Management Science Advances Volume 2, Issue 1 (2024) 19-58

SCIENTIFIC OASIS

Management Science Advances

Journal homepage: www.msa-journal.org
ISSN: 3042-2205

Decision-analytics-based Sustainable Location Problem - Neutrosophic CRITIC-COPRAS Assessment Model

Tripti Basuri[1], Kamal Hossain Gazi[2], Aditi Biswas[3], Prodip Bhaduri[2], Srabani Guria Das[4], Sankar Prasad Mondal*[2]

[1] Uttar Dum Dum Vidyapith (Girls) Primary section, Birati, West Bengal, India
[2] Department of Applied Mathematics, Maulana Abdul Kalam Azad University of Technology, West Bengal, India
[3] Department of Basic Science and Humanities, Greater Kolkata College of Engineering & Management, West Bengal, India
[4] Department of Basic Science, NSHM Knowledge Campus, Durgapur, West Bengal, India

ARTICLE INFO

Article history:
Received 19 December 2024
Received in revised form21 January 2025
Accepted 28 January 2025
Available online 9 February 2025

Keywords:
School site selection; Educational institute; Neutrosophic numbers; CRITIC; COPRAS

ABSTRACT

School is the place where students get the opportunity to accrue knowledge and quality education. Choosing a suitable location for establishing a new school is dependent on various factors like population density, socio-economic situation, environment of that place, land availability, accessibility, infrastructure, etc. In this paper, our aim is to identify the optimal site for establishing a new school in Paschim Bardhaman district using the Multi Criteria Decision Making (MCDM) method. Here, two MCDM methods, namely the Criteria Importance Through Intercriteria Correlation (CRITIC) method, is used for evaluating criteria weight and further, the Complex Proportional Assessment (COPRAS) method is applied for ranking the sites chosen as alternatives. We consider the neutrosophic numbers (NNs) to incorporate uncertainty in the data set. Further sensitivity and comparative analysis are performed to verify the accuracy and stability of the result. Thus we obtain a framework which will be very helpful for urban planners and government policy makers to make informed decisions for educational development.

1. Introduction

The process of selecting a perfect location for a school is a difficult task. It directly helps to improve the education quality and students' and staffs' well-being. In the process of selecting a site it requires to focus on a secure, accessible and a learning friendly environment. A perfect site need to be meet the requirements of space for classrooms, playgrounds and future expansions while providing

*Corresponding author.
E-mail address: sankar.res07@gmail.com

https://doi.org/10.31181/msa2120257

to zoning laws and restrictions. Cost estimation plays a key role to balance affordability with quality. Several environmental factors such as, air quality, water quality and noise levels must be computed carefully. Accessibility to public transport and residential areas is vital for easy access. Some adequate utilities like electricity and water sanitation must be available for the selection of school location. In the final segment, a proper-choosed site develops a inclusive, nurturing and future-ready educational environment.

As a mathematical tool, the fuzzy set and number are considered for this research work. Particularly, Neutrosophic Number (NNs) are applied here to process this school site selection problem. As the preference of the proper location is influenced by multiple factors, it can be selected as an application of multi-criteria decision making (MCDM) problem. The decision making methods like the Criteria Importance Through Inter-criteria Correlation (CRITIC) [1, 2] and Complex Proportional Assessment (COPRAS) [3, 4] are used in this study to process the site selection problem. To calculate the criteria weight and ranking of sites, we use the CRITIC and COPRAS methodologies, respectively.

1.1 *Motivation of this study*

This section explains the motivation of this work in brief way. The main purpose of this study is to select a perfect site for a new school. The motivation for this research work is describe as bellow,

(a) Various criteria are choosed here to identify a perfect site for a new school.

(b) Neutrosophic Numbers (NNs) are taken for handling the ambiguity of the data set. All the data are choosen in terms of linguistic and modified into NNs.

(c) A new de-neutrosophic function is created and used to process the solution.

(d) Evaluate the criteria and sub-criteria weight using the decision matrix and utilise it in further computation.

(e) Establish a weighted-based ranking model for ideal site selection.

(f) Two NNs based MCDM models are developed, namely CRITIC & COPRAS to find the criteria weight & for ranking alternative, respectively.

(g) Two decision makers (DMs) are given required data in linguistic terms in an unbiased procedure.

(h) Ranking different locations for building a school based on criteria.

(i) A sensitivity and comparative analysis verify the model's durability and robustness.

1.2 *Research outline*

On the basis of above study and motivation, we design a research outline of this study in this section. Rank the different sites based on various important criteria in a proper way is the main objective of this work. There are six critical criteria, some sub-criteria corresponding to those criteria and five sites are taken for evaluation. Two MCDM methods are considered as optimization tools and Neutrosophic Numbers (NNs) are assessed as uncertainty tool. Data are gathered in an unbiased process and numerically computed the result on it. Ultimately, sensitivity and comparative analysis are performed.

1.3 Structure of this paper

This section mainly explains the total structure of this research work. The introduction of this paper is describe in Section 1. Section 2 analyses the literature survey of this paper. Section 3 and Section 4 discuss the basics of mathematical tools and multi-criteria decision making (MCDM) technologies elaborately. Criteria selection and alternative selection are shortly described in Section 5 and Section 6, respectively. The model formulation and data collection are demonstrated in Section 7 and Section 8 particularly. The numerical illustration and discussion are revealed in Section 9. In Section 10 shows the sensitivity analysis and comparative analysis of the work briefly. Moreover, research implications of this research are highlights in Section 11. Finally, conclusions and future research scope are disclosed in Section 12.

2. Literature survey of this study

This section highlights the literature survey on this research paper. Firstly, we discuss the strategy for site selection for a new School in Paschim Bardhaman District (West Bengal, India), then study the background of neutrosophic numbers with applications. Finally, we surveyed MCDM methods and two used decision making methods, CRITIC and COPRAS processes.

2.1 Background on application

Selecting a site for establishing a new school is very critical work. There are many factors on which this process is dependent. There are a lot of research works related to school site selection. A brief literature review on school site selection is presented in Table 1.

Table 1
Some recent literature on School Site Selection

Author	Year	Methodology	Application Area
[5] Gennaro, G. D. et al.	2013	Sampling and Analytical Method	Health Risk Assessment in School Building
[6] Mukherjee, M.	2013	Regression Discontinuity	School enrollment with better roads
[7] Bowers, A.J.	2014	Hierarchical Longitudinal Growth Models	Site selection in school district research
[8] Talam. et al.	2015	GIS, MCE, AHP	Integration of GIS and Multicriteria Evaluation for School Site Selection
[9] Jamal, I.	2016	GIS, AHP	Analysis for School Site Selection
[10] Panahi, M. et al.	2019	GIS, RBF, ICA.	Determining suitability of existing schools and site selection of new school buildings
[11] Baser, V.	2020	AHP	Land Use Policy for School Site Selection
[12] Palm, M. et al.	2020	Seemingly Unrelated Regression (SUR)	Public transit's role in school selection
[13] Zaheer, N. et al.	2021	Deep Neural Networks	Optimal school site selection in Urban areas
[14] González-Espejo, F. et al.	2022	Discrete Choice Models	Relation between school and residential location

2.2 Background of Mathematical tool

Fuzzy numbers are used to tackle the uncertainty in the data set. There are various extensions of fuzzy numbers [15], like triangular fuzzy numbers, Interval-valued fuzzy numbers [16], Type 2 fuzzy numbers [17], Intuitionistic fuzzy numbers [18], Neutrosophic fuzzy numbers [19], etc. In our paper, the Neutrosophic number is used. So, here we will provide a short literature review on Neutrosophic numbers in Table 2, as follows:

