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Bipolar Pythagorean Neutrosophic Aggregation Operator for Voice of the Guest: Evaluating Hotel Management Service Quality through Customer Feedback

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Abstract: Providing top-notch service is crucial to preserving customer loyalty and happiness in the cutthroat hospitality sector of today. The "Voice of the Guest" is emphasized as a crucial data source in this study, which examines how hotel management service quality is assessed from the viewpoint of consumer input. The research highlights key service aspects, such as personnel professionalism, cleanliness, responsiveness, and service diversity, by combining qualitative and quantitative analysis. Eight hotel options were evaluated. This study uses the Bipolar Pythagorean Neutrosophic Number to evaluate the criteria and alternatives. The neutrosophic aggregation operator is used to combine values in criteria and alternatives.

The results show notable differences in how guests perceive various hotel types, underscoring the impact of location, automation, and personalized services on quality assessment. The study emphasizes how crucial it is for hotel operations to actively use customer feedback systems, including surveys, reviews, and sentiment analysis tools, as a real-time quality control tool. This data-driven method supports guest-centered management techniques and ongoing service enhancement.

Keywords: Bipolar Pythagorean Neutrosophic; Aggregation Operators; Hotel Management Service; Customer Feedback.

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1. Introduction

The Bipolar Pythagorean Neutrosophic Set (BPNS) theory, which was first presented by Ahmad et al. [1], combines bipolarity, neutrosophic logic, and Pythagorean fuzzy sets to address these complexities. It provides a strong framework for assessing indeterminacy and non-membership degrees across a variety of criteria, as well as positive and negative membership degrees. When

it comes to managing contradicting data, BPNS successfully overcomes the drawbacks of both classical fuzzy sets (FS) and intuitionistic fuzzy sets (IFS)[2].

BPNS and its expansions, including Interval Neutrosophic Set (INS), Interval-Valued Neutrosophic Set (IVNS), and Single-Valued Neutrosophic Set (SVNS), are derived from Neutrosophic Set (NS) theory[3], [4].

1.1 Literature Review

Using an electronic visitor feedback system built on online and Internet technologies, this study examines hotel guest satisfaction. Prasad et al. [5]examined data from a sample of 1,218 hotel visitors who spent a year staying at two mid-range full-service hotels in Orlando, Florida. The underlying link between perceived value, contentment, and desire to return and suggest, on the one hand, and guest evaluations of hotel amenities and staff service, on the other, was determined using structural equation modeling.

The findings demonstrate how value, contentment, and the desire to return and recommend are directly impacted by visitor assessments of staff service quality, guest room quality, security, and service issues. It is also observed that the visitor assessments of the hotel's amenities and personnel service quality were impacted by notable moderating effects. Implications for management include recommendations for using web-based technologies to improve visitor satisfaction with hotel operations. The results of this study should assist hotel management in concentrating on the elements of the visitor experience that have the greatest impact on satisfaction scores.

The volume of words on the internet is constantly increasing, and enterprises have a difficult task in effectively and efficiently interpreting this unstructured data. There is still much space for improvement in the organizational use of such text data, particularly in the context of decision-making assistance, even though the computer science community has created several ways. Marcolin et al. [6] bring the tourist sector into the conversation by proposing and validating a framework for the efficient use of text data inside the hotel business. In a unique approach, they integrated three text mining techniques—text classification, sentiment analysis, and topic modeling—to enable managers to examine visitor feedback and evaluate rivals in the hospitality sector using SERVQUAL.

It is well acknowledged that the service sector is seen as a barometer of market modernization. The measuring of service quality is the subject of several studies on the service sector. Systematic theoretical study on hotel service quality management is important for the hotel business, which is a general services sector. This study suggests a way to assess the caliber of hotel services in China. First, a questionnaire based on the HSQ-CS Model is created. Additionally, AHP is used to determine each variable's weight in the survey.

Shi et al. [7] analyzed using several useful techniques to gauge the level of customer satisfaction (CS), which is a measure of service quality. First, hotel service quality is assessed using the

Customer Satisfaction Degree (CSD) calculation. Second, several enlightening insights are made using discriminant analysis, correlation analysis, etc. To mention a few, 1) When it comes to client pleasure, the reception hall's service quality is more crucial than that of the restaurant and guest rooms. 2) Three important factors for reception hall customer pleasure are "attender technique," "attorney service initiative," and "reception hall environment and decoration." 3)

2. Bipolar Pythagorean Neutrosophic Number (BPNN)

This section shows some concepts of neutrosophic set with aggregation operators to overcome uncertainty problems[8].

