Neutrosophic Sets and Systems

Volume 31 Article 5

5-2-2020

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Neutrosophic Sets and Systems, Vol. 31, 2020
University of New Mexico

A Novel Methodology for Assessment of Hospital Service according to BWM, MABAC, PROMETHEE II

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Abstract: In this study, a proposed methodology of Best Worst Method (BWM), Multi-Attributive Border Approximation Area Comparison (MABAC), and Preference Ranking Organization Method for Enrichment Evaluations (PROMETHEE II) are suggested to achieve a methodical and systematic procedure to assess the hospital serving under the canopy of neutrosophic theory. The assessing of hospital serving challenges of ambiguity, vagueness, inconsistent information, qualitative information, imprecision, subjectivity and uncertainty are handled with linguistic variables parameterized by bipolar neutrosophic scale. Hence, the hybrid methodology of Bipolar Neutrosophic Linguistic Numbers (BNLNs) of BWM is suggested to calculate the significance weights of assessment criteria, and MABAC as an accurate method is presented to assess hospital serving. In addition to consider the qualitative criteria compensation in hospital service quality in MABAC in order to overcome drawbacks PROMETHEE II of non-compensation to reinforce the serving effectiveness arrangements of the possible alternatives. An experiential case including 9 assessment criteria, 2 public and 3 private hospitals in Sharqiyah EGYPT assessed by 3 evaluators from several scopes of medical industry to prove validity of the suggested methodology. The case study shows that the service effectiveness of private hospitals is superior to public hospitals, since the public infirmaries are scarcely reinforced by governmental institutions.

Keywords: Hospital service; Neutrosophic Sets; Bipolar; BWM; MABAC; PROMETHEE II

1. Introduction

Nowadays, the achievements of best service are regarded as the key success for organizations. The major aim to estimate service fitness is to measure service execution, detect service trouble, spun service allocation, and deliver the best service for users[1]. Several studies have been performed to gauge service efficiency of different scopes. e.g. web [2], airport [3, 4], transportation [5], bank [6] and healthcare [7]. In healthcare, control and service efficiency rating are very important for hospitals and medical centers fields. There are more than 50 generic and private hospitals in Sharqiyah EGYPT with tackled unceasing competitive pressure. The medical providers claim that the ability to deliver an efficient healthcare service to patients grantee the future achievement in healthcare[8].

For patients, who looking for healthcare services there are two main anxieties superiority and efficiency of the hospitals and medical centers. Hospitals and medical centers have to augment their healthcare value and effectiveness to help patients to achieve the most desirable service [9]. The managements of hospital try to fulfill the requirements of patients [10]. Such that, the hospital and medical centers are the service that directly connect, interact, and supply people with medical facilities [11]. The main goal for hospitals includes hold and engage more patients as possible by achieving their latent requirements and desires [11]. The main challenge for healthcare in hospitals is the service value given for patients [11]The growing of service value includes assessment the value of connecting with the doctors, employers, mangers, physicians, surgeons and nurses with patients in an efficient manner [12].

The hospital service value can be described according to various criterions either qualitative or quantitative. Hence, the hospital services are a problem of multi-criteria decision making (MCDM) with multiple criterions, alternatives, and decision makers. Researches illustrated various methodologies evaluate the service value [13-15] . However, the environment of hospital services is surrounded with complexity conditions of ambiguity, vagueness, inconsistent information, qualitative information, imprecision, subjectivity and uncertainty. Hence, the study proposed a hybrid methodology of BWM, MABAC, and PROMETHEE II as an effective tool in multi-criteria decision making based on BNLNs to make assessment of hospital services. The traditional BWM is extended with BNLNs terms to facilitate the description of qualitative criterions and alternatives [16]. The MABAC is suggested as an influential methodology to handle the complex and uncertain decision making problems [17]. The PROMETTEE is a methodology depends on non-compensation of criteria. The MABAC is combined with PROMETTEE to overcome the limitations of non-compensation and challenges of hospital service problems and recommend the final rankings to assess service value in Sharqiyah EGYPT.

The article is planned as follows: Section 2 presents the literature review. Section 3 presents the hybrid methodology of decision making for assessing of hospital serving by the use of neutrosophic theory by the integration of the BWM, MABAC and PROMETHEE II. Section 4 presents a case study to validate the proposed model and achieve to a final efficient rank. Section 5 summarizes the aim of the proposed study and the future work.

2. Related Studies

In this section, a review of literature will be displayed about the environment assessment of hospital service quality. The SERVQUAL is a well-defined methodology used to evaluate service effectiveness. The SERVQUAL has been applied in several aspects which comprise education [18], retail [19-21] and healthcare [22]. The MABAC been extended under various fuzzy environments [23]. E.g. combined interval fuzzy rough sets with the MABAC method to rank the firefighting chopper [24]. [25] presented rough numbers with the MABAC for sustainable system evaluation. Hence, to beat limitations of MABAC method the concept of PROMETHE II has been presented. Many of studies have been enhanced the PROMETHEE II method to solve decision making issues under ambiguous contexts [26]. In [27], presented the PROMETHEE II method under hesitant fuzzy linguistic circumstances to choose green logistic suppliers. Due to conditions of uncertainty and incomplete information, a novel PROMETHEE II method is proposed to solve decision making issues under probability multi-valued neutrosophic situation [28]. Usually, it is hard for DMs to straight allocate the weight values of assessment criteria in advance. [16] presented a novel weights calculation method, the BWM approach. In [29], combined the BWM method with grey system to calculate the weights of criteria. In [30], the BWM method enhanced with applying hesitant fuzzy numbers to explain criteria relative significance grades. In real life situations decisions, alternatives, criterions are taken in conditions of ambiguity, vagueness, inconsistent information, qualitative information, imprecision, subjectivity and uncertainty. In [31-43], proposes LNNs based on descriptive expressions to describe the judgments of decision makers, criterions, and alternatives. We propose to build a hybrid methodology of BNLNs based on BWM, MABAC, and PROMETHEE II.

