

Research Article

Large Group Decision-Making Approach Based on Stochastic MULTIMOORA: An Application of Doctor Evaluation in Healthcare Service

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Purpose. This paper presents a new method and model based on stochastic MULTIMOORA method and discuss its application to the doctor evaluation in healthcare service. **Design/Methodology/Approach.** In the previous studies, the number of decision group is often assumed to be small, and the different dimensions of the evaluation indexes were also less. In this paper, the authors study how to evaluate the healthcare service quality of doctors by the large group. Based on the stochastic MULTIMOORA theory, the authors use the method that builds the function of the net probability, the distance between the ideal solutions, and the utility of each doctor. **Findings.** This paper presents a novel model to determine the optimal doctor that considers both two dimensions in the index system and balances the evaluation results of the two dimensions. The authors designed the questionnaire and conducted field survey to make the proposed method closer to the actual situation in China. Then, they determined the optimal evaluation result for the healthcare service quality of doctors. **Research Limitations/Implications.** In the process of practical decision-making, there are differences in intellectual literacy level, regional background, and language preference between different decision-makers. It is impossible for the method we proposed to consider the differentiation index system of decision-makers' preference comprehensively. And this will be a further research direction. **Practical Implications.** The authors proposed two evaluation index dimensions and tried to balance the evaluation results of the two dimensions as much as possible. Meanwhile, the information aggregation method based on stochastic MULTIMOORA is distinguished. **Social Implications.** The proposed method can be applied to the evaluation of doctors in actual healthcare service. It is helpful to improve the healthcare service quality and the hospital management level, further improve the core competition of hospitals. **Originality/Value.** This paper makes up for the lack of existing studies of the large group evaluation decision in the healthcare service. A new method on the evaluation of doctors by the large group is established and applied to a healthcare management decision-making problem with Chinese characteristics in reality.

1. Introduction

Service quality improvement as a strategy to attain a competitive advantage in an industry improved the reputation and profitability of a health organization. The healthcare service quality of the hospital has always been a matter of close concern to the national government and the general public. In the wave of healthcare reform, the competition in hospitals is increasingly fierce. Doctor-patient relationship and patient satisfaction are important indicators that reflect the service quality of a healthcare institution. Most hospitals have found

it necessary to measure, monitor, and improve the quality of healthcare services in order to survive and achieve patient satisfaction. In China, the healthcare service evaluation industry develops rapidly, the doctor is the principal part of the healthcare service, and the service quality of the doctors is directly related to the healthcare service quality. And many healthcare institutions in China have implemented the evaluation system of service quality of the doctors. For example, in some telemedical consultation platforms, patients will be invited to evaluate the service after the diagnosis is over. The doctors who obtained better comprehensive evaluation will

be paid more and will be recommended preferentially for the same patients in the future; the number of diagnosis is directly related to the reward. A reasonable and complete healthcare service quality evaluation system for doctors can improve the work motivation and healthcare service quality of doctors. At the same time, it can further improve the core competitiveness of healthcare treatment and support the sustainable development of hospitals to help deepen the health reform. To sum up, the evaluation of service quality of the doctors is a research question with important theoretical and practical significance.

It should be noted that in the real service quality evaluation problem, the patient often plays the role of evaluator as the direct beneficiary of healthcare services. Therefore, the research on the quality evaluation of healthcare service belongs to the category of group decision-making. Furthermore, due to the large number of patients participating in evaluating the healthcare service quality, the healthcare service quality evaluation problem belongs to large group decision-making. In addition, the aggregation and processing of the large number of multisource evaluation information belong to the category of the large group decision-making. The large group decision-making of healthcare service quality evaluation problem has become the focus of the current domestic and foreign scholars and a forefront project that needs key funding (Rutherford 2011; Adriano et al. 2009). There have been some research results of the current healthcare evaluation. Dimovska et al. (2016) did a questionnaire survey on clinic patients in a week extracting the patients' degree of satisfaction or evaluation of the hospital or doctor's with empirical method. Gao (2007) determined the performance evaluation index of doctors through questionnaire and evaluated briefly the completion of the task with weighted TOPSIS. The large group decision-making problem has obtained many research results. Jiang et al. [1] put forward a measure decision method of the distance between two discrete random variables using TOPSIS method to solve the discrete stochastic multiattribute decision-making problem. Fan et al. [2] propose a novel method to solve stochastic multiattribute decision-making problems. The consequences of attribute selection are expressed with the cumulative distribution function of random variable. Zhang [3] put forward a decision-making method based on random dominant criterion for multiple index scale large group decision-making problems. A decision analysis method based on prospect theory is proposed to consider the group reference point multiattribute decision-making problems. Li et al. [4–6] put forward an improved TOPSIS based on prospect theory and method of decision-making for multicriteria decision-making problems whose criteria values are interval grey numbers and intuitionistic fuzzy numbers and the criteria weights are partially known with natural state probability for grey numbers. Gong (2010) researched the optimal sorting method of intuitionistic fuzzy group judgment matrix with incomplete information. He (2015a, 2015b) researched the theoretical and practical problems of the consensus strategy based on the minimum cost and maximum return with interval preference opinions. Stochastic multiattribute decision theory is applied

to uncertainty mathematical theories [4–13, 17–20], Logic-Mathematical theory [11], rough set theory [14], game theory [17], consensus decision [18–20], matrix games [4], fuzzy information [5, 6], and so on.

There are two main approaches to the existing decision-making method. One is to directly assemble the evaluation matrix of each individual, but due to participation of numerous individuals, this method is of low efficiency, and the calculation is too large to operate. The other is to adopt clustering methods to reduce the complexity of decision-making, but clustering methods tend to make some important expert opinions be ignored; in fact, the opinions of these important experts often deserve our attention. At the same time, the evaluation method of the existing service quality is not suitable for the evaluation of healthcare service quality. For example, it ignores the characteristics of large group decision-making.

The aim of this paper is to propose a method of stochastic MULTIMOORA to resolve the healthcare evaluation in large groups. On the basis of this method, considering the existing problems about large group decision-making of multisource healthcare service quality evaluation and the extraction of the evaluation index among the large group of patients and the superiority of the stochastic MULTIMOORA in decision-making of evaluation problems, it is innovative to use stochastic MULTIMOORA in the field of large group decision-making of multisource healthcare service quality evaluation problem. This paper first considers the multisource of the evaluation index to the large group decision-making problem and then introduces stochastic MULTIMOORA into the healthcare service quality evaluation problems.