Table 2
Some recent studies on Neutrosophic Number with Applications

Author	Year	Uncertainty taken	Application Area
[20] Deli, I. et al.	2017	Single Valued Neutrosophic Number (SVNN)	Introduced a methodology for solving MADM problems using SVNN
[21] Abdel-Basset, M. et al.	2017	Trapezoidal Neutrosophic Number	Integrating AHP and Delphi framework in Neutrosophic environment
[22] Garg, H. et al.	2018	Single-Valued Neutrosophic Numbers (SVNN)	Developing new logarithmic operational laws and it's applications MADM problem
[23] Nabeeh, N. A. et al.	2019	Neutrosophic Number	Personnel selection process
[24] Fan, C. et al.	2019	Linguistic Neutrosophic Number	Introduction of a new approach for finding solution of MAGDM problems
[25] Muhamediyeva, D. et al.	2021	Gauss's Neutrosophic Number	Application in medical diagnosis problem
[26] Das, S. K. et al.	2020	Neutrosophic Triangular Number	A new approach for solving neutrosophic integer programming related issues
[19] Alamin, A. et al.	2024	Neutrosophic fuzzy set	Financial model formulation in discrete system
[27] Biswas, A. et al.	2024	Triangular neutrosophic number	Canteen site selection in an educational institute
[28] Rahaman, M. et al.	2025	Bell-shaped Neutrosophic number (BNN)	Solution of linear differential equations

2.3 *Literature of MCDM methodologies*

MCDM is a very powerful optimizing technique used to solve many complex problems. MCDM [29] is very effective when multiple criteria and alternatives appear in a problem. Momena, A. F. et al. [30] applied MCDM methods to determine the challenges of different supply chain companies and Adhikari, D. et al. [31] utilized entropy and VIKOR methodologies to rank states in India based on women empowerment. There are various types of MCDM methods, of which here we have involved CRITIC and COPRAS methods. There are many applications of the CRITIC method, some of which are given in Table 3, as follows:

Table 3
Literature on CRITIC Method

Author	Year	Uncertainty	Application Area
[32] Wu, H. W. et al.	2020	Fuzzy and random	Urban rail transit operation safety evaluation
[33] Krishnan, A. R. et al.	2021	Crisp number	Estimating the objective weights of decision criteria
[34] Pamucar, D. et al.	2022	Fuzzy rough numbers	Modification of the CRITIC method
[35] Haktanır, E. et al.	2022	Picture fuzzy	Wearable health technology
[36] Puška, A. et al.	2022	Fuzzy	Pear varieties market assessment
[37] Sharkasi, N. et al.	2022	Fuzzy	Hamming distance
[38] Kahraman, C. et al.	2022	Spherical fuzzy	Prioritization of supplier selection
[39] Mishra, A.R. et al.	2023	Fermatean fuzzy number	Novel score function

COPRAS is an MCDM-based ranking methodology. Some of the applications in recent times of the COPRAS method are discussed in Table 4.

Table 4
Literature on COPRAS Method

Author	Year	Uncertainty	Application Area
[3] Jianping Lu. et al.	2012	Picture fuzzy environment	Green supplier selection
[40] Bekar, E.T. et al.	2016	Fuzzy	Performance measurement in total productive maintenance
[18] Kumari, R. et al.	2020	Intuitionistic Fuzzy	Green supplier selection
[41] Saraji, M.K. et al.	2021	Fermatean Fuzzy	Sustainable Digital Transformation
[42] Fan, J. et al.	2022	T-spherical fuzzy	Comparative analysis
[16] Mishra, R.J. et al.	2022	Interval-valued hesitant Fermatean fuzzy	Desalination technology
[43] Naz, S. et al.	2022	Orthopair Fuzzy	Network security service
[44] Naz, S. et al.	2023	T-spherical fuzzy	Group decision making

3. Preliminaries of Mathematical Tools

This section will discuss the fuzzy number and its extensions in detail.

3.1 Fuzzy Set and Fuzzy Number

In 1965, Lotfi A. Zadeh [45] introduced fuzzy set theory. Fuzzy set theory [46] changes the concept of strictly belonging or non belonging of an element in a set as per classical set theory and introduces the idea of partial membership of elements in a set. The definition and properties of the fuzzy set are discussed as follows:

Definition 1. *A fuzzy set [47] $\tilde{\mathscr{A}}$ on the universe of discourse $\mathscr{U}$ is defined as,*

$$\tilde{\mathscr{A}} = \{(\zeta, \mu_{\tilde{\mathscr{A}}}(\zeta)) : \zeta \in \mathscr{U}\} \tag{1}$$

and corresponding membership function is, $\mu_{\tilde{\mathscr{A}}}(\zeta) : \mathscr{U} \to [0,1]$.

Example 1. *Let $\tilde{\mathscr{B}}$ be a fuzzy set of 'meritorious' students having reference set $\mathscr{U} = \{a_1', a_2', a_2', a_4', a_5'\}$. The merit of a_1' is 0.2, merit of a_2' is 0.7, merit of a_3' is 0.5, merit of a_4' is 1 and merit of a_5' is 0.4. So, the fuzzy set $\tilde{\mathscr{B}}$ can be represented as $\tilde{\mathscr{B}} = \{(a_1', 0.2), (a_2', 0.7), (a_3', 0.5), (a_4', 1), (a_5', 0.4)\}$.*

Definition 2. *A fuzzy set $\tilde{\mathscr{A}}$ is known as a fuzzy number[48] if it satisfies the following four properties,*

(i) $\tilde{\mathscr{A}}$ is a normalized fuzzy set that means there exists $\zeta \in \mathscr{U}$ such that $\mu_{\tilde{\mathscr{A}}}(\zeta) = 1$

(ii) $\tilde{\mathscr{A}}$ is a convex fuzzy set i.e, $\mu_{\tilde{\mathscr{A}}}(\lambda\zeta_1 + (1-\lambda)\zeta_2) \geq \min\{\mu_{\tilde{\mathscr{A}}}(\zeta_1), \mu_{\tilde{\mathscr{A}}}(\zeta_2)\}, \forall \zeta_1, \zeta_2 \in \tilde{\mathscr{A}}$ and $\lambda \in [0,1]$.

(iii) $\tilde{\mathscr{A}}$ must have a bounded support.

(iv) The membership function $\mu_{\tilde{\mathscr{A}}}$ is piecewise continuous.

3.2 Intuitionistic fuzzy set

There are many extensions of the fuzzy set, one of them is the Intuitionistic fuzzy set. In the Intuitionistic fuzzy set, we considered the degree of membership and non-membership of each element of that set.

Definition 3. *An Intuitionistic fuzzy set (IFS) [49] $\tilde{\mathscr{A}}$ on the universe of discourse $\mathscr{U}$ is defined as,*

$$\tilde{\mathscr{A}} = \{\langle \zeta, \mu_{\tilde{\mathscr{A}}}(\zeta), \nu_{\tilde{\mathscr{A}}}(\zeta)\rangle : \zeta \in \mathscr{U}\} \tag{2}$$

where $0 \leq \mu_{\tilde{\mathscr{A}}}(\zeta) + \nu_{\tilde{\mathscr{A}}}(\zeta) \leq 1$.

Here, $\mu_{\tilde{\mathscr{A}}}(\zeta) : \mathscr{U} \rightarrow [0, 1]$ represents the degree of membership and $\nu_{\tilde{\mathscr{A}}}(\zeta) : \mathscr{U} \rightarrow [0, 1]$ denotes the degree of non-membership of an element ζ to the set $\tilde{\mathscr{A}}$. Now, the degree of hesitation of an element ζ to the set $\tilde{\mathscr{A}}$ is defined as, $\pi_{\tilde{\mathscr{A}}}(\zeta) = 1 - \mu_{\tilde{\mathscr{A}}}(\zeta) - \nu_{\tilde{\mathscr{A}}}(\zeta)$.

The intuitionistic fuzzy set is further divided into two types: the first one is the Type I Intuitionistic fuzzy set (IFS) and the second one is the Type II Intuitionistic fuzzy set (IFS). For a Type I Intuitionistic fuzzy set $\tilde{\mathscr{A}}$ degree of membership $\mu_{\tilde{\mathscr{A}}}(\zeta)$ and degree of non membership $\nu_{\tilde{\mathscr{A}}}(\zeta)$ both belongs to the set $[0, 1]$ and give crisp values. It also satisfies the relation $0 \leq \mu_{\tilde{\mathscr{A}}}(\zeta) + \nu_{\tilde{\mathscr{A}}}(\zeta) \leq 1$. The Type II Intuitionistic Fuzzy Set is an extension of the Type I Intuitionistic fuzzy set. For a Type II Intuitionistic Fuzzy Set, both the membership and the non membership functions take fuzzy values.