Definition 1

The BPNN is presented as:

$$X = \left\{ \begin{pmatrix} A_X^+(Y), B_X^+(Y), C_X^+(Y), \\ A_X^-(Y), B_X^-(Y), C_X^-(Y) \end{pmatrix} : Y \in y \right\}$$

$$A_X^+(Y), B_X^+(Y), C_X^+(Y): Y \to [0,1]$$

$$A_X^-(Y), B_X^-(Y), C_X^-(Y): Y \to [-1,0]$$

$A_X^+(Y), B_X^+(Y), C_X^+(Y)$ are positive membership functions.

$A_X^-(Y), B_X^-(Y), C_X^-(Y)$ are negative membership functions.

$$0 \le A_X^+(Y)^2 + B_X^+(Y)^2 \le 1$$

$$0 \le A_X^-(Y)^2 + B_X^-(Y)^2 \le 1$$

$$0 \le A_X^+(Y)^2 + B_X^+(Y)^2 + C_X^+(Y)^2 \le 2$$

$$0 \le A_X^-(Y)^2 + B_X^-(Y)^2 + C_X^-(Y)^2 \le 2$$

3. Heronian Mean Operators (HM)

This section shows the HM operator to combine different neutrosophic values.

Definition 2

The generalized Heronian Mean Operators (GHM) are introduced as:

$$GHM^{p,q}(y_1, y_2, \dots, y_n) = \left[\frac{2}{n(m+1)} \left(\sum_{i=1}^{n} \sum_{j=1}^{n} y_i^p y_j^q \right) \right]^{\frac{1}{p+q}}$$

4. Hamacher Operations Under BPNS

Definition 3

Hamacher product is a t-norm and Hamacher sum is a t-conorm which are introduced as:

$$D(y_i, y_j) = y_i \otimes y_j = \frac{y_i y_j}{\delta + (1-\delta)(y_i + y_j - y_i y_j)} \delta > 0$$

$$D(y_i, y_j) = y_i \oplus y_j = \frac{y_i + y_j - y_i y_j - (1-\delta)(y_i y_j)}{1 - (1-\delta)(y_i y_j)} \delta > 0$$

Definition 4

Operations of Hamacher are introduced as:

$$X_1 \oplus X_2 = \left(\begin{array}{c} \sqrt{\frac{\left(A^+_{X_1}(Y)\right)^2 + \left(A^+_{X_2}(Y)\right)^2 - \left(A^+_{X_1}(Y)\right)^2 \left(A^+_{X_2}(Y)\right)^2 - (1-\delta)\left(A^+_{X_1}(Y)\right)^2 \left(A^+_{X_2}(Y)\right)^2}{1 - (1-\delta)\left(A^+_{X_1}(Y)\right)^2 \left(A^+_{X_2}(Y)\right)^2}}, \\ \frac{B^+_{X_1}(Y) B^+_{X_2}(Y)}{1 + (1-\delta)\left(B^+_{X_1}(Y) + B^+_{X_2}(Y) - B^+_{X_1}(Y) B^+_{X_2}(Y)\right)}, \\ \frac{C^+_{X_1}(Y) C^+_{X_2}(Y)}{1 + (1-\delta)\left(C^+_{X_1}(Y) + C^+_{X_2}(Y) - C^+_{X_1}(Y) C^+_{X_2}(Y)\right)}, \\ \frac{-A^-_{X_1}(Y) A^-_{X_2}(Y)}{1 + (1-\delta)\left(-A^-_{X_1}(Y) + A^-_{X_2}(Y) - A^-_{X_1}(Y) A^-_{X_2}(Y)\right)}, \\ \frac{-\left(-B^-_{X_1}(Y) - B^-_{X_2}(Y) - B^-_{X_1}(Y) B^-_{X_2}(Y) - (1-\delta) B^-_{X_1}(Y) B^-_{X_2}(Y)\right)}{1 - (1-\delta) B^-_{X_1}(Y) B^-_{X_2}(Y)}, \\ \sqrt{\frac{\left(C^-_{X_1}(Y)\right)^2 + \left(C^-_{X_2}(Y)\right)^2 - \left(C^-_{X_1}(Y)\right)^2 \left(C^-_{X_2}(Y)\right)^2 - (1-\delta)\left(C^-_{X_1}(Y)\right)^2 \left(C^-_{X_2}(Y)\right)^2}{1 - (1-\delta)\left(C^-_{X_1}(Y)\right)^2 \left(C^-_{X_2}(Y)\right)^2}} \end{array} \right)$$