3. Methodology

In this study, a hybrid methodology for assessment of hospital service quality is based on BNLNs.

The traditional BWM method is extended with descriptive BNLNs to prioritize the problem's criterions. The MABAC is proposed to deal with the complexity and uncertainty hospital service quality. The PROMETHEE II is used to solve the non-compensation problem of criteria. Hence, a hybrid methodology is built by using BWM, MABAC and PROMETHEE II as mentioned in **Figure 1**.

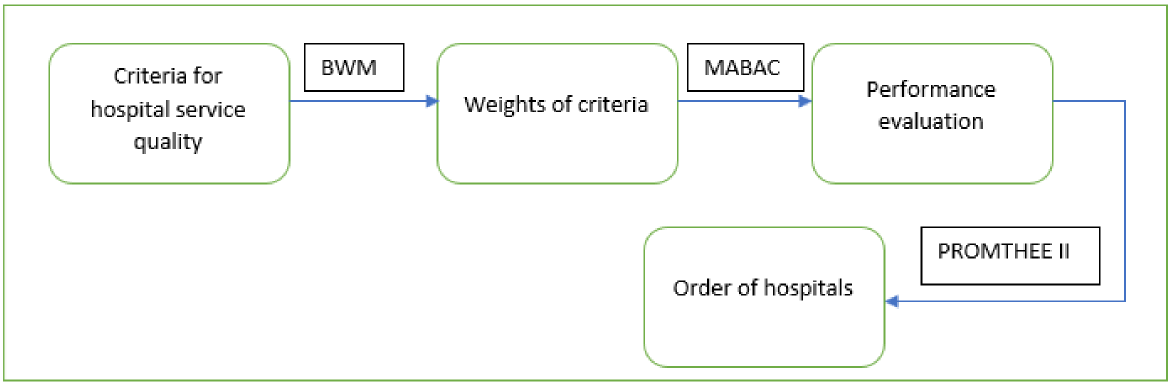

Figure.1. The overall conceptualization of the proposed approach

In this section, a hybrid decision making framework is designed built on the integration of extended BWM, MABAC and PROMETHEE II methodologies to determine the desirable substitute hospital that achieves the requirements and the expectation of patients by evaluating a group of candidate hospitals. The steps of the proposed bipolar neutrosophic with BWM, MABAC and PROMETHEE II are modeled in **Figure 2** and mentioned in details as following

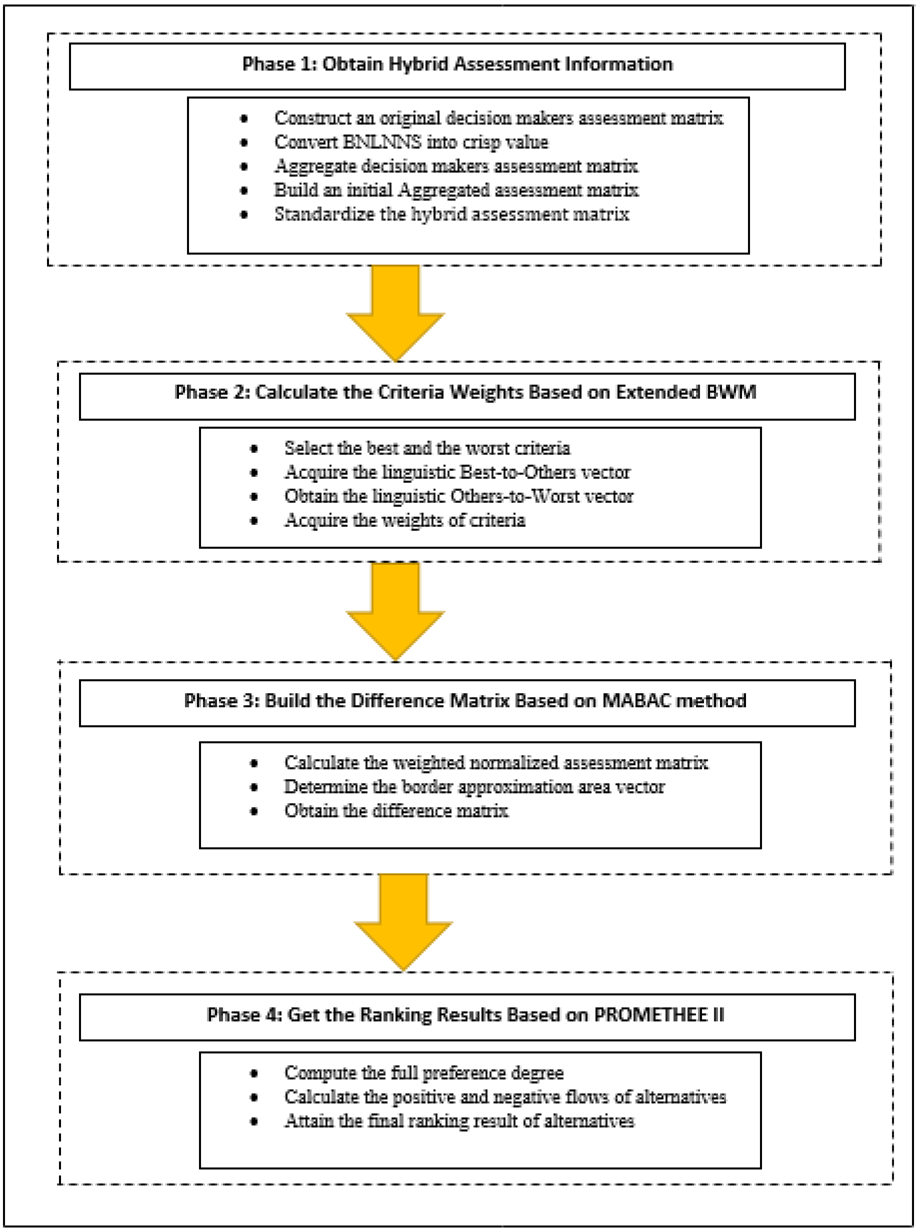

Figure 2. Framework of hybrid decision making

Phase 1: Obtain Hybrid Assessment Information

The goal from this phase is to obtain the hybrid assessment information:

Step 1: Construct an original decision makers assessment matrix

The linguistic term (LTS) provided by DMs using descriptive expressions such as: (Extremely important, Very important, Midst important, Perfect, Approximately similar, Poor, Midst poor, Very poor, Extremely poor. The BNLNS is an extension of fuzzy set, bipolar fuzzy set, intuitionistic fuzzy set, LTS, and neutrosophic sets is introduced by [35]. Bipolar Neutrosophic is $[T^+, I^+, F^+, T^-, I^-, F^-]$ where T^+, I^+, F^+ range in [1,0] and T^-, I^-, F^- range in [-1,0]. T^+, I^+, F^+ is the positive membership degree indicating the truth membership, indeterminacy membership and falsity membership and T^-, I^-, F^- is the negative membership degree indicates the truth membership, indeterminacy membership and falsity membership. E.g. [0.3, 0.2, 0.6, -0.2, -0.1, -0.5] is a bipolar neutrosophic number.

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For BNLNS qualitive criteria values can be calculated by decision makers under a predefined the LTS. Then, an initial hybrid decision making matrix is built as [32]

$$G^D = \begin{array}{c} \\ H_1 \\ \vdots \\ H_o \end{array} \begin{array}{c} \begin{array}{ccc} C1 & \dots & C_p \end{array} \\ \begin{bmatrix} b_{11}^D & \cdots & b_{1p}^D \\ \vdots & \ddots & \vdots \\ b_{o1}^D & \cdots & b_{op}^D \end{bmatrix} \end{array} \tag{1}$$

Where b_{sr}^D is a BNLNS, representing the assessment result of alternative $H_s(s = 1,2, \dots . o)$ with respect to criterion $C_r(r = 1,2, \dots . p)$ and $D = 1,2,3$ represent number of decision maker.

Step 2: Convert BNLNs into crisp value using score function mentioned as [36]

$$s(b_{op}) = \left(\frac{1}{6}\right) * (T^+ + 1 - I^+ + 1 - F^+ + 1 + T^- - I^- - F^-) \tag{2}$$

Step 3: Aggregate decision makers assessment matrix [34]

$$b_{sr} = \frac{\sum_{D=1}^{D}(b_{op}^D)}{D} \tag{3}$$

Where T_{sr}^{+D} is a truth degree in positive membership for decision makers (D), I_{sr}^{+D} is a indeterminacy degree and F_{sr}^{+D} the falsity degree. T_{sr}^{-D} the truth degree in negative membership for decision maker (D), I_{sr}^{-D} the indeterminacy degree and F_{sr}^{-D} the falsity degree.

Step 4: Build an initial aggregated assessment matrix

$$G = \begin{array}{c} \\ H_1 \\ \vdots \\ H_o \end{array} \begin{array}{c} \begin{array}{ccc} C1 & \dots & C_p \end{array} \\ \begin{bmatrix} b_{11} & \cdots & b_{1r} \\ \vdots & \ddots & \vdots \\ b_{s1} & \cdots & b_{sr} \end{bmatrix} \end{array} \tag{4}$$

Step 5: Standardize the hybrid assessment matrix.

Normalize the positive and negative criteria of the decision matrix as follows:

For crisp value, the assessment data $b_{sr}(s = 1,2, \dots \dots . o,\ r = 1,2, \dots \dots . p)$ can be normalized with [17]:

$$N_{sr} = \begin{cases} \dfrac{b_{sr} - \min\limits_r(b_{sr})}{\max\limits_r(b_{sr}) - \min\limits_r(b_{sr})}, & For\ benefit\ criteria \\ \dfrac{\max\limits_r(b_{sr}) - b_{sr}}{\max\limits_r(b_{sr}) - \min\limits_r(b_{sr})}, & For\ cost\ criteria \end{cases} \tag{5}$$

Then, a normalized hybrid assessment matrix is formed as

$$N = \begin{array}{c} \\ H_1 \\ \vdots \\ H_o \end{array} \begin{array}{c} \begin{array}{ccc} C1 & \dots & C_p \end{array} \\ \begin{bmatrix} N_{11} & \cdots & N_{1p} \\ \vdots & \ddots & \vdots \\ N_{o1} & \cdots & N_{op} \end{bmatrix} \end{array} \tag{6}$$

Where N_{sr} shows the normalized value of the decision matrix of S[th] alternative in R[th] criteria

Phase 2: Calculate the Criteria Weights Based on Extended BWM

In this study, the BWM is extended with LTS to obtain the weights of criteria given linguistic expressions.

Step 6: Select the best and the worst criteria

When calculated the assessment criteria $\{C1 \ \dots \ C_p\}$, decision makers need to choose the best (namely, the most significant) criterion, denoted as C_B. Meanwhile the worst (namely, the least significant) criterion should be selected and represented as C_W.

Step 7: Acquire the linguistic Best-to-Others vector

Make pairwise comparison between the most important criterion C_B and the other criteria, then a linguistic Best to-Others vector is obtained with [16]:

$$LC_B = \left(C_{B1}, C_{B2} \dots \dots \dots \dots \ C_{Bp}\right) \tag{7}$$

Where C_{Br} is a linguistic term within a certain LTS, representing the preference degree of the best criterion C_B over criterion $c_r(r = 1,2, \dots \dots p)$ In specific, $C_{BB} = 1$.

Step 8: Obtain the linguistic Others-to-Worst vector.