Definition 4. *An Intuitionistic Fuzzy Set (IFS) $\tilde{\mathscr{A}}$ defined on $\mathbb{R}$ is said to be an Intuitionistic Fuzzy Number if it satisfies the properties of fuzzy numbers as mentioned in Definition 2.*

Example 2. *Let $\tilde{\mathscr{B}}$ represent student's ratings (ζ) about a particular lecture of History, where rating 1 means Poor, rating 3 means Average and rating 5 means Excellent. Then the Intuitionistic Fuzzy Number $\tilde{\mathscr{B}}$ can be represented as,*

$$\tilde{\mathscr{B}} = \{< 1, 0.3, 0.6 >, < 3, 0.5, 0.2 >, < 5, 0.7, 0.1 >\}$$

3.3 Neutrosophic set (NS):

The neutrosophic set(NS) is an extension of the Intuitionistic Fuzzy Set (IFS). In the Intuitionistic Fuzzy Set (IFS), we consider only two components, namely membership and non-membership functions for representing an element, whereas the Neutrosophic Set (NS) include the degree of Indeterminacy as an extra component. So, every element of a Neutrosophic Set (NS) is expressed in terms of three components such as membership function, indeterminacy function and non-membership function.

Definition 5. *A Neutrosophic Set (NS) [50] $\tilde{\mathscr{A}}$ on the universe of discourse $\mathscr{U}$ is of the form,*

$$\tilde{\mathscr{A}} = \{\langle \zeta, \mu_{\tilde{\mathscr{A}}}, (\zeta), \pi_{\tilde{\mathscr{A}}}(\zeta), \nu_{\tilde{\mathscr{A}}}(\zeta)\rangle : \zeta \in \mathscr{U}\} \tag{3}$$

where $\mu_{\tilde{\mathscr{A}}}(\zeta) : \mathscr{U} \rightarrow]0^-, 1^+[$ is the membership function, $\pi_{\tilde{\mathscr{A}}}(\zeta) : \mathscr{U} \rightarrow]0^-, 1^+[$ is the indeterminacy function and $\nu_{\tilde{\mathscr{A}}}(\zeta) : \mathscr{U} \rightarrow]0^-, 1^+[$ is the non-membership function. These three components also satisfies the relation $0^- \leq \mu_{\tilde{\mathscr{A}}}(\zeta) + \pi_{\tilde{\mathscr{A}}}(\zeta) + \nu_{\tilde{\mathscr{A}}}(\zeta) \leq 3^+$.

Definition 6. *Neutrosophic Number (NN) [23] is a Neutrosophic Set (NS) $\tilde{\mathscr{A}}$ defined on $\mathbb{R}$ which satisfies the properties of fuzzy numbers as mentioned in Definition 2.*

Here, we have provided a diagram in Figure 1 for understanding the evaluation of Neutrosophic Sets.

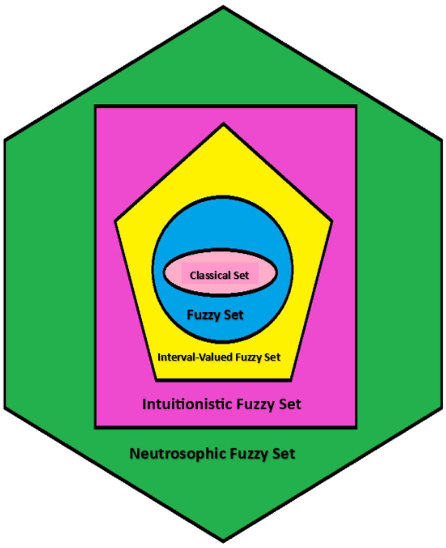

Fig. 1. Diagram of evaluation of fuzzy Sets

3.4 *Some Basic Set Operations of Neutrosophic Set(NS):*

In this section, we will discuss about some basic set operations of Neutrosophic Sets. Let $\tilde{\mathscr{E}} = \langle \zeta, \mu_{\tilde{\mathscr{E}}}(\zeta), \pi_{\tilde{\mathscr{E}}}(\zeta), \nu_{\tilde{\mathscr{E}}}(\zeta) : \zeta \in \mathscr{U} \rangle$ and $\tilde{\mathscr{F}} = \langle \zeta, \mu_{\tilde{\mathscr{F}}}(\zeta), \pi_{\tilde{\mathscr{F}}}(\zeta), \nu_{\tilde{\mathscr{F}}}(\zeta) : \zeta \in \mathscr{U} \rangle$ be two Neutrosophic Sets.

(i) **Complement of Neutrosophic Set(NS):** The complement of a Neutrosophic Set $\tilde{\mathscr{E}}$ is denoted by $\tilde{\mathscr{E}}^c$ and is represented as,

$$\tilde{\mathscr{E}}^c = \langle \zeta, \nu_{\tilde{\mathscr{E}}}(\zeta), 1 - \pi_{\tilde{\mathscr{E}}}(\zeta), \mu_{\tilde{\mathscr{E}}}(\zeta) : \zeta \in \mathscr{U} \rangle \tag{4}$$

(ii) **Union of two Neutrosophic Sets (NSs):** The union of two Neutrosophic Sets $\tilde{\mathscr{E}}$ and $\tilde{\mathscr{F}}$ is defined as,

$$\tilde{\mathscr{E}} \cup \tilde{\mathscr{F}} = \langle \zeta, \max\{\mu_{\tilde{\mathscr{E}}}(\zeta), \mu_{\tilde{\mathscr{F}}}(\zeta)\}, \min\{\pi_{\tilde{\mathscr{E}}}(\zeta), \pi_{\tilde{\mathscr{F}}}(\zeta)\}, \min\{\nu_{\tilde{\mathscr{E}}}(\zeta), \nu_{\tilde{\mathscr{F}}}(\zeta)\} : \zeta \in \mathscr{U} \rangle \tag{5}$$

(iii) **Intersection of two Neutrosophic Sets (NSs):** The intersection of two Neutrosophic Sets $\tilde{\mathscr{E}}$ and $\tilde{\mathscr{F}}$ is expressed as,

$$\tilde{\mathscr{E}} \cap \tilde{\mathscr{F}} = \langle \zeta, \min\{\mu_{\tilde{\mathscr{E}}}(\zeta), \mu_{\tilde{\mathscr{F}}}(\zeta)\}, \max\{\pi_{\tilde{\mathscr{E}}}(\zeta), \pi_{\tilde{\mathscr{F}}}(\zeta)\}, \max\{\nu_{\tilde{\mathscr{E}}}(\zeta), \nu_{\tilde{\mathscr{F}}}(\zeta)\} : \zeta \in \mathscr{U} \rangle \tag{6}$$

Example 3. *Let us consider two Neutrosophic Sets such as,* $\tilde{\mathscr{E}} = \langle \zeta, 0.75, 0.1, 0.15 \rangle$ *and* $\tilde{\mathscr{F}} = \langle \zeta, 0.6, 0.2, 0.1 \rangle$. *Then,*

$$\tilde{\mathscr{E}}^c = \langle \zeta, 0.15, 1 - 0.1, 0.75 \rangle = \langle \zeta, 0.15, 0.9, 0.75 \rangle$$

$$\tilde{\mathscr{E}} \cup \tilde{\mathscr{F}} = \langle \zeta, \max\{0.75, 0.6\}, \min\{0.1, 0.2\}, \min\{0.15, 0.1\} \rangle = \langle \zeta, 0.75, 0.1, 0.1 \rangle$$

$$\tilde{\mathscr{E}} \cap \tilde{\mathscr{F}} = \langle \zeta, \min\{0.75, 0.6\}, \max\{0.1, 0.2\}, \max\{0.15, 0.1\} \rangle = \langle \zeta, 0.6, 0.2, 0.15 \rangle$$

