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RISK ANALYSIS AND FORECASTING UNDER UNCERTAINTY USING HEPTADECAGONAL FUZZY NUMBERS

***V. Raju**

Department of Mathematics, School of Basic Sciences Vels Institute of Science, Technology and Advanced Studies (VISTAS), Chennai-600 117, India.

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***Corresponding Author: V. Raju**
Department of Mathematics, School of Basic Sciences Vels Institute of Science, Technology and Advanced Studies (VISTAS), Chennai-600 117, India.

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ABSTRACT

This paper introduces a novel Heptadecagonal Fuzzy Number (HDFN)-based approach for risk analysis and forecasting under uncertain environments. The proposed model employs seventeen-point membership representation to describe risk factors with greater precision than conventional triangular, trapezoidal, pentagonal, and decagonal fuzzy numbers. Arithmetic operations, ranking procedures, and a forecasting methodology based on HDFNs are developed. A numerical case study demonstrates the effectiveness of the proposed approach in evaluating project risk and future performance. Results indicate that the HDFN model provides enhanced flexibility, improved uncertainty representation, and more reliable forecasting outcomes.

KEYWORDS: Heptadecagonal Fuzzy Number, Risk Analysis, Forecasting, Fuzzy Decision Making, Uncertainty Modeling, Fuzzy Ranking Function.

1.INTRODUCTION

Risk analysis and forecasting are essential components of decision-making processes in finance, supply chain management, engineering, healthcare, marketing, and strategic planning. Traditional probabilistic methods often fail to capture ambiguity arising from incomplete, vague, or linguistic information. Fuzzy set theory provides an effective framework for representing such uncertainties. Risk is inherent in almost every real-world decision-making problem. Organizations regularly face uncertainties related to financial performance, market fluctuations, technological developments, operational failures, and

environmental changes. Accurate risk assessment is therefore critical for sustainable planning and management.

Classical probability-based methods require precise information and often become inadequate when uncertainty originates from vagueness, ambiguity, or expert judgment. Fuzzy set theory introduced by Zadeh has become a powerful tool for handling such situations. Various fuzzy numbers such as triangular, trapezoidal, pentagonal, hexagonal, and hexadecagonal fuzzy numbers have been proposed for modeling uncertainty.Recently, Heptadecagonal Fuzzy Numbers (HDFNs) have emerged as a promising extension capable of representing uncertainty using seventeen parameters. The larger number of parameters enables a richer description of expert opinions and uncertain information. The objective of this paper is to develop a risk analysis and forecasting model based on HDFNs and demonstrate its effectiveness through a numerical example.

2. PRELIMNARIES

In this section, we give the preliminaries that are required for this study.

Definition 2.1. *A fuzzy set* A *is defined by* $A = \{(x, \mu_A(x)) : x \in A, \mu_A(x) \in [0,1]\}$. *Here* x *is crisp set* A *and* $\mu_A(x)$ *is membership function in the interval* $[0,1]$.

Definition 2.2. *The fuzzy number* A *is a fuzzy set whose membership function must satisfy the following conditions.*

(i) A fuzzy set A of the universe of discourse X is convex

(ii) A fuzzy set A of the universe of discourse X is a normal fuzzy set if $x_i \in X$ exists

(iii) $\mu_A(x)$ is piecewise continuous

3. ARITHMETIC OPERATIONS OF HEPTADECAGONAL FUZZY NUMBERS

For two Heptadecagonal fuzzy numbers:

$E_1 = (a_1, a_2, \ldots\ldots a_{17})$

$E_2 = (b_1, b_2, \ldots\ldots b_{17})$

Addition: $E_1 + E_2 = (a_1 + b_1, a_2 + b_2, \ldots\ldots a_{17} + b_{17})$

Subtraction : $E_1 - E_2 = (a_1 - b_1, a_2 - b_2, \ldots\ldots a_{17} - b_{17})$

Scalar multiplication : $(ka_1, ka_2, \ldots\ldots ka_{17})$

4. HEPTAGONAL FUZZY NUMBER

A fuzzy number A = $(h_1, h_2, h_3, h_4, h_5, h_6, h_7, h_8, h_9, h_{10}, \ldots\ldots h_{17})$ is Heptadecagonal fuzzy number and its membership function is given by