In the proposed method, we established the stochastic MULTIMOORA-based large group decision-making method and constructed the different decision-making perspectives of the multisource evaluators. With the reality of China, differentiation index evaluation method of healthcare service quality is established firstly. In the decision-making process, an information aggregation method for multisource evaluator and the normalized decision matrix is proposed. Based on the classic distance measure, a comprehensive evaluation method based on multisource evaluation information is proposed. Last, the feasibility of the proposed method is proved through numerical example analysis. Through this study, we hope that the large group decision-making method will be enriched and expanded. And more theoretical and practical problems will be solved by proposing large group decision-making. There are three main advantages in the proposed method. First, a large group of multisource methods for evaluating doctors are presented. Second, a two-dimensional index system based on the questionnaire survey is established. Third, the balance of the two dimensions is considered to choose the best doctor.

The rest of this paper is organized as follows. In Section 2, we reviewed some preliminary knowledge about method MULTIMOORA. In Section 3, we briefly described the problems of the multisource healthcare service quality evaluation and then set the parameters. In Section 4, we aggregated

multisource evaluation information and obtained the comprehensive healthcare service quality evaluation results by using the method of stochastic MULTIMOORA. In Section 5, an example illustrating the feasibility and effectiveness of the proposed method is presented. At last, we conclude our research and set out further research directions in Section 6.

2. Preliminary Knowledge

In this section, we introduce a classical MULTIMOORA method, which will provide a good basis for the proposed method.

Before introducing the MULTIMOORA method, we consider a standard MADM problem. Let $X = \{X_1, X_2, \dots, X_m\}$ be the set of alternatives, where X_i denotes the i th alternative. Let $C = \{C_1, C_2, \dots, C_n\}$ be the set of attributes, where C_j denotes the j th attribute. The attribute set is divided into two types, i.e., benefit attribute and cost attribute. Without loss of generality, let $C^1 = \{C_1, C_2, \dots, C_g\}$ be the subset of benefit attributes, and let $C^2 = \{C_{g+1}, C_{g+2}, \dots, C_n\}$ be the subset of cost attributes. Let $V = [v_{j1}, v_{j2}, \dots, v_{jn}]^T$ be the weight vector of the attributes, where $v_j \geq 0$, such that $\sum_{j=1}^n v_j = 1$. Let $A = [\alpha_{ij}]_{m \times n}$ be a decision matrix, where α_{ij} denotes the evaluation of X_i with respect to C_j , for $i = 1, 2, \dots, m$ and $j = 1, 2, \dots, n$.

Then, the MULTIMOORA method can be introduced in the following procedure.

Step 1 (the ratio system). Let α_{ij}^* be the normalized value of α_{ij} , where

$$\alpha_{ij}^* = \sqrt{\frac{\alpha_{ij}}{\left[\sum_{i=1}^m \alpha_{ij}^2\right]}}. \quad (1)$$

Let β_i^* be the normalized ratings of X_i . The normalized ratings for benefit attributes (in case of maximization) are added and the cost attributes (in case of minimization) are subtracted for the evaluation values of the ratio system:

$$\beta_i^* = \sum_{j=1}^g \alpha_{ij}^* - \sum_{j=g+1}^n \alpha_{ij}^*. \quad (2)$$

Then, let β_i^v be the weighted form of the ratio system. By considering weights of attributes, the weighted form of the ratio system could be obtained as follows:

$$\beta_i^v = \sum_{j=1}^g v_j \alpha_{ij}^* - \sum_{j=g+1}^n v_j \alpha_{ij}^*. \quad (3)$$

Furthermore, let X_{VRS}^* be the optimal alternative of the weighted form of the ratio system, where

$$X_{VRS}^* = \left\{ X_i \mid \max_i \beta_i^v \right\}. \quad (4)$$

Step 2 (the reference point approach). Let r_j be the reference point of attribute α_{ij} , where

$$r_j = \begin{cases} \max_i \alpha_{ij}^*, & j \leq g, \\ \min_i \alpha_{ij}^*, & j > g. \end{cases} \quad (5)$$

Let d_{ij} be the distance between the evaluation α_{ij}^* of alternative X_i and the reference point r_j , where

$$d_{ij} = r_j - \alpha_{ij}^*. \quad (6)$$

Let d_i^* be the maximum distance among the d_{ij} . Then, the maximum deviation for each alternative, namely, the evaluation value of reference point approach, could be specified as

$$d_i^* = \max_j |r_j - \alpha_{ij}^*|. \quad (7)$$

Let d_i^v be the weighted form of evaluation value of the reference point approach, where

$$d_i^v = \max_j |v_j r_j - v_j \alpha_{ij}^*|. \quad (8)$$

Let X_{VRP}^* be the minimum value of d_i^v . The optimal alternative of the reference point approach and its weighted form can be calculated as follows:

$$X_{VRP}^* = \left\{ X_i \mid \min_i d_i^v \right\}. \quad (9)$$

Step 3 (the full multiplicative form). Let U_i' be the utility of attribute α_{ij} ; it can be determined as follows:

$$U_i' = \frac{\prod_{j=1}^g \alpha_{ij}}{\prod_{j=g+1}^n \alpha_{ij}}. \quad (10)$$

The numerator of (10) denotes the product of responses of i th alternative to beneficial attributes while the denominator of (10) shows the product of responses of i th alternative to nonbeneficial attributes.