Similarly, make pairwise comparison between the other criteria and the worst criterion C_W, then a linguistic Others-to-Worst vector is obtained with [16]:

$$LC_W = \left(C_{1W}, C_{2W} \dots \dots \dots \dots \ C_{pW}\right) \tag{8}$$

Where C_{rW} is a linguistic term within a certain LTS, representing the preference degree of criterion $c_r(r = 1,2, \dots \dots p)$ over the worst criterion C_W in precise, $C_{WW} = 1$.

Step 9: Acquire the weights of criteria

The goal from this step to obtain optimal weights of criteria so that the BWM is extended with crisp number for nonlinear programming model as mentioned [16]:

min ε

S.t.

$$\begin{cases} \left|\frac{w_B}{w_r} - C_{Br}\right| \le \varepsilon \text{ For all r} \\ \left|\frac{w_r}{w_W} - C_{rW}\right| \le \varepsilon \text{ For all r} \end{cases} \tag{9}$$

Where w_r is the weight of criterion C_r , w_B is the weight of the best criteria C_B and, w_W is the weight of the worst criteria C_W. when solving model (9) the weight of w_r and optimal consistency index ε can be computed.

Phase 3: Build the Difference Matrix Based on MABAC method

Build difference matrix built on the idea of MABAC method

Step 10: Calculate the weighted normalized assessment matrix

Given the normalized values of assessment and the weights of criteria. The weighted normalized values of each criterion are got as follow [17]:

$$\widehat{N}_{sr} = (w_r + N_{sr} * w_r, \quad s = 1,2, \dots . o, r = 1,2, \dots . p \tag{10}$$

Where w_r is a weight of criteria r and N_{sr} is a normalized value of s and r.

Step 11: Determine the border approximation area vector

The border approximation area vector X is computed as [17]:

$$X_r = \frac{1}{p}\sum_{s=1}^{p} \widehat{N}_{sr} \quad s = 1,2, \ldots . o, r = 1,2, \ldots . p \tag{11}$$

By calculating the values of the border approximation area matrix, a $o \times 1$ matrix is obtained.

Step 12: Obtain the difference matrix

The difference degree between the border approximation area X_r and each element $\widehat{N}_{sr}$ in the weighted normalized assessment matrix can be calculated with [17]:

$$S_{sr} = \widehat{N}_{sr} - X_r \tag{12}$$

Hence, the difference matrix $S = (S_{sr})_{oxp}$ is accomplished.

Phase 4: Get the Ranking Results Based on PROMETHEE II

Attain the rank of hospitals based on PROMETHEE II method

Step 13: Compute the full preference degree

Compute the alternative difference of s^{th} alternative with respect to other alternative. the preference function is used in this study as follows [37]:

$$P_r(H_s, H_t) = \begin{cases} 0 & \text{if } S_{sr} - S_{tr} \leq 0 \\ S_{sr} - S_{tr} & \text{if } S_{sr} - S_{tr} > 0 \end{cases} s, t = 1,2, \ldots . . o \tag{13}$$

Then the aggregated preference function can be computed as:

$$P(H_s, H_t) = \sum_{p}^{o} w_r * P_r(H_s, H_t) / \sum_{p}^{o} w_r \tag{14}$$

Step 14: Calculate the positive and negative flows of alternatives

The positive fl0w (namely, the outgoing flow) $\psi^+(H_i)$ [37]:

$$\psi^+(H_i) = \frac{1}{n-1}\sum_{t=1, t\neq s}^{o} P(H_s, H_t) \; s = 1,2, \ldots \ldots . . o \tag{15}$$

The negative fl0w (namely, the entering flow) $\psi^-(H_i)$ [37]:

$$\psi^-(H_i) = \frac{1}{n-1}\sum_{t=1, t\neq s}^{o} P(H_t, H_s) \; s = 1,2, \ldots \ldots . . o \tag{16}$$

Step 15: Attain the final ranking result of alternatives

The net outranking $\psi(H_i)$ of alternative H_i [37]:

$$\psi(H_i) = \psi^+(H_i) - \psi^-(H_i) \; s = 1,2, \ldots . o \tag{17}$$

Hence, the final ranking order can be achieved according to the net outranking flow value of each alternative. The larger the value of $\psi(H_i)$, the better the alternative H_i.

4. Case Study

In this section, a case of hospital service quality for 2 public and 3 private hospitals in Sharqiyah EGYPT is presented to verify the applicability for the method. The hybrid methodology aims to provide best medical and health-care serving performance for patients. Two governmental hospitals: Zagazig University Hospital (ZUH, H_1) and MABARRA Hospital (MH, H_2), and three private hospitals - El-Salam Hospital (ESH, H_3), GAWISH hospital (GH, H_4) and EL-HARAMAIN hospital (EHH, H_5). The proposed hospitals are selected to be assessed by 3 evaluators with regard to 9 assessing criteria. The 3 evaluators notice that the actual state of affairs, meeting patients people, doctors, and nurses of these 5 hospitals with regard to 15 criteria to measure the service performance. The suggested approach integrates the BWM, MABAC and PROMETHEE II with BNLNs in order to make assessing for hospital service

The main and sub-criteria of hospital service quality is decided by the aid of consultation involving healthcare managers, experts and academicians. Therefore, the study considers the four main criteria and 9 sub-criteria as shown in **Figure 3**, and described in **Table 1.**