3.5 Arithmetic Operations of Neutrosophic Numbers

In this section we will use $\tilde{\mathscr{P}}_1 = \left\langle \mu_{\tilde{\mathscr{P}}_1}(\zeta), \pi_{\tilde{\mathscr{P}}_1}(\zeta), \nu_{\tilde{\mathscr{P}}_1}(\zeta) \right\rangle$ instead of $\tilde{\mathscr{P}}_1 = \left\langle \zeta, \mu_{\tilde{\mathscr{P}}_1}(\zeta), \pi_{\tilde{\mathscr{P}}_1}(\zeta), \nu_{\tilde{\mathscr{P}}_1}(\zeta) \right\rangle$. Let $\tilde{\mathscr{P}}_1 = \left\langle \mu_{\tilde{\mathscr{P}}_1}(\zeta), \pi_{\tilde{\mathscr{P}}_1}(\zeta), \nu_{\tilde{\mathscr{P}}_1}(\zeta) \right\rangle$ and $\tilde{\mathscr{P}}_2 = \left\langle \mu_{\tilde{\mathscr{P}}_2}(\zeta), \pi_{\tilde{\mathscr{P}}_2}(\zeta), \nu_{\tilde{\mathscr{P}}_2}(\zeta) \right\rangle$ be two Neutrosophic Numbers (NNs) and $\kappa > 0$ be a scalar. Then the arithmetic operations on NNs are defined as follows:

(i) **Addition of NNs:**

$$\tilde{\mathscr{P}}_1 \oplus \tilde{\mathscr{P}}_2 = \left\langle \mu_{\tilde{\mathscr{P}}_1}(\zeta) + \mu_{\tilde{\mathscr{P}}_2}(\zeta) - \mu_{\tilde{\mathscr{P}}_1}(\zeta)\mu_{\tilde{\mathscr{P}}_2}(\zeta), \pi_{\tilde{\mathscr{P}}_1}(\zeta)\pi_{\tilde{\mathscr{P}}_2}(\zeta), \nu_{\tilde{\mathscr{P}}_1}(\zeta)\nu_{\tilde{\mathscr{P}}_2}(\zeta) \right\rangle \tag{7}$$

(ii) **Multiplication of NNs:**

$$\tilde{\mathscr{P}}_1 \otimes \tilde{\mathscr{P}}_2 = \left\langle \mu_{\tilde{\mathscr{P}}_1}(\zeta)\mu_{\tilde{\mathscr{P}}_2}(\zeta), \pi_{\tilde{\mathscr{P}}_1}(\zeta) + \pi_{\tilde{\mathscr{P}}_2}(\zeta) - \pi_{\tilde{\mathscr{P}}_1}(\zeta)\pi_{\tilde{\mathscr{P}}_2}(\zeta), \nu_{\tilde{\mathscr{P}}_1}(\zeta) + \nu_{\tilde{\mathscr{P}}_2}(\zeta) - \nu_{\tilde{\mathscr{P}}_1}(\zeta)\nu_{\tilde{\mathscr{P}}_2}(\zeta) \right\rangle \tag{8}$$

(iii) **Scalar Multiplication of NN:**

$$\kappa \odot \tilde{\mathscr{P}}_1 = \left\langle 1 - \left(1 - \mu_{\tilde{\mathscr{P}}_1}(\zeta)\right)^{\kappa}, (\pi_{\tilde{\mathscr{P}}_1}(\zeta))^{\kappa}, (\nu_{\tilde{\mathscr{P}}_1}(\zeta))^{\kappa} \right\rangle \tag{9}$$

(iv) **Scalar Power of NN:**

$$\tilde{\mathscr{P}}_1^{\kappa} = \left\langle (\mu_{\tilde{\mathscr{P}}_1}(\zeta))^{\kappa}, 1 - \left(1 - \pi_{\tilde{\mathscr{P}}_1}(\zeta)\right)^{\kappa}, 1 - \left(1 - \nu_{\tilde{\mathscr{P}}_1}(\zeta)\right)^{\kappa} \right\rangle \tag{10}$$

Example 4. *Let us consider two NNs namely,* $\mathscr{P}_1 =< 0.7, 0.05, 0.15 >$ *and* $\mathscr{P}_2 =< 0.5, 0.1, 0.2 >$. *Then,*

$$\tilde{\mathscr{P}}_1 \oplus \tilde{\mathscr{P}}_2 = \langle 0.7 + 0.5 - 0.35, 0.005, 0.03 \rangle = \langle 0.85, 0.005, 0.03 \rangle$$

$$\tilde{\mathscr{P}}_1 \otimes \tilde{\mathscr{P}}_2 = \langle 0.35, 0.05 + 0.1 - 0.005, 0.15 + 0.2 - 0.03 \rangle = \langle 0.35, 0.145, 0.32 \rangle$$

Let $\kappa = 2$ *then*

$$\kappa \odot \tilde{\mathscr{P}}_1 = \left\langle 1 - (1 - 0.7)^2, (0.05)^2, (0.15)^2 \right\rangle = \langle 0.91, 0.0025, 0.0225 \rangle = \langle 0.91, 0.003, 0.023 \rangle$$

Taking $\kappa = 2$ *we get,*

$$\tilde{\mathscr{P}}_1^{\kappa} = \left\langle (0.7)^2, 1 - (1 - 0.05)^2, 1 - (1 - 0.15)^2 \right\rangle = \langle 0.49, 0.0975, 0.2775 \rangle = \langle 0.49, 0.098, 0.278 \rangle$$

3.6 Score and Accuracy Function of Neutrosophic Number (NN):

In this paper, to compare neutrosophic numbers, we will apply the score function and accuracy functions. Different types of Score and Accuracy functions are defined in many research papers [51–53]. But here, we will propose a new Score and Accuracy function for NNs.

Consider a Neutrosophic Number (NN) $\tilde{\mathscr{P}} = \langle \mu_{\tilde{\mathscr{P}}}(\zeta), \pi_{\tilde{\mathscr{P}}}(\zeta), \nu_{\tilde{\mathscr{P}}}(\zeta) \rangle$.
Then the new Score function is defined as,

$$\mathscr{S}(\tilde{\mathscr{P}}) = \frac{(3 + \mu_{\tilde{\mathscr{P}}} - \pi_{\tilde{\mathscr{P}}} - 3\nu_{\tilde{\mathscr{P}}})(3 - \nu_{\tilde{\mathscr{P}}})(1 + \pi_{\tilde{\mathscr{P}}})}{6} \tag{11}$$

and the new Accuracy function is,

$$\mathcal{A}(\tilde{\mathscr{P}}) = (3 + \mu_{\tilde{\mathscr{P}}} - \pi_{\tilde{\mathscr{P}}} - 3\nu_{\tilde{\mathscr{P}}}) \tag{12}$$

3.6.1 Comparison of two Neutrosophic Numbers:

We can compare any two Neutrosophic numbers with the help of the Score function and Accuracy function. Let $\tilde{\mathscr{P}}_1$ and $\tilde{\mathscr{P}}_2$ be two Neutrosophic numbers. Then

(1)
$$\mathscr{S}(\tilde{\mathscr{P}}_1) < \mathscr{S}(\tilde{\mathscr{P}}_2) \Rightarrow \tilde{\mathscr{P}}_1 < \tilde{\mathscr{P}}_2 \tag{13}$$

(2)
$$\mathscr{S}(\tilde{\mathscr{P}}_1) > \mathscr{S}(\tilde{\mathscr{P}}_2) \Rightarrow \tilde{\mathscr{P}}_1 > \tilde{\mathscr{P}}_2 \tag{14}$$

(3)
$$\mathscr{S}(\tilde{\mathscr{P}}_1) = \mathscr{S}(\tilde{\mathscr{P}}_2) \tag{15}$$

then we will use the Accuracy function in following manner,

(i)
$$\mathcal{A}(\tilde{\mathscr{P}}_1) < \mathcal{A}(\tilde{\mathscr{P}}_2) \Rightarrow \tilde{\mathscr{P}}_1 < \tilde{\mathscr{P}}_2 \tag{16}$$

(ii)
$$\mathcal{A}(\tilde{\mathscr{P}}_1) > \mathcal{A}(\tilde{\mathscr{P}}_2) \Rightarrow \tilde{\mathscr{P}}_1 > \tilde{\mathscr{P}}_2 \tag{17}$$

(iii)
$$\mathcal{A}(\tilde{\mathscr{P}}_1) = \mathcal{A}(\tilde{\mathscr{P}}_2) \Rightarrow \tilde{\mathscr{P}}_1 = \tilde{\mathscr{P}}_2 \tag{18}$$

4. Proposed methodology

In this section, we will describe the methods we have taken for this study. In this paper, we have used two Multi criteria Decision Making (MCDM) methods, namely CRITIC and COPRAS. At first, we applied the Criteria Importance Through Inter-criteria Correlation (CRITIC) method, which is a particular type of MCDM method used for evaluating criteria weight. After that, we used the Complex Proportional Assessment (COPRAS) method for ranking the alternatives. The methodologies are discussed as follows:

4.1 Criteria Importance Through Inter-criteria Correlation (CRITIC) method

In 1995, the CRITIC Method was proposed by Diakoulaki et al. [54]. This method is very effective for finding criteria weight. This method focuses on two dimensions, such as variability and correlation of criteria. Here, one criterion is considered as important if it's value varies a lot and it is not similar to the other.