$$X_1 \otimes X_2 = \left(\begin{array}{c} \frac{A^+_{X_1}(Y) A^+_{X_2}(Y)}{1 + (1-\delta)\left(A^+_{X_1}(Y) + A^+_{X_2}(Y) - A^+_{X_1}(Y) A^+_{X_2}(Y)\right)}, \\ \frac{B^+_{X_1}(Y) + B^+_{X_2}(Y) - B^+_{X_1}(Y) B^+_{X_2}(Y) - (1-\delta) B^+_{X_1}(Y) B^+_{X_2}(Y)}{1 - (1-\delta)\left(B^+_{X_1}(Y) B^+_{X_2}(Y)\right)}, \\ \sqrt{\frac{\left(C^+_{X_1}(Y)\right)^2 + \left(C^+_{X_2}(Y)\right)^2 - \left(C^+_{X_1}(Y)\right)^2 \left(C^+_{X_2}(Y)\right)^2 - (1-\delta)\left(C^+_{X_1}(Y)\right)^2 \left(C^+_{X_2}(Y)\right)^2}{1 - (1-\delta)\left(C^+_{X_1}(Y)\right)^2 \left(C^+_{X_2}(Y)\right)^2}}, \\ -\sqrt{\frac{\left(A^-_{X_1}(Y)\right)^2 + \left(A^-_{X_2}(Y)\right)^2 - \left(A^-_{X_1}(Y)\right)^2 \left(A^-_{X_2}(Y)\right)^2 - (1-\delta)\left(A^-_{X_1}(Y)\right)^2 \left(A^-_{X_2}(Y)\right)^2}{1 - (1-\delta)\left(A^-_{X_1}(Y)\right)^2 \left(A^-_{X_2}(Y)\right)^2}}, \\ \frac{B^-_{X_1}(Y) B^-_{X_2}(Y)}{\delta + (1-\delta)\left(B^-_{X_1}(Y) + B^-_{X_2}(Y) - B^-_{X_1}(Y) B^-_{X_2}(Y)\right)}, \\ \sqrt{\frac{-C^-_{X_1}(Y) C^-_{X_2}(Y)}{\delta + (1-\delta)\left(C^-_{X_1}(Y) + C^-_{X_2}(Y) - C^-_{X_1}(Y) C^-_{X_2}(Y)\right)}} \end{array} \right)$$

5. Results

This part shows the results of Voice of the Guest: Evaluating Hotel Management Service Quality through Customer Feedback. We show the BPNN under aggregation operators to combine different values. This study uses four criteria and eight alternatives. The criteria are: Service Responsiveness, Room Cleanliness and Maintenance, Staff Professionalism and Courtesy, Amenities and Service Variety. The alternatives are: Luxury Business Hotel in a Capital City, Budget Chain Hotel Near Airport, Eco-Friendly Resort in a Rural Area, Boutique Hotel in a Historical District, Mid-Range Hotel in a Coastal Tourist Area, Smart Hotel with Automated Check-in Services, Family-Oriented Resort with Theme Activities, Convention Center Hotel Near Urban Transit.

Three experts evaluate the criteria and alternatives using the Bipolar Pythagorean Neutrosophic Numbers (BPNNs) as shown in Table 1.

Table 1. BPNNs.