Let U_i^* be the equivalent form of U_i' ; it can be computed utilizing the arrays of normalized decision matrix as follows:

$$U_i^* = \frac{\prod_{j=1}^g \alpha_{ij}^*}{\prod_{j=g+1}^n \alpha_{ij}^*}, \quad (11)$$

The evaluation values U_i^* are not the same as U_i' ; however, ranking of (10) and (11) is identical. Let U_i^v be the weighed form of U_i^* . The formula for full multiplicative form considering weights of attributes can be calculated as

$$U_i^v = \frac{\prod_{j=1}^g (\alpha_{ij}^*)^{v_j}}{\prod_{j=g+1}^n (\alpha_{ij}^*)^{v_j}}. \quad (12)$$

Compared with the ratio system, let X_{MF}^* be the maximum value of U_i^* . The optimal alternative has the maximum evaluation value:

$$X_{MF}^* = \left\{ X_i \mid \max_i U_i^* \right\}. \quad (13)$$

Let X_{VMF}^* be the maximum value of U_i^v . The optimal alternative of the weighted full multiplicative form is

$$X_{VMF}^* = \left\{ X_i \mid \max_i U_i^v \right\}. \quad (14)$$

Step 4 (final ranking of the MULTIMOORA method based on the dominance theory). The dominance theory helps in translating several ordinal scales, namely, rankings, into other ordinal scales based on propositions like dominance, being dominated, transitivity, and equability. Circular reasoning may occur in the process of employing the dominance theory.

Based on the theory of dominance, the MULTIMOORA rank can be integrated into the subordinate ranks from Steps 1, 2, and 3.

3. Large Group Decision-Making Problem of Multisource Healthcare Service Quality Evaluation

3.1. Description of Multisource Healthcare Service Quality Evaluation Problem. In practical decision-making problem for healthcare service quality evaluation, to judge the healthcare service quality in public, the hospital usually contacts the patient or family and familiar people through different channels and ways to evaluate healthcare service quality of doctors. For example, for the patients undergoing healthcare treatment, the hospital often receives evaluation information by directly asking the patient; for the patients who have been discharged from hospital, the hospital receives the evaluation information by call-back; for the patients who have made an appointment online, the hospital receives the evaluation information online; and for the families waiting for the patient's treatment according to Fan et al. [21], the hospital receives the evaluation information through questionnaires. Before the formal evaluation, the hospital first needs to collect the effective evaluation information of all patients; the hospital immediately launches the preset evaluation rules and evaluates the healthcare service quality of the doctors.

3.2. A Framework for the Healthcare Service Quality Evaluation. In this section, a healthcare service quality hierarchy is firstly finalized. Then, a framework for healthcare service quality evaluation is presented.

To determine a healthcare service quality hierarchy effectively, we designed a questionnaire in order to analyze the evaluation indexes of doctors. The details of a questionnaire can be seen in the appendix. We choose the four kinds of multisource objects in order to more fairly judge the healthcare service quality in public, such as the patients undergoing healthcare treatment, the patients who have been discharged from hospital, the patients who have made an appointment online, and the families waiting for the patient's treatment. We sent out 316 questionnaires and withdrew 291 questionnaires, including 277 valid questionnaires. Here, if an evaluator gives the same value for all indexes of any doctors, or the values for any index of all doctors, then we think the evaluation is random. If any value is very high for one doctor and very low for all the other doctors, then we think that the

patient deliberately improves the values of this doctor; in the same way, if any value is very low for one doctor and very high for all the other doctors, then we think that the patient deliberately decreases the values of this doctor. In these cases, we regard these unfair questionnaires as invalid.

Based on the result of questionnaires, combined with the existing literature on medical service quality evaluation or doctor performance evaluation, two dimensions of ability and reputation are identified to evaluate the healthcare service quality. Here, "ability" in this paper denotes the comprehensive ability of healthcare services, which is composed of four attributes: responsibility, healthcare ability, efficiency, and error rate. "Reputation" in this paper denotes the professional ethics of the doctors composed of four attributes: service attitude, responsibility, integrity, and communication skill.

The descriptions of two dimensions and their components can be seen in Table 1.

Then, we propose a multisource healthcare service quality evaluation framework, as shown in Figure 1. The framework includes four components: dimensions, attributes, evaluators, and matrix model. The brief illustrations of these four components are given below.

(i) *Dimensions.* There are two dimensions to be considered in evaluating the doctors, i.e., ability and reputation, and each dimension is composed of several attributes. According to the doctors' performances on the attributes in each dimension, their performances on the two dimensions can be measured. Moreover, according to the evaluation results on the two dimensions, the better doctor can be identified by a matrix model.

(ii) *Attributes.* This part shows two types of attributes. One type is the subordinate attributes concerning the dimension of ability (R^1), including research level (R_1^1), healthcare ability (R_2^1), efficiency (R_3^1), and error rate (R_4^1). The other type is those concerning the dimension of reputation (R^2), including service attitude (R_1^2), responsibility (R_2^2), integrity (R_3^2), and communication skill (R_4^2). The detailed descriptions of these attributes are presented in Table 1.

(iii) *Doctors.* This part shows an evaluator set $\{x_1, x_2, \dots, x_m\}$; the doctors in the set constitute the doctors in the hospital.

(iv) *Matrix Model.* This part shows a matrix model for identifying the healthcare service quality. The model is expressed as a two-dimensional space. The horizontal and vertical axes denote the dimensions of ability and reputation, respectively. Any point in the two-dimensional space represents a healthcare service quality level concerning the evaluation results of two dimensions. For analytical tractability, four regions, I, II, III, and IV, are partitioned to show the different healthcare service quality level. Points in region I represent the higher trust level; namely, the performances on ability and reputation are both higher.

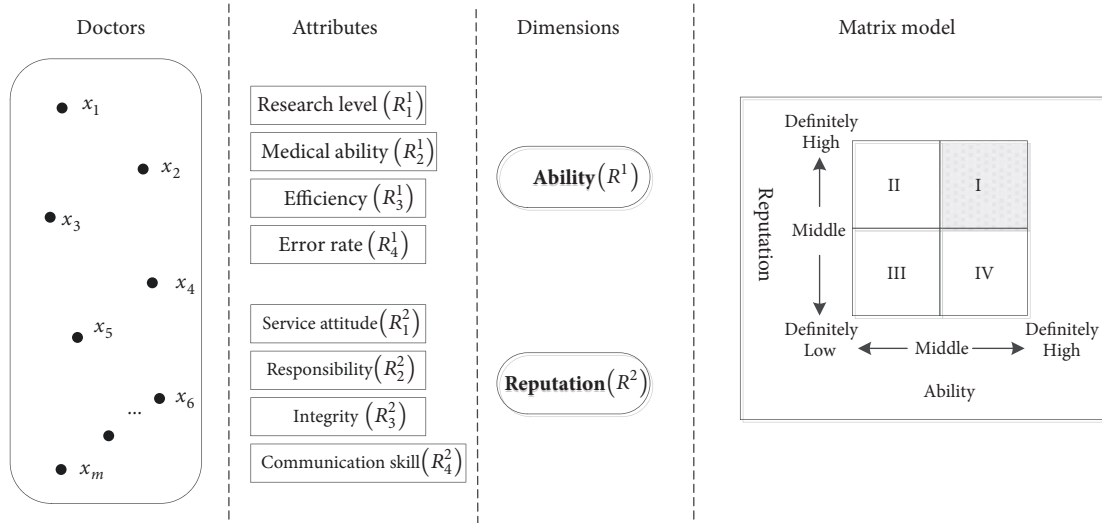


FIGURE 1: The framework of healthcare service quality evaluation of doctors.