Here, we consider α number of criteria where every criteria $n\,(n = 1, 2, \ldots, \alpha)$ is associated with τ_n number of sub-criteria and there is γ number of alternatives chosen for ranking. q number of decision makers (DMs) provide their opinions based on these criteria and sub-criteria for ranking the alternatives. The procedure of the CRITIC method is given in a brief way through Figure 2 and is discussed in detail as follows:

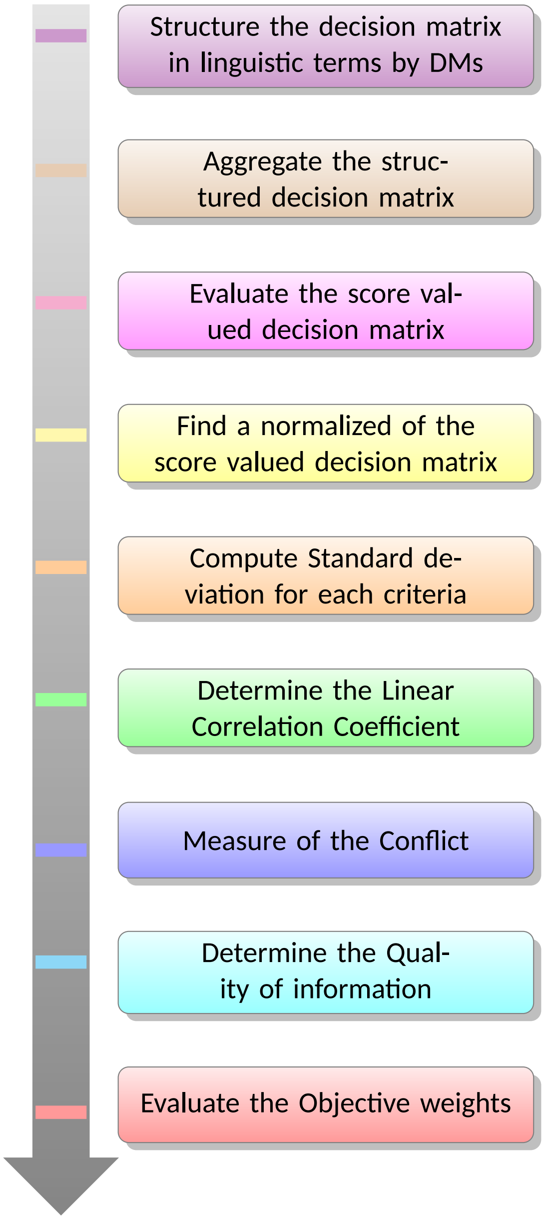

Fig. 2. Constructional framework of the CRITIC methodology

Step i. Decision Matrix Formulation:
At first, decision makers (DMs) provided their opinions in linguistic terms and further, it converted to Neutrosophic Number (NN) with the help of the conversation table described in the data selection section. The decision matrix formulated by ξ^{th} decision maker is denoted by $\tilde{\mathcal{D}}_\xi$ and represented as,

$$\tilde{\mathcal{D}}_\xi = \begin{bmatrix} \left(\tilde{\mathscr{P}}_{11}\right)_\xi & \left(\tilde{\mathscr{P}}_{12}\right)_\xi & \cdots & \left(\tilde{\mathscr{P}}_{1n}\right)_\xi & \cdots & \left(\tilde{\mathscr{P}}_{1\alpha}\right)_\xi \\ \left(\tilde{\mathscr{P}}_{21}\right)_\xi & \left(\tilde{\mathscr{P}}_{22}\right)_\xi & \cdots & \left(\tilde{\mathscr{P}}_{2n}\right)_\xi & \cdots & \left(\tilde{\mathscr{P}}_{2\alpha}\right)_\xi \\ \vdots & \vdots & \ddots & \vdots & \ddots & \vdots \\ \left(\tilde{\mathscr{P}}_{m1}\right)_\xi & \left(\tilde{\mathscr{P}}_{m2}\right)_\xi & \cdots & \left(\tilde{\mathscr{P}}_{mn}\right)_\xi & \cdots & \left(\tilde{\mathscr{P}}_{m\alpha}\right)_\xi \\ \vdots & \vdots & \ddots & \vdots & \ddots & \vdots \\ \left(\tilde{\mathscr{P}}_{\gamma 1}\right)_\xi & \left(\tilde{\mathscr{P}}_{\gamma 2}\right)_\xi & \cdots & \left(\tilde{\mathscr{P}}_{\gamma n}\right)_\xi & \cdots & \left(\tilde{\mathscr{P}}_{\gamma\alpha}\right)_\xi \end{bmatrix}_{\gamma\times\alpha} \tag{19}$$

i.e.,

$$\tilde{\mathcal{D}}_{\xi} = \left[\left(\tilde{\mathscr{P}}_{mn} \right)_{\xi} \right]_{\gamma \times \alpha} \tag{20}$$

where $n = 1, 2, \ldots, \alpha$, $m = 1, 2, \ldots, \gamma$ and $\xi = 1, 2, \ldots, q$. The input $\tilde{\mathscr{P}}_{mn}$ represents ξ^{th} decision maker's opinion about m^{th} alternative on the basis of n^{th} criteria. In a similar way, the decision matrix $(\tilde{\mathcal{D}}_{\xi}^{s_n})$ for sub-criteria of the criteria n where $n = 1, 2, \ldots, \alpha$ can be defined as follows:

$$\tilde{\mathcal{D}}_{\xi}^{s_n} = \begin{bmatrix} \left(\tilde{\mathscr{P}}_{11_n}\right)_{\xi} & \left(\tilde{\mathscr{P}}_{12_n}\right)_{\xi} & \ldots & \left(\tilde{\mathscr{P}}_{1s_n}\right)_{\xi} & \ldots & \left(\tilde{\mathscr{P}}_{1\tau_n}\right)_{\xi} \\ \left(\tilde{\mathscr{P}}_{21_n}\right)_{\xi} & \left(\tilde{\mathscr{P}}_{22_n}\right)_{\xi} & \ldots & \left(\tilde{\mathscr{P}}_{2s_n}\right)_{\xi} & \ldots & \left(\tilde{\mathscr{P}}_{2\tau_n}\right)_{\xi} \\ \vdots & \vdots & \ddots & \vdots & \ddots & \vdots \\ \left(\tilde{\mathscr{P}}_{m1_n}\right)_{\xi} & \left(\tilde{\mathscr{P}}_{m2_n}\right)_{\xi} & \ldots & \left(\tilde{\mathscr{P}}_{ms_n}\right)_{\xi} & \ldots & \left(\tilde{\mathscr{P}}_{m\tau_n}\right)_{\xi} \\ \vdots & \vdots & \ddots & \vdots & \ddots & \vdots \\ \left(\tilde{\mathscr{P}}_{\gamma1_n}\right)_{\xi} & \left(\tilde{\mathscr{P}}_{\gamma2_n}\right)_{\xi} & \ldots & \left(\tilde{\mathscr{P}}_{\gamma s_n}\right)_{\xi} & \ldots & \left(\tilde{\mathscr{P}}_{\gamma\tau_n}\right)_{\xi} \end{bmatrix}_{\gamma \times \tau_n} \tag{21}$$

i.e.,

$$\tilde{\mathcal{D}}_{\xi}^{s_n} = \left[\left(\tilde{\mathscr{P}}_{ms_n} \right)_{\xi} \right]_{\gamma \times \tau_n} \tag{22}$$

where $s_n = 1_n, 2_n, \ldots, \tau_n$ for the criteria n, $m = 1, 2, \ldots, \gamma$ and $\xi = 1, 2, \ldots, q$. The input $\tilde{\mathscr{P}}_{ms_n}$ represents ξ^{th} decision maker's opinion about m^{th} alternative on the basis of ${s_n}^{th}$ criteria and it given as

$$\left(\tilde{\mathscr{P}}_{ms_n} \right)_{\xi} = \left\{ \left(\mu_{\tilde{\mathscr{P}}_{ms_n}} \right)_{\xi}, \left(\pi_{\tilde{\mathscr{P}}_{ms_n}} \right)_{\xi}, \left(\nu_{\tilde{\mathscr{P}}_{ms_n}} \right)_{\xi} \right\} \tag{23}$$