	$BPNC_1$	$BPNC_2$	$BPNC_3$	$BPNC_4$
$BPNA_1$	(0.5,0.3,0.2, -0.6, -0.4, -0.3)	(0.9,0.6,0.2, -0.6, -0.5, -0.3)	(0.4, 0.2, 0.3, -0.3, -0.3, -0.2)	(0.5, 0.8, 0.6, -0.4, -0.1, -0.3)
$BPNA_2$	(0.5,0.3,0.2, -0.6, -0.4, -0.3)	(0.5, 0.1, 0.3, -0.2, -0.6, -0.7)	(0.2, 0.3, 0.4, -0.7, -0.3, -0.2)	(0.6,0.5,0.2, -0.3, -0.7, -0.7)
$BPNA_3$	(0.9,0.6,0.2, -0.6, -0.5, -0.3)	(0.4, 0.2, 0.3, -0.3, -0.3, -0.2)	(0.5, 0.8, 0.6, -0.4, -0.1, -0.3)	(0.6,0.5,0.2, -0.3, -0.7, -0.7)
$BPNA_4$	(0.5, 0.8, 0.6, -0.4, -0.1, -0.3)	(0.4, 0.2, 0.3, -0.3, -0.3, -0.2)	(0.9,0.6,0.2, -0.6, -0.5, -0.3)	(0.5,0.3,0.2, -0.6, -0.4, -0.3)
$BPNA_5$	(0.6,0.5,0.2, -0.3, -0.7, -0.7)	(0.5, 0.8, 0.6, -0.4, -0.1, -0.3)	(0.4, 0.2, 0.3, -0.3, -0.3, -0.2)	(0.9,0.6,0.2, -0.6, -0.5, -0.3)
$BPNA_6$	(0.6,0.5,0.2, -0.3, -0.7, -0.7)	(0.6,0.5,0.2, -0.3, -0.7, -0.7)	(0.5, 0.8, 0.6, -0.4, -0.1, -0.3)	(0.6,0.5,0.2, -0.3, -0.7, -0.7)
$BPNA_7$	(0.2, 0.3, 0.4, -0.7, -0.3, -0.2)	(0.5, 0.1, 0.3, -0.2, -0.6, -0.7)	(0.9,0.6,0.2, -0.6, -0.5, -0.3)	(0.5, 0.1, 0.3, -0.2, -0.6, -0.7)
$BPNA_8$	(0.5, 0.1, 0.3, -0.2, -0.6, -0.7)	(0.5,0.3,0.2, -0.6, -0.4, -0.3)	(0.5,0.3,0.2, -0.6, -0.4, -0.3)	(0.5,0.3,0.2, -0.6, -0.4, -0.3)
	$BPNC_1$	$BPNC_2$	$BPNC_3$	$BPNC_4$
$BPNA_1$	(0.5, 0.8, 0.6, -0.4, -0.1, -0.3)	(0.9,0.6,0.2, -0.6, -0.5, -0.3)	(0.4, 0.2, 0.3, -0.3, -0.3, -0.2)	(0.5, 0.8, 0.6, -0.4, -0.1, -0.3)
$BPNA_2$	(0.4, 0.2, 0.3, -0.3, -0.3, -0.2)	(0.5, 0.1, 0.3, -0.2, -0.6, -0.7)	(0.2, 0.3, 0.4, -0.7, -0.3, -0.2)	(0.5, 0.8, 0.6, -0.4, -0.1, -0.3)
$BPNA_3$	(0.9,0.6,0.2, -0.6, -0.5, -0.3)	(0.4, 0.2, 0.3, -0.3, -0.3, -0.2)	(0.5, 0.8, 0.6, -0.4, -0.1, -0.3)	(0.4, 0.2, 0.3, -0.3, -0.3, -0.2)
$BPNA_4$	(0.5,0.3,0.2, -0.6, -0.4, -0.3)	(0.4, 0.2, 0.3, -0.3, -0.3, -0.2)	(0.9,0.6,0.2, -0.6, -0.5, -0.3)	(0.9,0.6,0.2, -0.6, -0.5, -0.3)