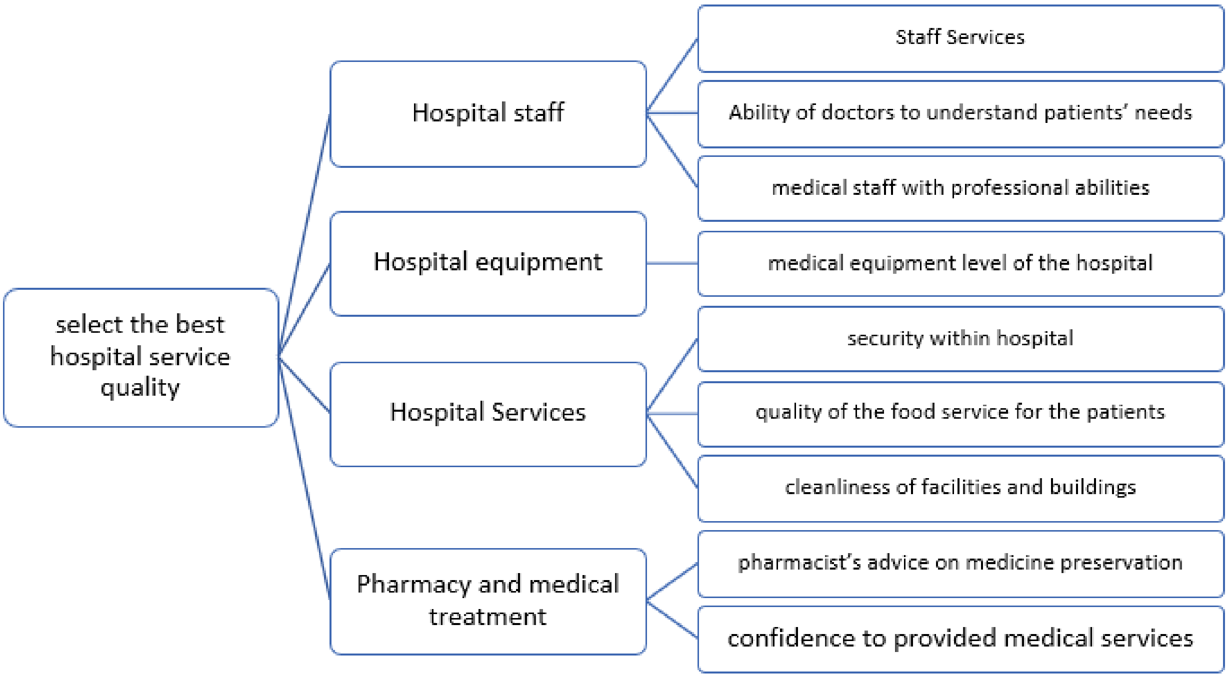

Figure. 3. The structure for assessing the hospitals service quality.

Table 1. hospital of service quality criteria

Factor	**Criteria**	**Description**
Hospital staff	C_1	Staff Services
	C_2	Ability of doctors to understand patients' needs
	C_3	Medical staff with professional abilities
Hospital equipment	C_4	Medical equipment level of the hospital
Hospital services	C_5	Security within hospital
	C_6	Quality of the food service for the patients
	C_7	Cleanliness of facilities and buildings
pharmacy and medical treatment	C_8	Pharmacist's advice on medicine preservation
	C_9	Confidence to provided medical services

In phase 1. Experts make assessment with respect to the evaluation criteria in table 1. As criteria C_1 to C_9 are qualitative factors, evaluation information of these subjective criteria is by means of BNLNs. Even though all the 9 criteria belong to benefit type, their scopes are different.

Step 1: Construct an original decision makers assessment matrix

calculate the suitable LTS for weights of criteria and alternatives with respect to every criterion. Each LTS is extended by bipolar neutrosophic sets to be BNLNs as mentioned in table 2. The BNLNs is described as follows [36]: Extremely important = [0.9,0.1,0.0,0.0, -0.8, -0.9] Where the first three numbers present the positive membership degree. $(T^+(x), I^+(x), F^+(x))$ 0.9, 0.1 and 0.1, such that $T^+(x)$ the truth degree in positive membership. $I^+(x)$ the indeterminacy degree and $F^+(x)$ the falsity degree. The last three numbers present the negative membership degree. $(T^-(x), I^-(x), F^-(x))$ 0.0, -0.8, and -0.9, $T^-(x)$ the truth degree in negative membership, such that $I^-(x)$ the indeterminacy degree and $F^-(x)$ the falsity degree. Table 1, table 2, and table 3 represent the assessments for the three evaluators by the use of Eq. (1).

Step 2: Convert BNLNs into crisp value using score function

Convert BNLNs to crisp value in table 2 by using score function in Eq. (2).

Step 3: Aggregate decision makers assessment matrix using Eq. (3).

Step 4: Build an initial Aggregated assessment matrix using Eq. (4), and shown in table 6.

Step 5: Standardize the hybrid assessment matrix

Normalized the aggregated decision matrix, given the positive or negative type of the criteria using Eq. (5), the normalized values of the aggregated decision matrix using Eq. (6) are shown as in Table 11.

Table 2. Bipolar neutrosophic numbers scale

LTS	Bipolar neutrosophic numbers scale $[T^+(x), I^+(x), F^+(x), T^-(x), I^-(x), F^-(x)]$	Crisp value
Extremely important	[0.9,0.1,0.0,0.0, -0.8, -0.9]	0.92
Very important	[1.0,0.0,0.1, -0.3, -0.8, -0.9]	0.73
Midst important	[0.8,0.5,0.6, -0.1, -0.8, -0.9]	0.72
Perfect	[0.7,0.6,0.5, -0.2, -0.5, -0.6]	0.58
Approximately similar	[0.5,0.2,0.3, -0.3, -0.1, -0.3]	0.52
Poor	[0.2,0.3,0.4, -0.8, -0.6, -0.4]	0.45
Midst poor	[0.4,0.4,0.3, -0.5, -0.2, -0.1]	0.42
Very poor	[0.3,0.1,0.9, -0.4, -0.2, -0.1]	0.36
Extremely poor	[0.1,0.9,0.8, -0.9, -0.2, -0.1]	0.13

In Phase 2. The goal from this phase determine the weights of criteria based on evaluation of decision maker. Use BWM to calculate weights of criteria.