Steo ii. Aggregating the Decisions Matrices:

Total q numbers of Decision Matrices are aggregated to obtain a single decision matrix by using the following equation,

$$\begin{aligned} \tilde{\mathscr{P}}_{mn} &= \left\{ \mu_{\tilde{\mathscr{P}}_{mn}}, \pi_{\tilde{\mathscr{P}}_{mn}}, \nu_{\tilde{\mathscr{P}}_{mn}} \right\} \\ &= \left\{ \min_{\xi=1,2,\ldots,q} \left(\mu_{\tilde{\mathscr{P}}_{mn}}\right)_{\xi}, \max_{\xi=1,2,\ldots,q} \left(\pi_{\tilde{\mathscr{P}}_{mn}}\right)_{\xi}, \max_{\xi=1,2,\ldots,q} \left(\nu_{\tilde{\mathscr{P}}_{mn}}\right)_{\xi} \right\} \end{aligned} \tag{24}$$

Then the Aggregated Decision Matrix $(\tilde{\mathcal{D}}^{\mathcal{A}})$ is of the form,

$$\tilde{\mathcal{D}}^{\mathcal{A}} = \left[\tilde{\mathscr{P}}_{mn} \right]_{\gamma \times \alpha} \tag{25}$$

where

$$\tilde{\mathscr{P}}_{mn} = \left\{ \mu_{\tilde{\mathscr{P}}_{mn}}, \pi_{\tilde{\mathscr{P}}_{mn}}, \nu_{\tilde{\mathscr{P}}_{mn}} \right\}$$

is an aggregated NN and $m = 1, 2, \ldots, \gamma$ and $n = 1, 2, \ldots, \alpha$. Only the decision matrix for the criteria is considered for further numerical calculations. The same type of calculation will be applied to finding the sub-criteria weight.

Step iii. Score Valued Decision Matrix Formulation:

Neutrosophic Numbers(NNs) are converted to crisp numbers by using the Score function and so the Score Valued Decision Matrix $(\tilde{\mathcal{D}}_{\mathcal{S}})$ is formulated as follows:

$$\mathcal{D}_{\mathcal{S}} = \left[\mathscr{P}_{mn} \right]_{\gamma \times \alpha} \tag{26}$$

where $\mathscr{P}_{mn}$ is the Score value corresponding to the NN $\tilde{\mathscr{P}}_{mn}$ and it evaluated by Equation (11).

Step iv. Normalization of the Score Valued Decision Matrix:
The Normalized Decision Matrix $(\mathcal{D}_{\mathcal{N}})$ is constructed from the Score Valued Decision Matrix $(\mathcal{D}_{\mathcal{S}})$ by using the following formula,

$$\mathscr{P}'_{mn} = \frac{\mathscr{P}_{mn} - \mathscr{P}_n^{worst}}{\mathscr{P}_n^{best} - \mathscr{P}_n^{worst}} \tag{27}$$

where

$$\begin{cases} \mathscr{P}_n^{best} = \max\limits_{m=1,2,\ldots,\gamma} \mathscr{P}_{mn} \\ \mathscr{P}_n^{worst} = \min\limits_{m=1,2,\ldots,\gamma} \mathscr{P}_{mn} \end{cases}$$

Step v. Calculating Standard deviation (σ_n) for each criteria:
For calculating the standard deviation σ_n of each criterion, the following formula is used,

$$\sigma_n = \sqrt{\frac{\sum\limits_{n=1}^{\alpha} \left(\mathscr{P}_n - \bar{\mathscr{P}}_n\right)}{\alpha - 1}} \tag{28}$$

where $\bar{\mathscr{P}}_n$ represents the population mean, α is the size of the population (i.e., number of criteria) and $n = 1, 2, \ldots, \alpha$.

Step vi. Finding the Linear Correlation Coefficient $(\theta_{nn'})$ between the criteria c_n and criteria $c_{n'}$:
Here, we will construct the $\alpha \times \alpha$ symmetric matrix with elements $\mathscr{P}'_{mn}$, which is the Linear Correlation Coefficient between the vectors $\mathscr{P}_n$ and $\mathscr{P}'_n$ and Correlation Coefficient between the criteria c_n and $c_{n'}$ which is denoted by $\theta_{nn'}$.

Step vii. Measure of the Conflict $(\mathcal{P}_n)$ created by the criteria:
The measure of the conflict $(\mathcal{P}_n)$ created by the criterion n with respect to the decision situation defined by the remaining criteria is calculated by using the following formula,

$$\mathcal{P}_n = \sum_{n'=1}^{\alpha} (1 - \theta_{nn'}) \tag{29}$$

Step viii. Determining the Quality of information (Q_n):
We determine the quality of the information (Q_n) in relation to each criteria by applying the formula given as,

$$Q_n = \sigma_n \times \mathcal{P}_n \tag{30}$$

where criteria $n = 1, 2, \ldots, \alpha$.

Step ix. Determining the Objective weights $(\mathscr{W}_n^{lw})$
The weight of n^{th} criteria is denoted by $\mathscr{W}_n^{lw}$ and defined as,

$$\mathscr{W}_n^{lw} = \frac{Q_n}{\sum_{n=1}^{\alpha} Q_n} \tag{31}$$

Thus we can evaluate the weight of each criterion for $n = 1, 2, \ldots, \alpha$.
Using the above equation we can determine the local weight of the criteria $(\mathscr{W}_n^{lw})$ for $n = 1, 2, \ldots, \alpha$ and local weight of the sub-criteria $(\mathscr{W}_{s_n}^{lw})$ for $s_n = 1_n, 2_n, \ldots, \tau_n$ respectively. After

that we will determine the global weight of the criteria $(\mathscr{W}_n^{gw})$ and global weight of the sub-criteria $(\mathscr{W}_{s_n}^{gw})$ as follows:

$$\mathscr{W}_{s_n}^{gw} = \mathscr{W}_n^{lw} \times \mathscr{W}_{s_n}^{lw} \tag{32}$$

and

$$\mathscr{W}_n^{gw} = \sum_{s_n=1}^{\tau_n} \mathscr{W}_{s_n}^{gw} \tag{33}$$

where $n = 1, 2, \ldots, \alpha$ and $s_n = 1_n, 2_n, \ldots, \tau_n$.

4.1.1 Advantages of taking CRITIC method:

There are many advantages of using the CRITIC method as an MCDM technique, such that:

1. This method is fair and unbiased, relying on the data set for calculating the weight.
2. In this method, some basic operations like standard deviation and correlation are performed, which makes this method easy to understand.
3. This method can be customized to fit the individual's specific needs due to its flexibility.

4.1.2 Disadvantages of taking CRITIC method:

Despite the various benefits of the CRITIC method, there are some drawbacks to using this method like,

1. This method takes a lot of time to collect and analyse the incidents, which makes it time consuming.
2. This method is very sensitive to the quality of data, which means from this method, we may get inaccurate results if the input data is biased or incomplete.
3. This method will become complicated when a large number of criteria are considered.

4.2 Complex Proportional Assessment (COPRAS) method

The Complex Proportional Assessment (COPRAS) method is a very useful MCDM technique. It is used for ranking the alternatives.