$BPNA_5$	(0.5, 0.1, 0.3, -0.2, -0.6, -0.7)	(0.5, 0.8, 0.6, -0.4, -0.1, -0.3)	(0.4, 0.2, 0.3, -0.3, -0.3, -0.2)	(0.5,0.3,0.2, -0.6, -0.4, -0.3)
$BPNA_6$	(0.5, 0.8, 0.6, -0.4, -0.1, -0.3)	(0.5, 0.8, 0.6, -0.4, -0.1, -0.3)	(0.5, 0.8, 0.6, -0.4, -0.1, -0.3)	(0.5, 0.1, 0.3, -0.2, -0.6, -0.7)
$BPNA_7$	(0.5, 0.1, 0.3, -0.2, -0.6, -0.7)	(0.9,0.6,0.2, -0.6, -0.5, -0.3)	(0.5, 0.1, 0.3, -0.2, -0.6, -0.7)	(0.9,0.6,0.2, -0.6, -0.5, -0.3)
$BPNA_8$	(0.9,0.6,0.2, -0.6, -0.5, -0.3)	(0.9,0.6,0.2, -0.6, -0.5, -0.3)	(0.9,0.6,0.2, -0.6, -0.5, -0.3)	(0.6,0.5,0.2, -0.3, -0.7, -0.7)
	$BPNC_1$	$BPNC_2$	$BPNC_3$	$BPNC_4$
$BPNA_1$	(0.5,0.3,0.2, -0.6, -0.4, -0.3)	(0.9,0.6,0.2, -0.6, -0.5, -0.3)	(0.4, 0.2, 0.3, -0.3, -0.3, -0.2)	(0.5, 0.8, 0.6, -0.4, -0.1, -0.3)
$BPNA_2$	(0.5, 0.1, 0.3, -0.2, -0.6, -0.7)	(0.5, 0.1, 0.3, -0.2, -0.6, -0.7)	(0.2, 0.3, 0.4, -0.7, -0.3, -0.2)	(0.6,0.5,0.2, -0.3, -0.7, -0.7)
$BPNA_3$	(0.2, 0.3, 0.4, -0.7, -0.3, -0.2)	(0.5,0.3,0.2, -0.6, -0.4, -0.3)	(0.5, 0.8, 0.6, -0.4, -0.1, -0.3)	(0.6,0.5,0.2, -0.3, -0.7, -0.7)
$BPNA_4$	(0.6,0.5,0.2, -0.3, -0.7, -0.7)	(0.5, 0.1, 0.3, -0.2, -0.6, -0.7)	(0.5,0.3,0.2, -0.6, -0.4, -0.3)	(0.5,0.3,0.2, -0.6, -0.4, -0.3)
$BPNA_5$	(0.5, 0.8, 0.6, -0.4, -0.1, -0.3)	(0.2, 0.3, 0.4, -0.7, -0.3, -0.2)	(0.5, 0.1, 0.3, -0.2, -0.6, -0.7)	(0.5,0.3,0.2, -0.6, -0.4, -0.3)
$BPNA_6$	(0.4, 0.2, 0.3, -0.3, -0.3, -0.2)	(0.6,0.5,0.2, -0.3, -0.7, -0.7)	(0.2, 0.3, 0.4, -0.7, -0.3, -0.2)	(0.5, 0.1, 0.3, -0.2, -0.6, -0.7)
$BPNA_7$	(0.5,0.3,0.2, -0.6, -0.4, -0.3)	(0.5,0.3,0.2, -0.6, -0.4, -0.3)	(0.5,0.3,0.2, -0.6, -0.4, -0.3)	(0.5,0.3,0.2, -0.6, -0.4, -0.3)
$BPNA_8$	(0.5, 0.1, 0.3, -0.2, -0.6, -0.7)	(0.5, 0.1, 0.3, -0.2, -0.6, -0.7)	(0.5, 0.1, 0.3, -0.2, -0.6, -0.7)	(0.9,0.6,0.2, -0.6, -0.5, -0.3)