TABLE 1: Attributes for evaluating the performances on ability and reputation.

Dimensions	Attributes	Descriptions
Ability (R^1)	Research level(R_1^1)	Research level is the ability of doctors to combine healthcare skills with actual summaries and sublimation. Usually it is associated with research projects and papers.
	Healthcare ability(R_2^1)	Healthcare ability is an important index of the professional level for the doctors.
	Efficiency(R_3^1)	Efficiency is an important index to evaluate work ability. Here, it refers to the ratio of the ease of a disease and time needed to treat it.
	Error rate(R_4^1)	Error rate is the probability that the doctors fail to treat. Usually, the better the doctors, the smaller the error rate.
Reputation (R^2)	Serve attitude(R_1^2)	Serve attitude is the patience of doctors with patients. It is related to healthcare ethics.
	Responsibility(R_2^2)	Responsibility is the embodiment of professional ethics of doctors, and it is the basic quality that doctor should have.
	Integrity(R_3^2)	Integrity is the doctor's quality of being honest and morally upright. It is an important embodiment of healthcare ethics.
	Communication skill(R_4^2)	Communication skill is the ability to perceive a patient's disease and to communicate properly. Usually, doctors with good communication skills are more productive.

3.3. *The Main Assumption and General Parameters.* The set and variables for describing the large group decision-making problem of healthcare service quality evaluation are given below.

(i) X : the set of the doctors need to be evaluated, $X = \{x_1, x_2, \dots, x_m\}$.

(ii) x_i : the i th doctor, $i = 1, 2, \dots, m$.

(iii) Q : the set of evaluators, $Q = \{q_1, q_2, \dots, q_n\}$.

(iv) q_j : the j th evaluator, $j = 1, 2, \dots, n$. Each evaluator will give an evaluation of the multiattribute performance of the doctor.

(v) R^r : the set of the attributes included in the r th dimension, $R^r = \{R_1^r, R_2^r, \dots, R_l^r\}$.

(vi) R_k^r : the k th attribute included the r th dimension, $k = 1, 2, \dots, l$.

(vii) w_k^r : the weight of the patient q_j to the attribute R_k^r , $0 \leq w_k^r \leq 1$ and $\sum_{k=1}^l w_k^r = 1$.

(viii) W^r : the weight vector of the balance of dimensions W^1 and the evaluation score W^2 .

(ix) $V = \{v_1, v_2, \dots, v_q\}$: the linguistic term set used for evaluating the doctors, $V = \{v_1 = VP \text{ (very poor)}, v_2 = P \text{ (poor)}, v_3 = M \text{ (medium)}, v_4 = G \text{ (good)}, v_5 = VG \text{ (very good)}\}$.

good). In this paper, we transform V into a set of score values. For example, when $q = 5$, $V = \{v_1 = 1, v_2 = 2, v_3 = 3, v_4 = 4, v_5 = 5\}$, where “1” denotes the worst and “5” denotes the best.

The problem concerning us in this paper is, in the large group decision-making of healthcare service quality evaluation problems, how to select the best doctor among the set X , based on the evaluators from multiple sources.

4. The Proposed Method for Healthcare Service Quality Evaluation Problem

In this section, we propose a novel multisource large group evaluation based on stochastic MULTIMOORA method in healthcare service quality evaluation compared with Hafezalkotob et al. [22]. Firstly, we normalize the decision matrix into a standardized matrix. Then, we calculate the net advantage probability of each doctor over others, the distance between the evaluations and the ideal solutions, and the utility of each doctor. Furthermore, we determine the equilibrium results between two dimensions. Last, the final ranking result could be determined.

Step 1 (normalize the decision matrix). Let P_{it}^{kr} be the probability for the i th doctor be evaluated as H_t under the k th attribute of the r th dimension

$$P_{it}^{kr} = \frac{1}{j} \sum_{j=1}^n h(e_{it}^{kr}), \quad (15)$$

$$i = 1, 2, \dots, m; \quad j = 1, 2, \dots, n; \quad t = 1, 2, \dots, q_j$$

where

$$h^p(e_{it}^{kr}) = \begin{cases} 1, & e_{it}^{kr} = H_t \\ 0, & e_{it}^{kr} \neq H_t. \end{cases} \quad (16)$$

Let $P(e_{it})$ be the probability distribution of group decision opinion; then

$$P(e_{it}) = \begin{cases} P_{it}^1, & \beta_{it} = H_1 \\ P_{it}^2, & \beta_{it} = H_2 \\ \dots & \dots \\ P_{it}^p, & \beta_{it} = H_p \\ \dots & \dots \\ P_{it}^{q_i}, & \beta_{it} = H_{q_i}, \end{cases} \quad (17)$$

$$i = 1, 2, \dots, m; \quad t = 1, 2, \dots, q; \quad p = 1, 2, \dots, q_i$$

and, obviously, $P_{it}^p \geq 0, \sum_{p=1}^{q_i} P_{it}^p = 1$,

Step 2 (calculate the probability of each doctor over others). Let $P(x_i > x_l)$ be the probability that alternative x_i is better than alternative x_l . Let $P(x_i = x_l)$ be the probability that alternative x_i is not different from alternative x_l . Let

$P(x_i < x_l)$ be the probability that alternative x_i is worse than alternative x_l . Then, $P(x_i > x_l)$, $P(x_i = x_l)$ and $P(x_i < x_l)$ are determined by the following.