Step 6: Select the best and the worst criteria

At the beginning C_3 is the best criteria and the C_1 is the worst criteria.

Step 7: Acquire the linguistic Best-to-Others vector

Construct pairwise comparison vector for the best criteria using Eq. (7) in table 7.

Step 8: Obtain the linguistic Others-to-Worst vector

Construct pairwise comparison vector for the worst criteria using Eq. (8) in table 8.

Step 9: Acquire the weights of criteria

By applying best to others and worst to others using Eq. (9) the weights are computed in table 10. Figure 4 shows priority of criteria. Compute consistency ratio: $\varepsilon = 0.05$. For the consistency ratio, as $C_{BW} = 0.7$ the consistency index for this problem is 3.73 from table 9 and the consistency ratio 0.05/3.73 = 0.013, which indicates a desirable consistency.

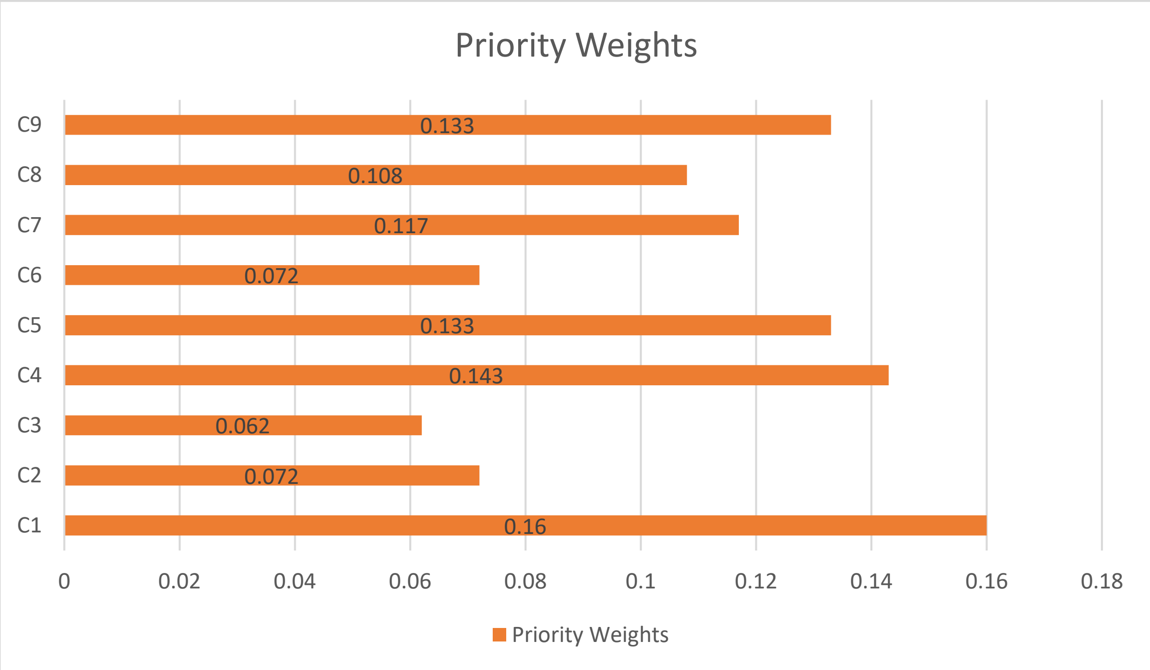

Figure 4. Priority weights of criteria

Table 3. Assessment of hospitals services by the first evaluator

Criteria/Alternatives	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9
H_1	0.13	0.36	0.92	0.73	0.52	0.36	0.52	0.92	0.73
H_2	0.36	0.42	0.52	0.36	0.42	0.52	0.73	0.42	0.36
H_3	0.72	0.73	0.92	0.73	0.73	0.73	0.52	0.72	0.73
H_4	0.36	0.42	0.52	0.36	0.42	0.52	0.73	0.42	0.36
H_5	0.92	0.73	0.52	0.92	0.73	0.52	0.73	0.72	0.92

Table 4. Assessment of hospitals service by the second evaluator

Criteria/Alternatives	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9
H_1	0.42	0.13	0.92	0.72	0.36	0.36	0.13	0.92	0.73
H_2	0.36	0.42	0.52	0.36	0.42	0.52	0.73	0.42	0.36
H_3	0.72	0.73	0.73	0.92	0.73	0.73	0.72	0.72	0.73
H_4	0.36	0.42	0.52	0.36	0.42	0.52	0.73	0.42	0.36
H_5	0.92	0.73	0.52	0.92	0.73	0.52	0.73	0.72	0.92

Table 5. Assessment of hospitals service by the third evaluator.

Criteria/Alternatives	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9
H_1	0.36	0.42	0.92	0.73	0.42	0.36	0.52	0.73	0.73
H_2	0.36	0.52	0.52	0.42	0.73	0.52	0.52	0.42	0.73
H_3	0.72	0.73	0.73	0.72	0.73	0.52	0.52	0.72	0.73
H_4	0.36	0.42	0.52	0.36	0.42	0.52	0.73	0.42	0.36
H_5	0.92	0.73	0.52	0.92	0.73	0.52	0.73	0.72	0.92

Table 6. Aggregation values of ranking alternatives by all decision makers

Criteria/Alternatives	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9
H_1	0.30	0.30	0.92	0.73	0.43	0.36	0.39	0.86	0.73
H_2	0.36	0.45	0.52	0.38	0.52	0.52	0.66	0.42	0.48
H_3	0.72	0.73	0.79	0.79	0.73	0.66	0.56	0.72	0.73
H_4	0.36	0.42	0.52	0.36	0.42	0.52	0.73	0.42	0.36
H_5	0.92	0.73	0.52	0.92	0.73	0.52	0.73	0.72	0.92

Table 7. pairwise comparison vector for the best criterion

Criteria	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9
C_5	0.72	0.13	1	0.13	0.58	0.45	0.52	0.42	0.36