BPNNs are combined using the Hamacher aggregation operator into a single matrix as shown in Figure 1-4.

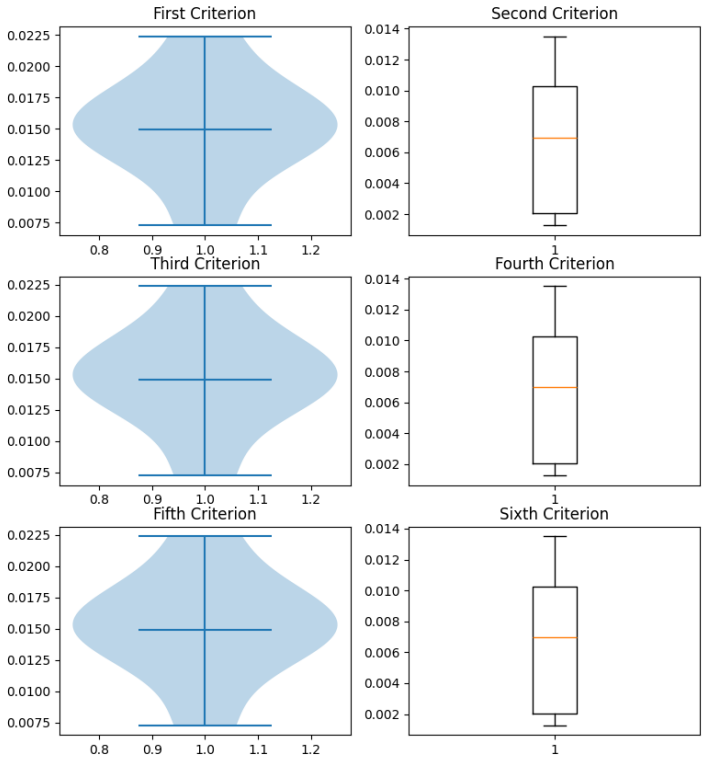

Figure 1. Hamacher aggregation operator for first criterion.

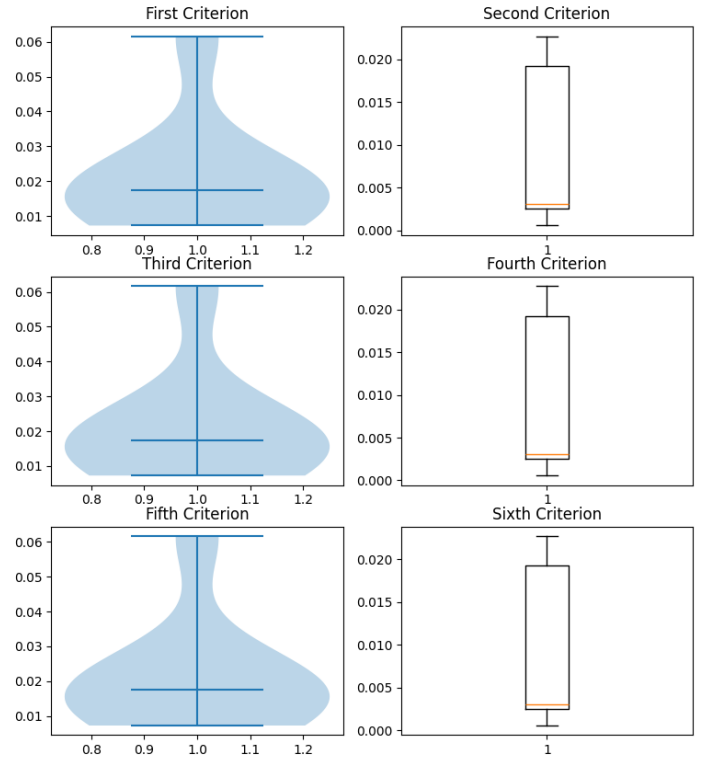

Figure 2. Hamacher aggregation operator for second criterion.