Let there be α number of criteria and each criteria $n\,(n = 1, 2, \ldots, \alpha)$ have τ_n number of sub-criteria. There is q number of decision makers (DMs) who purvey their decisions depending on that γ number of alternatives are ranked. The steps of the COPRAS method are described in Figure 3 and discussed as follows,

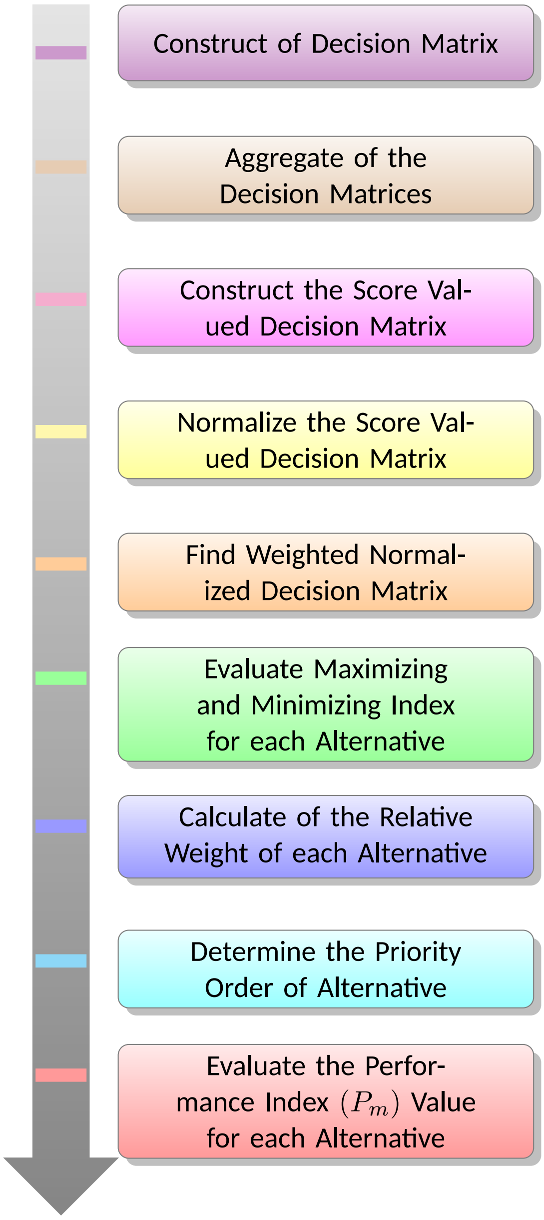

Fig. 3. Structure process of the COPRAS methodology

Step A. Construction of Decision Matrix:
The formation of decision matrix $\tilde{\mathcal{D}}_\xi$ by the ξ^{th} decision maker is the same as the Step i. of CRITIC method.

Step B. Aggregation of the Decision Matrices:
The Aggregated Decision Matrix $(\tilde{\mathcal{D}}^{\mathcal{A}})$ is formulated from q numbers of Decision Matrices in a similar way as mentioned in Step ii. of the CRITIC method.

Step C. Construction of Score Valued Decision Matrix:
The construction of Score Valued Decision Matrix $(\mathcal{D}_S)$ is the same as discussed in Step iii. of the CRITIC method.

Step D. Normalization of the Score Valued Decision Matrix:

Normalized Score Valued Decision Matrix $(\mathcal{D}^{\mathscr{N}})$ is formed by using the following equation,

$$P'_{mn} = \frac{\mathscr{P}_{mn}}{\sum_{m=1}^{\gamma} \mathscr{P}_{mn}} \tag{34}$$

where $\mathscr{P}_{mn}$ is the m^{th} alternative's performance with respect to n^{th} criteria, P'_{mn} is the corresponding normalized value and γ is the number of alternatives.

Step E. Finding Weighted Normalized Decision Matrix:
The Weighted Normalized Decision Matrix is denoted by $(\mathcal{D}_{\omega})$ and defined as,

$$\mathcal{D}_{\omega} = [d_{mn}]_{\gamma \times \alpha} \tag{35}$$

where each element d_{mn} is evaluated from the formula,

$$d_{mn} = P'_{mn} \times \mathscr{W}_n^w \tag{36}$$

Here, $\mathscr{W}_n^w$ is the weight of the n^{th} criteria.

Step F. Evaluating Maximizing and Minimizing Index for each Alternative:
In this step, every alternative is categorized as maximizing index and minimizing index. For this purpose, the following formulae are used,

$$\mathcal{S}_{m+} = \sum_{n=1}^{\kappa} d_{mn}, n = 1, 2, ..., \kappa, \text{maximizing index.} \tag{37}$$

$$\mathcal{S}_{m-} = \sum_{n=\kappa+1}^{\alpha} d_{mn}, n = \kappa+1, \kappa+2, ..., \alpha, \text{minimizing index.} \tag{38}$$

Step G. Calculation of the Relative Weight of each Alternative:
The relative weight of m^{th} alternative is denoted by $\mathscr{Q}_m$ and defined as,

$$\mathscr{Q}_m = \mathcal{S}_{m+} + \frac{\min_m \mathcal{S}_{m-} \sum_{m=1}^{\gamma} \mathcal{S}_{m-}}{\mathcal{S}_{m-} \sum_{m=1}^{\gamma} \frac{\min_m \mathcal{S}_{m-}}{\mathcal{S}_{m-}}} \tag{39}$$

Step H. Determining the Priority Order of Alternative:
Depending upon the relative weight, the priority order of alternatives is determined. The alternative consisting of higher relative weight $\mathscr{Q}_m$ has higher priority; that is, it possesses higher rank and the alternative having highest relative weight $\mathscr{Q}_m$ can be considered as the most acceptable alternative.

$$A^* = \{A_m : \max_m \mathscr{Q}_m\} \tag{40}$$

Step I. Evaluating the Performance Index (P_m) Value for each Alternative:
The Performance Index (P_m) Value for each alternative is evaluated by using the formula,

$$P_m = \frac{\mathscr{Q}_m}{\mathscr{Q}_{\max}} \times 100 \tag{41}$$

An alternative is considered the best one if its degree is 100 and a ranking of alternatives is performed from large to small.

4.3 Advantages of using COPRAS method:

There are various advantages of using the COPRAS method as an MCDM method like,

(i) COPRAS method provides a clear idea about how each criterion affects the final ranking of alternatives by evaluating the impact of beneficial and non-beneficial criteria.

(ii) In the COPRAS method, some simple arithmetic calculations are used. Thus, there is no need to use iterative methods, specialized software or complex mathematical modelling.

(iii) COPRAS method produces an objective framework to compare alternatives by including the proportional relationships among criteria values.

4.4 Disadvantages of using COPRAS method:

In spite of the various benefits of using the COPRAS method, there are some disadvantages of using the COPRAS method like,

(i) COPRAS method strongly depends on the normalization of the method. So, in this method, the result can be influenced if any inappropriate normalization techniques are used.

(ii) COPRAS method highly relies on the criteria weight. So, if the weight corresponding to each criterion is not accurately measured, then the ranking might not be correct.

(iii) In real life situations, some criteria may influence each other. But, in the COPRAS method, it is considered that all criteria are independent. So, it will be difficult to apply the COPRAS method to many real world problems.

5. Criteria Selection

Schools are an important part of the educational system. Choosing a place to build a school is very difficult work. There are many criteria which may have an impact on this site selection process. Here, we have considered the 6 criterion and the total 19 sub-criteria associated with those criteria. In this section, we will briefly discuss these criteria and sub-criteria.

5.1 Location and Accessibility $(\mathscr{E}_1)$:

Location and accessibility is the key identification to select the site for a new school. The location ensures the popularity of schools in the surrounding areas. Students from dense localities can be interested in a nearby school, whereas employees from out of the city can easily get flats for rent. A well connected road provides a smooth and efficient traveling experience for both the students and staff with cost affordability. With a smooth transportation system, students from long distances will come to school easily by bus, train and even auto. Proper location and accessibility provide efficient connectivity and ensure safety for students and staffs. Here, Public transportation access, Proximity to residential areas and Road connectivity are taken as the sub-criteria of this criterion. For more details: [55–57].

5.1.1 Public Transportation Access $(\mathscr{E}_{1A})$:

Access to the public transportation system is one of the most important sub-criteria of Location and Accessibility $(\mathscr{E}_1)$ for the selection of a school site. It confirms the daily journey of students, teaching and non-teaching staff with all convenient and cost-effectiveness. The site of the school must be connected to nearby stations, bus stop and local vehicles like auto and toto. With good connectivity, students, teachers and staff come with affordability. Good connectivity will also reduce the travel by foot for students ensuring more safety. For more details: [12, 58].

