened from the database. The calculation of TOPSIS and aggregation of data will heavily rely on the chairman end. The result and its graphic representation are shown in Figures 8 and 9, respectively. And the final step shows Acura RSX is the most preferred one by the task group.



RANK	member1	member2	member3	member4	member5
Acura RSX	3	1	2	4	1
Chevrolet Cavakier	1	5	5	1	2
Ford Focus	5	2	4	3	3
Honda Accord DX Sedan	4	2	1	2	5
Daewoo Leganza	2	2	3	5	4

Borda Function	member1	member2	member3	member4	member5	Total
Acura RSX	2	4	3	1	4	14
Chevrolet Cavakier	4	0	0	4	3	11
Ford Focus	0	3	1	2	2	8
Honda Accord DX Sedan	1	3	4	3	0	11
Daewoo Leganza	3	3	2	0	1	9

Figure 8. The choice of the team.

Note:
Member 5 is designated as the chairman of the team.

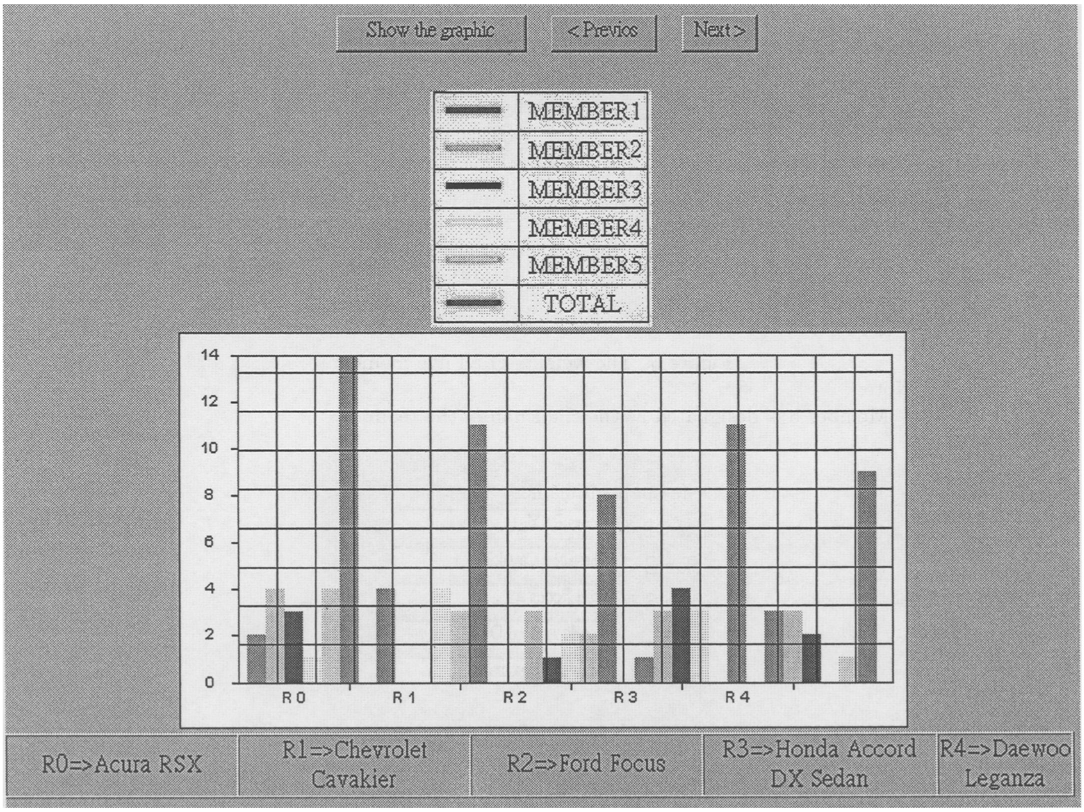


Figure 9. Graphic representaion of the choice of the team.

5. CONCLUSIONS AND REMARKS

We have proposed an integrated decision model and implemented a prototype GDSS with multiple attributes. The car-selection example has verified the feasibility of the study. However, it is realized only for a small-size example here. And large-size problems are expected to be dealt with in the future. In addition, the system is executed on the web to fulfill a task. Thus, it is possibly to be utilized by any working group or virtual group among organizations for collaborative support [5].

Despite decision quality can be improved by the integrated procedure, the most interesting part is the suggested qualitative consensus indicators. They can show how much the consensus can amount to graphically; thus, providing all members an easy understanding of the disparity of one another. In addition, the impacts of groupthink and decision power in organizations on decision quality will be left for future study.

Data collection and verification is the most time-consuming work in the decision-making process; however, a variety of commercial databases and other immediate information on the web could relief the burden somehow. Hence, a specified DSS or an online analytical processing (OLAP) tool can be developed promptly based on our proposed procedure.

A spreadsheet-based decision tool, e.g., Excel, is rather efficient for noninformation major specialists to build a customized GDSS. Nevertheless, its inflexibility will result in much labor, e.g., for the choices of different number of members, attributes, and alternatives, when it links with the web. For instance, Figure 6 shows the weights only for five attributes with five members included. To manipulate such complex combinations, much effort has been made in modifying the similar calculating process. Thus, a fully ASP executed program can be a good choice to replace Excel's calculation in the future.

TeamEC [33] is a popular, commercial MCDM software supporting collaborative work. Its man-machine interface is very user-friendly and is capable of a variety of decision-making problems. However, its ability is restricted due to its closed environment. In this respect, our system sounds more promising.

Fuzzy sets might involve many parts in the integrated procedure, e.g., transition between agreement and disagreement [34], or ratings and weights of criteria represented by triangular fuzzy numbers [35]; and this will be a new direction for future study.

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