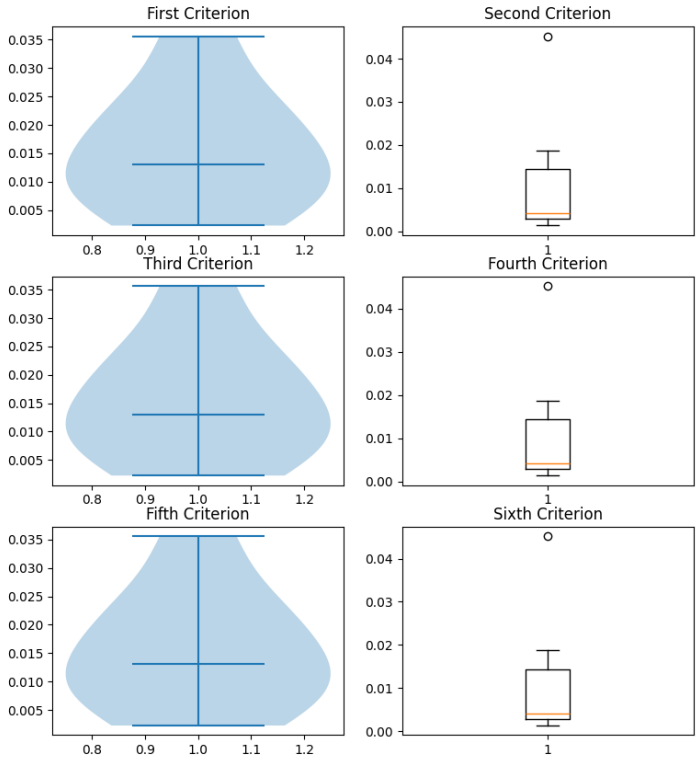

Figure 3. Hamacher aggregation operator for third criterion.

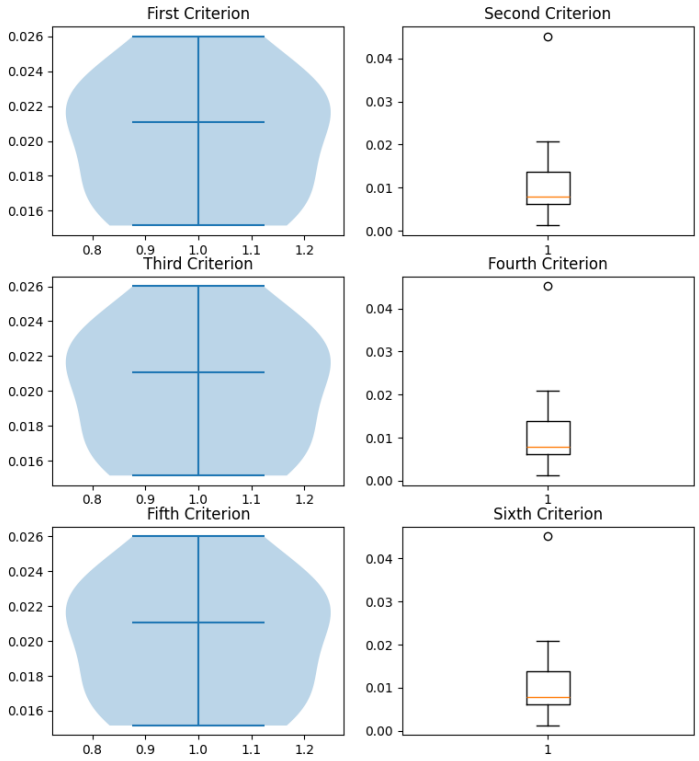

Figure 4. Hamacher aggregation operator for fourth criterion.

The Hamacher aggregation operator is used to obtain the final value of each alternative. As shown in Figure 5. Figure 6 shows the ranks of alternatives.