$$P(x_i > x_l) = \sum_{j=1}^n \sum_{k=2}^q \sum_{s=1}^{k-1} w_j P_{ij}^k P_{lj}^s \quad (18)$$

$$P(x_i = x_l) = \sum_{j=1}^n \sum_{k=1}^q w_j P_{ij}^k P_{lj}^k \quad (19)$$

$$P(x_i < x_l) = \sum_{j=1}^n \sum_{k=1}^{q-1} \sum_{s=k+1}^q w_j P_{ij}^k P_{lj}^s \quad (20)$$

For disposal convenience, let $\tilde{P}(x_i \geq x_l)$ be the probability that alternative x_i is no worse than alternative x_l and $\tilde{P}(x_i \leq x_l)$ be the probability that alternative x_l is no worse than alternative x_i . Then, $\tilde{P}(x_i \geq x_l)$ and $\tilde{P}(x_i \leq x_l)$ are determined by the following.

$$\tilde{P}(x_i \geq x_l) = P(x_i > x_l) + \frac{1}{2}P(x_i = x_l) \quad (21)$$

$$\tilde{P}(x_i \leq x_l) = P(x_i < x_l) + \frac{1}{2}P(x_i = x_l) \quad (22)$$

Let $Net(x_i)$ be the net probability that alternative x_i is better than all other alternatives, $Net(x_i)^1$ be the net probability that alternative x_i is better than all other alternatives under the dimension ability, and $Net(x_i)^2$ be the net probability that alternative x_i is better than all other alternatives under the dimension reputation.

$$Net(x_i) = \sum_{l=1}^m [\tilde{P}(x_i \geq x_l) - \tilde{P}(x_i \leq x_l)], \quad (23)$$

$$i = 1, 2, \dots, m, \quad i \neq l$$

Therefore, the bigger value of $Net(x_i)$ indicates the better doctor x_i .

Step 3 (calculate the distance between the evaluations and the ideal solutions). Let $\alpha_{pt} = (\alpha_{p1}, \dots, \alpha_{pn})^T$ denote the ideal solutions determined by the patients, respectively, where $\alpha_{pt} = (\alpha_{p1}, \dots, \alpha_{pn})$ can be determined by the following.

$$\alpha_{pt} = \begin{cases} P_1(\alpha_{pt}) = 0, & \beta_{it} = H_1 \\ \vdots & \vdots \\ P_{k-1}(\alpha_{pt}) = 0, & \beta_{it} = H_{k-1} \\ P_k(\alpha_{pt}) = 1 - \sum_{v=k+1}^q P_v(\alpha_{pt}), & \beta_{it} = H_k \\ P_{k+1}(\alpha_{pt}) = \max_i \{P_{k+1}(\beta_{it}) \mid i = 1, 2, \dots, m\}, & \beta_{it} = H_{k+1} \\ \vdots & \vdots \\ P_q(\alpha_{pt}) = \max_i \{P_q(\beta_{it}) \mid i = 1, 2, \dots, m\}, & \beta_{it} = H_{q_i} \end{cases} \quad (24)$$

$$i = 1, 2, \dots, m; \quad t = 1, 2, \dots, n$$

Let d_{ij} denote the distances of the decision alternative x_i determined by the patients to ideal solution $\alpha_{pt} = (\alpha_{p1}, \dots, \alpha_{pn})$, where

$$d_{pi} = \sum_{h=1}^k \sqrt{\frac{1}{2} [P(\alpha_{pt}) - P(\beta_{ju})] Y [P(\alpha_{pt}) - P(\beta_{ju})]^T} \quad (25)$$

where $[P(\alpha_{sh}^+) - P(\beta_{ju})] = [P_1(\alpha_{sh}^+) - P_1(\beta_{ju}), P_2(\alpha_{sh}^+) - P_2(\beta_{ju}), \dots, P_q(\alpha_{sh}^+) - P_q(\beta_{ju})]$ and $[P_1(\alpha_{sh}^-) - P_1(\beta_{ju}), P_2(\alpha_{sh}^-) - P_2(\beta_{ju}), \dots, P_q(\alpha_{sh}^-) - P_q(\beta_{ju})]$. $Y = (y_{ij})_{q \times q}$ denotes q similarity matrixes of the decision scale, where

$$y_{ij} = q^2 - (H_i - H_j)^2. \quad (26)$$

Let d_i be the distance between alternative x_i and reference point, d_i^1 be the distances of the decision alternative x_i under the dimension ability, and d_i^2 be the distances of the decision alternative x_i under the dimension reputation. Then

$$d_i = \sum_{j=1}^n w_j d_{ij}. \quad (27)$$

There, the smaller the d_i , the better the alternative x_i .

Step 4 (calculate the utility of each doctor). Let $U(x_i)$ be the utility of x_i , $U(x_i)^1$ be the utility of the alternatives x_i under the dimension ability, and $U(x_i)^2$ be the utility of the alternatives x_i under the dimension reputation. $U(x_i)$ can be determined by

$$U(x_i) = \frac{\prod_{j=1}^n \tilde{P}_j(x_i > x_j)^{w_j}}{\prod_{j=1}^n \tilde{P}_j(x_i < x_j)^{w_j}} \quad (28)$$

where the calculations of $\tilde{P}_j(x_i > x_j)$ and $\tilde{P}_j(x_i < x_j)$ are defined in Step 2.

There, the bigger the $U(x_i)$, the better the alternative x_i .

Step 5 (determine the equilibrium results between two dimensions). Let $S_r^1 = (S_{r1}^1, \dots, S_{rn}^1)$, $S_r^2 = (S_{r1}^2, \dots, S_{rn}^2)$ and $S_r^3 = (S_{r1}^3, \dots, S_{rn}^3)$ denote the ranking of doctors based on the net probability, the distance between the evaluations and the ideal solutions, and the ranking of utility of each doctor including the r th dimension.