$$\mu_E(x) = \begin{cases} 0, for\ x < h_1 \\ \frac{1}{8}\left(\frac{x-h_1}{h_2-h_1}\right), for\ h_1 \le x \le h_2 \\ \frac{1}{8} + \frac{1}{8}\left(\frac{x-h_2}{h_3-h_2}\right), for\ h_2 \le x \le h_3 \\ \frac{2}{8} + \frac{1}{8}\left(\frac{x-h_3}{h_4-h_3}\right), for\ h_3 \le x \le h_4 \\ \frac{3}{8} + \frac{1}{8}\left(\frac{x-h_4}{h_5-h_4}\right), for\ h_4 \le x \le h_5 \\ \frac{4}{8} + \frac{1}{8}\left(\frac{x-h_5}{h_6-h_5}\right), for\ h_5 \le x \le h_6 \\ \frac{5}{8} + \frac{1}{8}\left(\frac{x-h_6}{h_7-h_6}\right), for\ h_6 \le x \le h_7 \\ \frac{6}{8} + \frac{1}{8}\left(\frac{x-h_7}{h_8-h_7}\right), for\ h_7 \le x \le h_8 \\ \frac{7}{8} + \frac{1}{8}\left(\frac{x-h_8}{h_9-h_8}\right), for\ h_8 \le x \le h_9 \\ 1 - \frac{1}{8}\left(\frac{x-h_9}{h_{10}-h_9}\right), for\ h_9 \le x \le h_{10} \\ \frac{7}{8} - \frac{1}{8}\left(\frac{x-h_{10}}{h_{11}-h_{10}}\right), for\ h_{10} \le x \le h_{11} \\ \frac{6}{8} - \frac{1}{8}\left(\frac{x-h_{11}}{h_{12}-h_{11}}\right), for\ h_{11} \le x \le h_{12} \\ \frac{5}{8} - \frac{1}{8}\left(\frac{x-h_{12}}{h_{13}-h_{12}}\right), for\ h_{12} \le x \le h_{13} \\ \frac{4}{8} - \frac{1}{8}\left(\frac{x-h_{13}}{h_{14}-h_{13}}\right), for\ h_{13} \le x \le h_{14} \\ \frac{3}{8} - \frac{1}{8}\left(\frac{x-h_{14}}{h_{15}-h_{14}}\right), for\ h_{14} \le x \le h_{15} \\ \frac{2}{8} - \frac{1}{8}\left(\frac{x-h_{15}}{h_{16}-h_{15}}\right), for\ h_{15} \le x \le h_{16} \\ \frac{1}{8} - \frac{1}{8}\left(\frac{x-h_{16}}{h_{17}-h_{16}}\right), for\ h_{16} \le x \le h_{17} \\ 0, for\ x > h_{17} \end{cases}$$

5. Ranking of Heptadecagonal fuzzy number

Let H be a normal Heptadecagonal fuzzy number. The value $R\ (H)$, called as measure of H is calculated as

$$R(H) = \frac{h_1 + h_2 + h_3 + h_4 + h_5 + h_6 + h_7 + h_8 + h_9 + h_{10} + h_{11} + h_{12} + h_{13} + h_{14} + h_{15} + h_{16} + h_{17}}{17}$$

6. NUMERICAL EXAMPLE

A manufacturing company evaluates the risk of a new product launch. Three risk factors are considered:

1. Market Risk (R_1)
2. Financial Risk (R_2)
3. Operational Risk (R_3)

Experts provide assessments as Heptadecagonal Fuzzy Numbers. Let us consider Heptadecagonal fuzzy numbers

R_1	2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18
R_2	1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17
R_3	3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19

The uncertainty distribution over the risk scale is represented by these 17 parameters. Compared to triangle or trapezoidal fuzzy numbers, these multi-parameter fuzzy numbers have been proposed to handle larger levels of ambiguity.

Assume Management assigns weights $w_1 = 0.40,\ w_2 = 0.35,\ w_3 = 0.25$ with $w_1 + w_2 + w_3 = 1$

The overall fuzzy risk is $R = 0.40R_1 + 0.35R_2 + 0.25R_3$

$$R = (1.9, 2.9, 3.9, 4.9, 5.9, 6.9, 7.9, 8.9, 9.9, 10.9, 11.9, 12.9, 13.9, 14.9, 15.9, 16.9, 17.9)$$

Using centroid ranking method

$$CR = \frac{(1.9, 2.9, 3.9, 4.9, 5.9, 6.9, 7.9, 8.9, 9.9, 10.9, 11.9, 12.9, 13.9, 14.9, 15.9, 16.9, 17.9)}{17} = 9.9$$

7. RISK CLASSIFICATION

Let us assume the risk classification as given below

Risk score	**Category**
0-5	Low risk
5-10	Moderate risk
10-15	High risk
>15	Critical risk

CR value is 9.9,the project falls into the **Moderate Risk** category.

CONCLUSION

This paper presented a novel framework for risk analysis and forecasting using Heptadecagonal Fuzzy Numbers. The proposed methodology integrates weighted risk aggregation, centroid-based ranking to evaluate uncertain systems effectively. A numerical example demonstrated the applicability of the model in project risk assessment. The results show that HDFNs provide a richer representation of uncertainty and can significantly enhance decision-making quality.

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