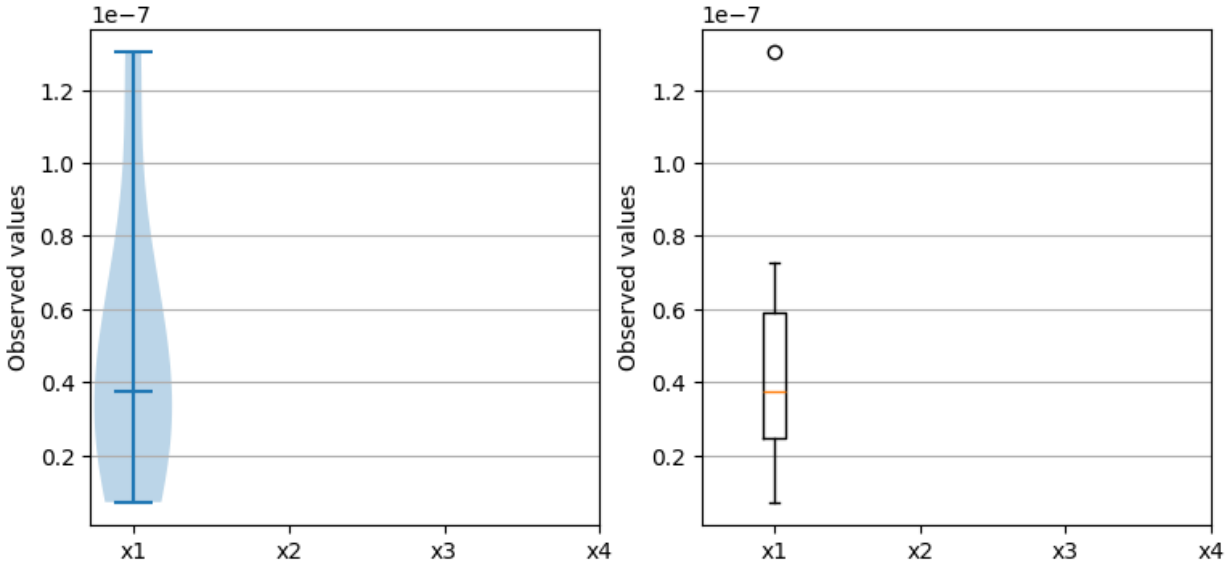

Figure 5. Final score of each alternative.

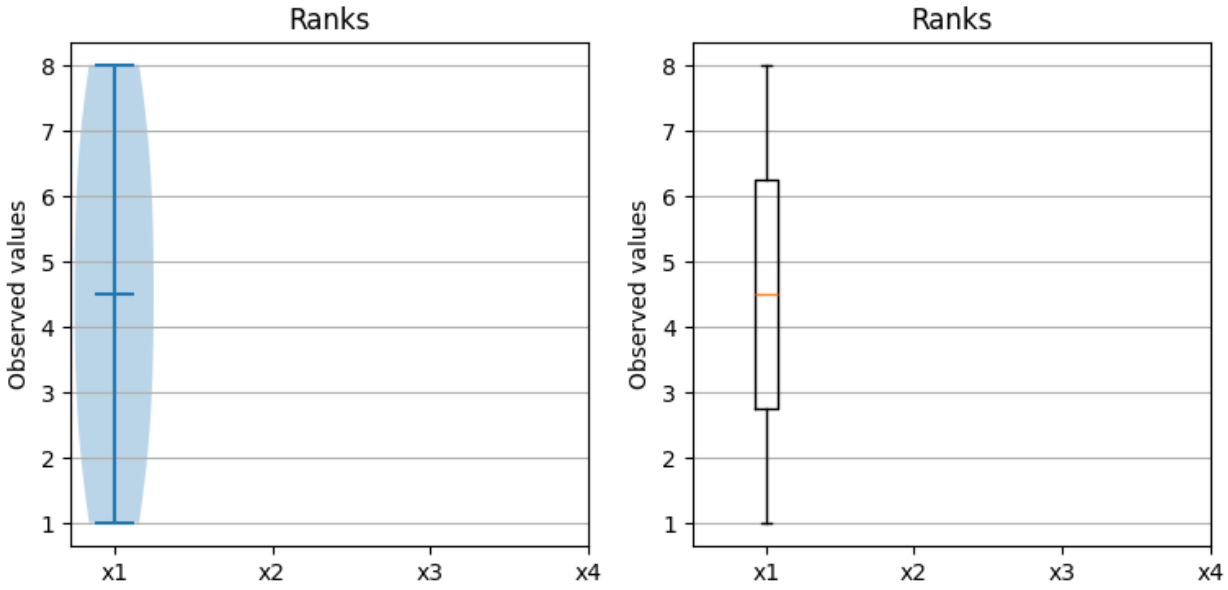

Figure 6. Ranks result of Hamacher aggregation operator.

6. Conclusions

This study demonstrates how important client input is for evaluating and improving the caliber of hotel management services. The evaluation's findings show that a variety of visitor services, staff conduct, quick reaction times, and room cleanliness all have a big impact on overall client satisfaction. Hotels that successfully integrate systems for guest input into their operational plan typically see improvements in quality measures. Furthermore, the study highlights that contemporary hospitality settings, especially those that make use of smart technology and digital feedback, have a competitive edge in satisfying changing visitor demands. This study used the Bipolar Pythagorean Neutrosophic Number (BPNN) to overcome uncertainty information. Hamacher operator is used under the BPNN to combine the values of criteria and alternatives.

To prioritize service enhancements, hotel management must implement structured feedback analytics and decision-making frameworks. Future research may look more closely at how big data and AI might improve and automate real-time service quality monitoring.

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