Then, let $f(S_{ri}^u)$ be the Borda score of the ranking S_{ri}^u , where

$$f(S_{ri}^u) = \begin{cases} 1, & S_{ri}^u = 1 \\ \frac{n-1}{n}, & S_{ri}^u = 2 \\ \dots & \dots \\ \frac{1}{n}, & S_{ri}^u = n, \end{cases} \quad (29)$$

$r = 1, 2; u = 1, 2, 3; i = 1, 2, \dots, n.$

Next, let $S_r = (S_{r1}, \dots, S_{rn})$ be the collective ranking of doctors under the r th dimension. Let $f(S_{ri})$ be the Borda score of the ranking S_{ri} , where

$$f(S_{ri}) = \sum_{u=1}^3 \frac{f(S_{ri}^u)}{3} \quad r = 1, 2; i = 1, 2, \dots, n. \quad (30)$$

Furthermore, the equilibrium of the two dimensions is considered. Without loss of generality, if $f(S_{1i}) = f(S_{2i})$ ($i = 1, 2, \dots, n$), we call the Borda value of doctor x_i reaching the equilibrium.

Let $f(S_i) = (f(S_{1i}), f(S_{2i}))$ be the Borda value vector of doctor x_i including two dimensions and $d(S_i)$ be the distance between the vector $f(S_i) = (f(S_{1i}), f(S_{2i}))$ and the line $y = x$; then we have the following.

$$d(S_i) = \frac{|f(S_{1i}) - f(S_{2i})|}{\sqrt{1^2 + 1^2}} \quad (31)$$

Step 6 (determine the final ranking result). Let $E(x_i)$ be the collective score of doctor x_i , where

$$E(x_i) = W^1 \frac{\min_i d(S_i)}{d(S_i)} + W^2 \frac{f(S_{1i}) + f(S_{2i})}{2} \quad (32)$$

$i = 1, 2, \dots, n.$

There, the bigger the $E(x_i)$, the better the alternative x_i .

5. Illustrative Example

In this section, an example of multisource healthcare service quality evaluation by the large group is used to illustrate the use of the proposed method.

Hospital A is a general hospital. The hospital regularly evaluates the healthcare service quality of doctors in order to monitor the overall healthcare level of the hospital and improve the competitiveness of the hospital. The hospital chooses ten employees as the evaluation objects $X = \{x_1, x_2, \dots, x_{10}\}$ and invites a hundred evaluators from different sources, such as patients undergoing healthcare treatment, patients who have been discharged from hospital, patients who have made an appointment online, where the hospital receives the evaluation information online, and the families waiting for the patient's treatment; the set of the evaluators $Q = \{q_1, q_2, \dots, q_{100}\}$. The dimensions of ability to evaluate the doctors are ability(R^1) and reputation(R^2). The subordinate attributes concerning the dimension of ability are research level(R_1^1), healthcare ability(R_2^1), efficiency(R_3^1), and error rate(R_4^1), and the subordinate attributes concerning the dimension of reputation are service attitude(R_1^2), responsibility(R_2^2), integrity(R_3^2), and communication skill(R_4^2).

The hospital established a set of linguistic terms in order to evaluate doctors $S = \{VG, G, M, P, VP\}$. Here, VG denotes the meaning of very good, G denotes the meaning of good, M denotes the meaning of middle, P denotes the meaning of poor, and VP denotes the meaning of very poor. The specific score of the set S is $S = \{1, 2, 3, 4, 5\}$ (1: very poor; 5: very good). The evaluator selects one language evaluation

TABLE 2: The evaluation values with respect to the dimensions ability.

P_{it}^{k1}	R_1^1					R_2^1				
	VG	G	M	P	VP	VG	G	M	P	VP
x_1	0.06	0.21	0.37	0.25	0.11	0.12	0.36	0.29	0.21	0.02
x_2	0.01	0.21	0.32	0.41	0.05	0.07	0.31	0.26	0.29	0.07
x_3	0.05	0.28	0.33	0.25	0.09	0.11	0.32	0.32	0.21	0.04
x_4	0.04	0.31	0.34	0.25	0.06	0.03	0.28	0.24	0.33	0.12
x_5	0.12	0.34	0.38	0.14	0.02	0.05	0.26	0.32	0.31	0.06
x_6	0.02	0.27	0.44	0.21	0.06	0.06	0.24	0.26	0.35	0.09
x_7	0.14	0.32	0.38	0.13	0.03	0.03	0.27	0.31	0.29	0.1
x_8	0.03	0.29	0.24	0.32	0.12	0.04	0.3	0.27	0.32	0.07
x_9	0.09	0.31	0.36	0.2	0.04	0.14	0.32	0.35	0.16	0.03
x_{10}	0.05	0.27	0.29	0.28	0.11	0.12	0.28	0.31	0.25	0.04
P_{it}^{k1}	R_3^1					R_4^1				
	VG	G	M	P	VP	VG	G	M	P	VP
x_1	0.09	0.29	0.31	0.24	0.07	0.03	0.24	0.32	0.32	0.09
x_2	0.06	0.24	0.29	0.33	0.08	0.04	0.22	0.29	0.34	0.11
x_3	0.08	0.31	0.33	0.23	0.05	0.03	0.17	0.29	0.39	0.12
x_4	0.05	0.32	0.28	0.28	0.07	0.06	0.27	0.3	0.33	0.04
x_5	0.09	0.31	0.36	0.21	0.03	0.07	0.19	0.28	0.37	0.09
x_6	0.05	0.27	0.35	0.25	0.08	0.02	0.24	0.26	0.36	0.12
x_7	0.09	0.3	0.36	0.19	0.06	0.03	0.21	0.24	0.39	0.13
x_8	0.05	0.28	0.29	0.29	0.09	0.05	0.11	0.31	0.42	0.11
x_9	0.12	0.31	0.37	0.17	0.03	0.14	0.31	0.32	0.2	0.03
x_{10}	0.11	0.27	0.32	0.26	0.04	0.09	0.28	0.33	0.27	0.03

TABLE 3: The weight of the patients group to the dimensions of ability.

w_h^1	R_1^1	R_2^1	R_3^1	R_4^1
Q	0.2	0.3	0.2	0.3

option from the preestablished language set to express his/her personal evaluation concerning each doctor. The evaluations presented for the dimensions of ability are shown in Table 2 and the weight of the patients group to the dimensions of ability is shown in Table 3.

The evaluation information presented for the dimensions of reputation is shown in Table 4.

The weight of the patients group to the dimensions of ability is shown in Table 5.