Table 8. pairwise comparison vector for the worst criterion

Criteria	C_3
C_1	1
C_2	0.13
C_3	0.72
C_4	0.58
C_5	0.52
C_6	0.13
C_7	0.42
C_8	0.36
C_9	0.52

Table 9. The consistency Index

Criteria	1	2	3	4	5	6	7	8	9
Weights	0.00	0.44	1.00	1.63	2.30	3.00	3.73	4.47	5.23

Table 10. Weights of criteria based on BWM

Criteria	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9
Weights	0.16	0.072	0.062	0.143	0.133	0.072	0.117	0.108	0.133

In Phase 3: Build the Difference Matrix Based on MABAC method:

Step 10: Calculate the weighted normalized assessment matrix

Construct the weighted normalized decision matrix using Eq. (10). E.g. the weighted normalized values of the first criteria are as follows:

$\widehat{N}_{11} = w_1 + N_{11} * w_1 = 0.16 * (1 + 0) = 0.16$

$\widehat{N}_{21} = w_1 + N_{21} * w_1 = 0.16 * (1 + 0) = 0.175$

$\widehat{N}_{31} = w_1 + N_{31} * w_1 = 0.16 * (1 + 0) = 0.268$

$\widehat{N}_{41} = w_1 + N_{41} * w_1 = 0.16 * (1 + 0) = 0.175$

$\widehat{N}_{51} = w_1 + N_{51} * w_1 = 0.16 * (1 + 0) = 0.32$

The other weighted normalized values of the criteria are determined in table 12.

Step 11: Determine the border approximation area vector

Compute the border approximate area matrix using Eq. (11). The amounts of the border approximate area matrix are as follows:

Criteria	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9
Approximation area	0.2196	0.1098	0.0826	0.2132	0.1954	0.1092	0.1939	0.1588	0.2

Figure 5 show amount of the border approximate area.

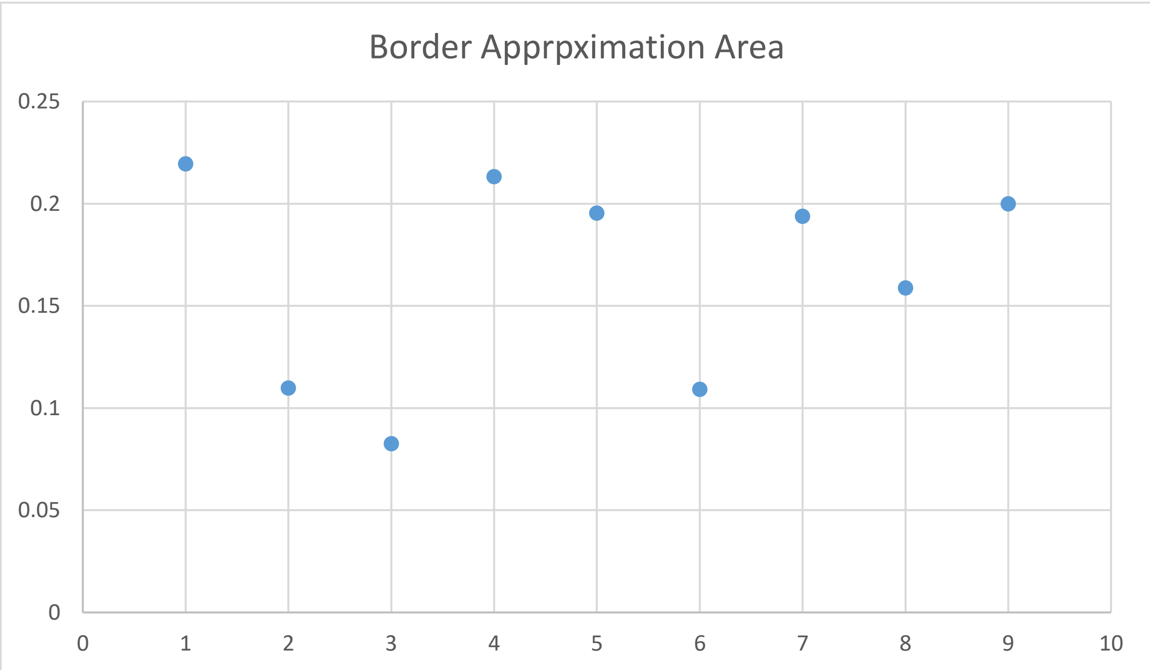

Figure 5. Border approximation area

Step 12: Obtain the difference matrix

Compute The distance from the border approximate area using Eq. (12). The distance of each alternative from the border approximate area, is shown in table 13.

Table 11. Normalized values of the Aggregated decision matrix

Criteria/Alternatives	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9
H_1	0	0	1	0.660	0.032	0	0	1	0.660
H_2	0.096	0.348	0	0.035	0.322	0.533	0.794	0	0.214
H_3	0.677	1	0.675	0.767	1	1	0.5	0.681	0.660
H_4	0.096	0.279	0	0	0	0.533	1	0	0
H_5	1	1	0	1	1	0.533	1	0.681	1

Table 12. Values of the weighted normalized decision matrix

Criteria/Alternatives	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9
H_1	0.16	0.072	0.124	0.237	0.137	0.072	0.117	0.216	0.220
H_2	0.175	0.097	0.062	0.148	0.175	0.110	0.209	0.108	0.161
H_3	0.268	0.144	0.103	0.252	0.266	0.144	0.1755	0.181	0.220
H_4	0.175	0.092	0.062	0.143	0.133	0.110	0.234	0.108	0.133
H_5	0.32	0.144	0.062	0.286	0.266	0.110	0.234	0.181	0.266

Table 13. Distance from the border approximate area

Criteria/Alternatives	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9
H_1	-0.05	-0.03	0.04	0.02	-0.05	-0.03	-0.07	0.05	0.02
H_2	-0.04	-0.01	-0.02	-0.06	-0.02	0.0008	0.01	-0.05	-0.03
H_3	0.04	0.03	0.02	0.03	0.07	0.03	-0.01	0.02	0.02
H_4	-0.04	-0.01	-0.02	-0.07	-0.06	0.0008	0.04	-0.05	-0.06
H_5	0.10	0.03	-0.02	0.07	0.07	0.0008	0.04	0.02	0.06

In phase 4: Get the Ranking Results Based on PROMETHEE II

Step 13: Compute the full preference degree

Calculate the evaluative differences of s^{th} alternative with respect to other alternatives. Compute the preference function using Eq. (13). Calculate the aggregated preference function using Eq. (14) in table 14.