We think it is important to evaluate scores, so we assume the weight as $W^1 = 0.1$, $W^2 = 0.9$. According to the stochastic MULTIMOORA method proposed in Section 4, $Net(x_i)$ are determined as in Table 6 by solving Step 2.

The distance d_i between alternative x_i and reference point is determined as in Table 7 by solving Step 3.

The utility $U(x_i)$ of the alternatives x_i is determined as in Table 8 by solving Step 4.

The ranking of the probability of net advantage (each doctor over others) R_1^1 , the ranking of the distance between the evaluations and the ideal solutions R_2^1 , the ranking of utility of each doctor R_3^1 of the dimensions of ability, the ranking of the probability of net advantage (each doctor over

others) R_4^1 , the ranking of the distance between the evaluations and the ideal solutions R_2^2 , and the ranking of utility of each doctor R_3^2 of the dimensions of reputation are determined as in Table 9 by solving Steps 5–6.

Then the Borda score of the ranking of the dimensions of ability and reputation and the Borda score of the ranking of the total dimension can be determined as in Table 10 by solving (29).

The collective score of doctors $E(x) = (0.55, 0.68, 0.53, 0.55, 0.47, 0.59, 0.50, 0.68, 0.48, 0.51)$ and can be determined by solving Step 6. Furthermore, the final total ranking $R = (2, 8, 6, 4, 1, 3, 10, 7, 9, 5)$ is the ranking of the ten doctors. And we could get that the doctor has the best quality of service from the order. However, if we only consider the evaluation value without the balance of two dimensions, the final ranking is $R = (2, 8, 6, 9, 10, 3, 4, 1, 7, 5)$.

We can analyze the differences between the result obtained by the proposed method and those obtained by the evaluation value simply. It can be seen that although the average values of two dimensions of the doctors x_9 and x_{10} are higher than those of the doctors x_3 and x_4 , one of the dimensions is too low. We know that, as the saying goes, how much water a barrel can hold depends on the shortest board; in such case, the comprehensive evaluation of doctors x_9 and x_{10} must be affected. However, it can be seen that the two dimensions are balanced based on the evaluation values in the proposed method, and the result is that doctors x_3 and x_4 rank higher than doctors x_9 and x_{10} . The same goes for doctors x_3 , x_4 , x_1 , and x_9 . In the proposed method, evaluation

TABLE 4: The evaluation values of the dimensions of reputation.

P_{it}^{k2}	R_1^2					R_2^2				
	VG	G	M	P	VP	VG	G	M	P	VP
x_1	0.10	0.32	0.25	0.16	0.11	0.10	0.32	0.25	0.16	0.11
x_2	0.01	0.21	0.32	0.41	0.05	0.01	0.21	0.32	0.41	0.05
x_3	0.05	0.28	0.33	0.25	0.09	0.05	0.28	0.33	0.25	0.09
x_4	0.04	0.31	0.34	0.25	0.06	0.04	0.31	0.34	0.25	0.06
x_5	0.12	0.34	0.38	0.14	0.02	0.12	0.34	0.38	0.14	0.02
x_6	0.02	0.27	0.44	0.21	0.06	0.02	0.27	0.44	0.21	0.06
x_7	0.14	0.32	0.38	0.13	0.03	0.14	0.32	0.38	0.13	0.03
x_8	0.03	0.29	0.24	0.32	0.12	0.03	0.29	0.24	0.32	0.12
x_9	0.09	0.31	0.36	0.2	0.04	0.09	0.31	0.36	0.2	0.04
x_{10}	0.05	0.27	0.29	0.28	0.11	0.05	0.27	0.29	0.28	0.11
	R_3^2					R_4^2				
	VG	G	M	P	VP	VG	G	M	P	VP
x_1	0.07	0.26	0.29	0.27	0.11	0.06	0.29	0.27	0.30	0.08
x_2	0.08	0.29	0.34	0.23	0.06	0.07	0.28	0.22	0.33	0.10
x_3	0.05	0.30	0.32	0.26	0.07	0.08	0.27	0.36	0.24	0.05
x_4	0.06	0.26	0.33	0.29	0.06	0.04	0.23	0.26	0.35	0.12
x_5	0.09	0.31	0.36	0.21	0.03	0.12	0.29	0.32	0.21	0.06
x_6	0.11	0.28	0.32	0.24	0.05	0.09	0.25	0.37	0.22	0.07
x_7	0.06	0.33	0.36	0.22	0.03	0.08	0.22	0.29	0.31	0.10
x_8	0.10	0.29	0.34	0.23	0.04	0.07	0.21	0.34	0.29	0.09
x_9	0.05	0.27	0.27	0.28	0.13	0.04	0.21	0.32	0.32	0.11
x_{10}	0.06	0.23	0.34	0.27	0.10	0.07	0.23	0.31	0.29	0.10

TABLE 5: The weight of the patients group to the dimensions of reputation.

w_h^2	R_1^2	R_2^2	R_3^2	R_4^2
Q	0.3	0.3	0.2	0.2

TABLE 6: The value of probability of alternative x_i under different dimensions.

	x_1	x_2	x_3	x_4	x_5	x_6	x_7	x_8	x_9	x_{10}
$Net(x_i)^1$	0.291	-0.738	-0.044	-0.235	0.259	-0.712	-0.119	-1.015	1.404	0.910
$Net(x_i)^2$	0.587	-1.149	-0.204	-0.419	1.502	0.006	1.138	-0.727	-0.329	-0.405

TABLE 7: The distance between alternative x_i and reference point under the different dimensions.

	x_1	x_2	x_3	x_4	x_5	x_6	x_7	x_8	x_9	x_{10}
d_i^1	0.721	0.569	0.667	0.597	0.689	0.548	0.613	0.511	0.887	0.754
d_i^2	0.917	0.883	0.816	0.798	0.761	0.723	0.722	0.698	0.684	0.649

TABLE 8: The utility of the alternatives x_i under the different dimensions.

	x_1	x_2	x_3	x_4	x_5	x_6	x_7	x_8	x_9	x_{10}
$U(x_i)^1$	0.969	1.166	1.007	1.041	0.923	1.125	0.979	1.199	0.792	0.870
$U(x_i)^2$	0.923	1.187	1.021	1.088	0.772	0.980	0.839	1.108	1.093	1.068

TABLE 9: The ranking of the probability of net advantage, the distance from the ideal solutions, and the utility of the dimensions of ability and reputation.

	R_1^1	R_2^1	R_3^1	R_1^2	R_2^2	R_3^2
x_1	3	8	7	3	7	8
x_2	9	3	2	10	1	1
x_3	5	6	5	5	8	6
x_4	7	4	4	8	5	4
x_5	4	7	8	1	10	10
x_6	8	2	3	4	6	7
x_7	6	5	6	2	9	9
x_8	10	1	1	9	3	2
x_9	1	10	10	6	4	3
x_{10}	2	9	9	7	2	5

TABLE 10: The Borda score of the ranking of the dimensions of ability and reputation and the total dimension.

	$f(S_{1i}^1)$	$f(S_{1i}^2)$	$f(S_{1i}^3)$	$f(S_{1i})$	$f(S_{2i}^1)$	$f(S_{2i}^2)$	$f(S_{2i}^3)$	$f(S_{2i})$
x_1	0.8	0.3	0.4	1.5	0.8	0.4	0.3	1.5
x_2	0.2	0.8	0.9	1.9	0.1	1.0	1.0	2.1
x_3	0.6	0.5	0.6	1.7	0.6	0.3	0.5	1.4
x_4	0.4	0.7	0.7	1.5	0.3	0.6	0.7	1.6
x_5	0.7	0.4	0.3	1.4	1.0	0.1	0.1	1.2
x_6	0.3	0.9	0.8	2.0	0.7	0.5	0.4	1.6
x_7	0.5	0.6	0.5	1.6	0.9	0.2	0.2	1.3
x_8	0.1	1.0	1.0	2.1	0.2	0.8	0.9	1.9
x_9	1.0	0.1	0.1	1.2	0.5	0.7	0.8	2.0
x_{10}	0.9	0.2	0.2	1.3	0.4	0.9	0.6	1.9

value and the balance of two dimensions determined quality of medical service. More precise ranking result of alternatives could be obtained when the balance of two dimensions is considered.

In the above calculation, we combine the evaluation model based on stochastic MULTIMOORA method with multisource healthcare service quality evaluation by the large group, and we get the wide attention of the society in medicine reform. Through the study, we hope to improve the existing medicine management in our country and avoid the existing problems of unilateral dependence on a single source in medicine evaluation.

6. Conclusion

A novel large group method combined with stochastic MULTIMOORA method is proposed to solve the problem of multisource healthcare service quality evaluation by the large group decision-making problem in this paper. In the proposed method, an evaluation framework with the two dimensions of ability and reputation is presented. And the equilibrium of evaluation results of two dimensions is considered. Furthermore, the questionnaires for healthcare service quality evaluation by the multisource evaluators are designed

to make our approach more adaptive. Specifically, the study mainly has the following conclusions:

(1) According to the evaluation of doctors, the dimension and attribute were extracted by questionnaire survey. At the same time, a differentiated approach of evaluation information aggregation for the multisource evaluators is adopted to overcome the shortcomings of the existing research methods to deal with the multisource large group by considering the different roles of the multisource large group in group decision-making.

(2) In this paper, traditional MULTIMOORA method is expanded to be a stochastic MULTIMOORA method. Compared with the previous methods which only give multiple evaluation indexes, the method to distinguish the evaluation indexes of two dimensions proposed in this paper can reflect each dimension and the overall evaluation. It can be seen that the determined ranking can reflect the equilibrium of the two dimensions of ability and reputation as much as possible. This effectively avoids the situation that the final evaluation result in the previous evaluation decision tends to one dimension and away from the other.

(3) Two dimensions of the integrated evaluation of the doctors are considered in a balanced way. The collected evaluation information is applied to the method we proposed. The validity and adaptability of the proposed method are proved by numerical analysis.

TABLE 11

Treatment Department		treat recently	online appointment	family of patient		
What kind of people do you belong to?	undergoing treatment					
Dimensions	questions	Quite agree	agree	neutral	disagrees	Quite disagrees
Ability	The ability of a doctor to conduct scientific research is helpful for clinical treatment.					
	The doctor can better serve patients by improving their scientific research.					
	The doctor can identify common acute conditions.					
	The doctor has clear clinical thinking and responds appropriately to the symptoms described.					
	This treatment is efficient to the extent of the disease.					
	There is unnecessary waiting or checking in the treatment process.					
Reputation	The doctor checks and treats you according to your description.					
	The doctor diagnosed the illness correctly.					
	You feel the treatment is very effective after the treatment					
	The doctor listened patiently to the description.					
	The doctor answered your question.					
	During your treatment, the doctor uses “please” or “excuse me” in your relationship?					
	During your treatment, the doctor can always pay attention to your illness and mood.					
	During your treatment, the doctor is responsible for your diagnosis and treatment.					
	During your treatment, the doctor forces you to buy expensive and unnecessary drugs.					
	During your treatment, the doctor advised you to have unnecessary tests.					
The doctor can effectively communicate your symptoms.						
The doctor can explain the illness and treatment plan clearly.						
The doctor can communicate effectively with your family.						

Appendix

Questionnaire

What are Your Opinions of the Healthcare Service Quality Evaluation. Hello! Welcome to participate in the questionnaire survey on healthcare service quality evaluation. We

hope to know the actual working conditions of the doctors in the hospital through your authentic answers so as to better improve the healthcare service and improve the service quality. Please tick “√” in each corresponding column (if not in your actual situation, please specify the reason). Thank you for your cooperation.

See Table 11.

Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

Additional Points

Further Remarks. In the process of practical decision-making, there are differences in intellectual literacy level, regional background, and language preference between different decision-makers. Considering there are differences among the indexes of the different decision-makers in the decision-making process, the next step is to propose a method of evaluation decision-making as fair as possible for the differentiation index system of decision-makers' preference. In addition, in the practical evaluation process of doctor service quality, it should be considered that the evaluation of doctors by patients and their families may be influenced by subjective factors such as personal preference and psychological reluctance to offend. In the selection of evaluators, in addition to selecting patients and their families who receive treatment, it is also possible to invite experts in the industry or third-party evaluation agencies for joint evaluation. Therefore, the consensus evaluation among different groups is also one of our next research directions.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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