Step 14: Calculate the positive and negative flows of alternatives

Calculate the positive and negative flows of alternatives using Eq. (15) Eq. (16) in table 14. Calculate the net outranking flow of each alternative in the fourth column using Eq. (17) in table 14. Indicates that $\psi(H_5) > \psi(H_3) > \psi(H_1) > \psi(H_2) > \psi(H_4)$.

Step 15: Attain the final ranking result of alternatives

Determine the ranking of all the considered alternatives in table 15 depending on the values of net flow in last column in table 14. The ranking order is $H_5 \succ H_3 \succ H_1 \succ H_2 \succ H_4$. Hence, the best hospital alternative isH_5. Figure 6 shows the order of hospitals.

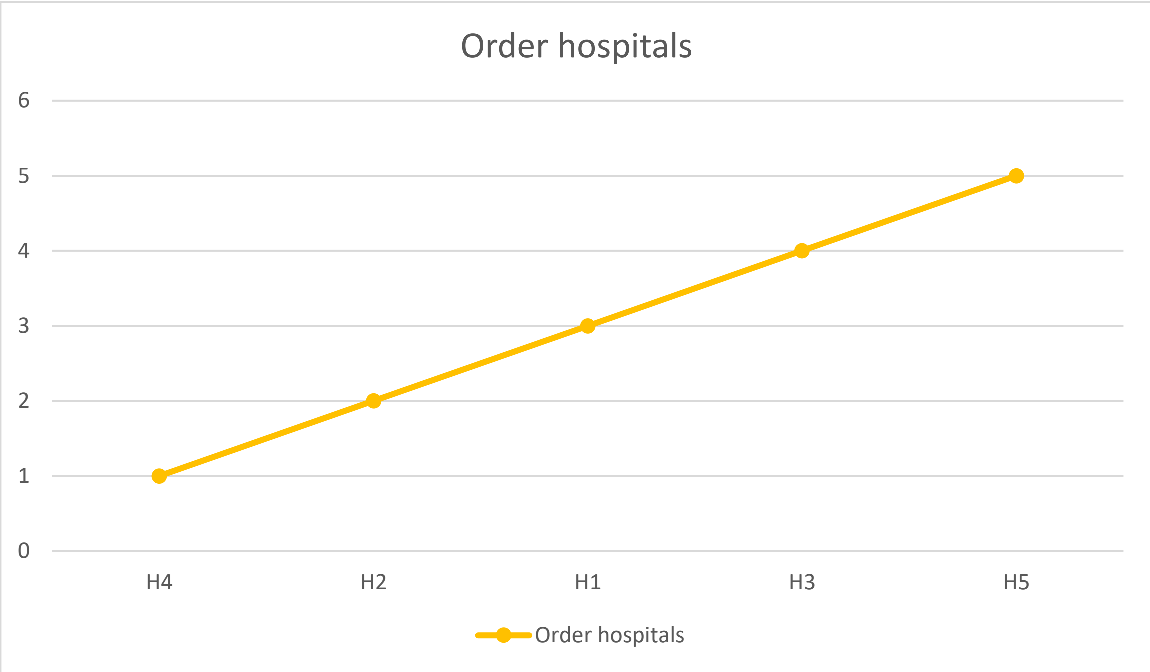

Figure 6. Order of hospitals

Table 14. The aggregated preference function

Alternatives	H_1	H_2	H_3	H_4	H_5	Leaving flow $\psi^+(H_i)$	Entering flow $\psi^-(H_i)$	Net flow
H_1	0	0.03261	0.00448	0.03936	0.00696	0.020853	0.039006	-0.01815
H_2	0.018608	0	0.00234	0.01074	0	0.007922	0.039006	-0.03108
H_3	0.04745	0.059312	0	0.070052	0.004582	0.045349	0.039006	0.006343
H_4	0.018128	0.00351	0.00585	0	0	0.006872	0.039006	-0.03213
H_5	0.071838	0.07888	0.02649	0.08611	0	0.06583	0.039006	0.026824

Table 15. Final Rank Of alternatives

Alternatives	Rank
H_1	3
H_2	4
H_3	2
H_4	5
H_5	1

5. Conclusion

The study proposes a hybrid methodology of neutrosophic set with BWM, MABAC and PROMETHEE II to assess a set of possible hospitals in an effort to reach to the superior qualified substitute that pleases the desires and the anticipations for patients. Consequently, raw data surveyed from 3 evaluators and assessed by the neutrosophic BWM, MABAC and PROMETHEE model to measure the proportional healthcare service effectiveness performance of 5 hospitals. The outcomes display that the 5 most significant criteria for assessing the hospital service effectiveness are: Staff Services, medical equipment level of the hospital, security within hospital, confidence to provided medical services and cleanliness of facilities and buildings. Particularly, because the private infirmaries are hardly supported by government intuitions, they are prompted to provide superior services than public infirmaries in order to enhance patients' gratification and consequently keep allegiance to the hospital. The future work includes using other applicable methodologies such as TOPSIS and making comparative studies that reflect on the assessing of hospital services.

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Received: Dec 02, 2019. Accepted: Feb 02, 2020