5.1.2 Proximity to Residential Areas $(\mathscr{E}_{1B})$:

Proximity to residential areas is one of the vital sub-criteria of Location and Accessibility $(\mathscr{E}_1)$ for selecting a site for a new school. A location closer to good residential surroundings confirms the availability of students. The school will immediately attract students from nearby areas to get admission. The surrounding neighborhoods will maximize the attendance of all students. A well-mannered neighborhood will promote the activity and participation of students in all cultural and social events. For more details, one can go through the papers: [14, 59].

5.1.3 Road Connectivity $(\mathscr{E}_{1C})$:

Road connectivity is one of the main sub-criteria of the criteria Location and Accessibility $(\mathscr{E}_1)$ for school site selection. To ensure safer journeys and effective access, good road connectivity is a major component. The site of the school must be well connected to all the roads of different roots. With good connectivity, students and staff can come to school with a minimum travel time and least hindrance. The roads must be on flat topography for flexible traveling and the service roads should be safe enough for students coming with cycles. The smooth daily commuting status will encourage more parents to admit their students to the school. For more details: [6, 11].

5.2 Environmental Factors$(\mathscr{E}_2)$:

Environmental factors will have a direct and indirect impact on the health of all students and staffs. An atmosphere of fresh air brings a comfortable environment in the school. With poor air quality, there are possibilities of multiple fatal diseases like lung cancer, asthma and many types of respiratory infections. Not only air but also the quality of water affects the health of all in various way. Due to dirty water, many waterborne diseases such as amoebiasis, giardia, cholera, etc. may take place. So, a good source of portable water is needed near the school. Along with all these, the school must be located in a place free from all possible noise. Heavy traffic on roads and factories should not be in the surrounding areas of the school. A fruitful class can never be conducted in a noisy environment. So, all these environmental factors will directly impact the health of students and staff and the overall performance of the school. For more details: [60–62].

5.2.1 Air Quality $(\mathscr{E}_{2A})$:

Air quality is one of the major sub-criteria of the criteria Environmental Factors$(\mathscr{E}_2)$ for selecting the school site. Clean air is very important for all students, along with all faculties, to have good health. There should be no factories near the school. The school site should avoid highly congested city traffic. Bad air quality will degrade the health of everyone, causing allergies and lung diseases. With good air quality on school site, the attendance and performance of the students will be enhanced. For more details: [5, 63–65].

5.2.2 Water Quality $(\mathscr{E}_{2B})$:

Water quality is one of the important sub-criteria of the criteria Environmental Factors$(\mathscr{E}_2)$ for selecting the school site. Just like air, the quality of water also impacts heavily the health of students, teachers and all stuffs. Drinking water is an unavoidable need that cannot be compromised in any way. There must be a well-maintained source of potable water which should be free from heavy metals, bacteria and harmful chemicals. Impure water will cause various diseases and affect the integrity of the school. With a good water quality on school site, the attendance and performance of the students will be increased. For more details: [66–69].

5.2.3 Noise Levels $(\mathscr{E}_{2C})$:

Noise levels is one of the vital sub-criteria of the criteria Environmental Factors$(\mathscr{E}_2)$ for selecting the school site. To maintain a good learning environment, a peaceful place is required in the school site. A place with high noise will disrupt the learning environment. A teacher cannot teach properly in a noisy surrounding and it is impossible for students to pay attention in that environment. So, the school site must be away from heavy traffic and core industrial. A peaceful environment with a well-maintained noise level will enhance the overall performance of the school. For more details: [70, 71].

5.3 Infrastructure and Utilities $(\mathscr{E}_3)$:

To maintain a well equipped, innovative school, the necessity of good infrastructure and requirement of utilities are irreplaceable. A proper supply of portable water will fulfill the requirement of drinking, sanitation and cleaning. In addition to a good water supply, the connection to an electric supply is crucial for the school. It will provide support for ventilation, running computer labs, proper light and visibility in classrooms, and many more. A proper system for sewage and drainage is also important to flush away dirty water. It will keep the surroundings neat and clean, providing safety from unwanted diseases. Moreover, a good connection to the internet will provide a modern day learning environment for the students with good access to technological support. For more details: [61, 72, 73].

5.3.1 Water Supply $(\mathscr{E}_{3A})$:

Water supply is one of the important sub-criteria of Infrastructure and Utilities $(\mathscr{E}_3)$. A dependable and satisfactory supply of water is crucial for the position selection of any academic institution to guarantee the daily health, hygiene and activities of the students and employees. Purified and safe water must be provided for drinking and sanitation. A proper source of water will help in sustainable accommodations such as common rooms, canteens and laboratories. In addition to that, activation of storage of water and systems for water treatment to look upon the quality and potential shortages is also needed. For more details: [74, 75].

5.3.2 Electricity Supply $(\mathscr{E}_{3B})$:

Electricity supply can be considered as a vital sub-criteria of Infrastructure and Utilities $(\mathscr{E}_3)$. An incessant source of electricity is important for the proper maintenance of classrooms, offices and necessary gadgets for a modern school. The position needs to be connected to a reliable grid of electricity to provide power for light, cooling system, heating and air passage. Sufficient electricity is important for maintaining different technological resources, such as laboratories of computers or different audiovisual classes. Power storage systems, such as solar panels or generators, must be counted on to ensure the stability of electricity during outages. For more details: [76, 77].

5.3.3 Sewage and Drainage $(\mathscr{E}_{3C})$:

Sewage and drainage is also a sub-criteria of Infrastructure and Utilities $(\mathscr{E}_3)$. A properly executed sewage and drainage system is obligatory for the continuance of cleanliness and restricting the logging of water at the site of the school. The location must have proper dumping of the waste water that is connected to the sewage system of the municipality of septic system installation. Proper infrastructure is crucial to restrict the flow of water during heavy rains to certify the safety and serviceability of spaces outside, such as sports fields or playgrounds. Acquiescence with the local environment protocol is necessary in order to dodge contamination and influence sustainable development. For more details: [78–80].

5.3.4 Internet and Telecommunication $(\mathscr{E}_{3D})$:

Internet and telecommunication is one of the main sub-criteria of Infrastructure and Utilities $(\mathscr{E}_3)$. Accessible telecommunications and the Internet are necessary for a modern schooling system to ensure both educational and administrative activities. The position needs to have high-speed internet that provides a seamless technological integration in the knowledge gaining process. Adequate internet networks are similarly important for active communication between parents, schools and the community in a broader aspect and during emergencies, it will ensure coordination and safety. For more details: [81–83].

5.4 Security and Safety $(\mathscr{E}_4)$:

The students can study efficiently whenever the students feel safe inside the school. Moreover, parents would not want to send their children to any unsafe environment. The local crime rates play a crucial role as the safety of every student, along with the safety of all teaching and non-teaching staff is concerned. So, conducting research on local crime statistics is very important. To maintain safety inside the school, proper CCTV cameras and alarm systems are necessary with some hired security executives. Unauthorized access can be completely controlled using all these equipment and security personnel. While taking measures for safety, catching fire in school is also a vital concern. We cannot risk the life of any student or even any employee of the school. There should be multiple exit doors in each building. A considerable amount of fire extinguishers should be present on each floor. Special fire controlling systems should be applied to all the laboratories and libraries. For more details: [84–86].

5.4.1 Local Crime Rates $(\mathscr{E}_{4A})$:

The local crime rate is an essential sub-criteria of Security and Safety $(\mathscr{E}_4)$ for the site selection of a school. Evolving with knowledge can only be possible by setting the location in a low crime area. Student and staff enrollment can be decreased in case the location is settled in a crime prone area. On the other hand, it will also increase the necessity for increasing security within the campus. The suitability of the location can be determined by assessing the statistics of local crime and agencies of law enforcement need to be consulted for ensuring the students of the community a safe environment. For more details: [87–89].

5.4.2 Systems Surveillance $(\mathscr{E}_{4B})$:

Systems surveillance is an important sub-criteria of Security and Safety $(\mathscr{E}_4)$. Proper planning of the security of a school can be amplified to ensure safety. The location must support the activation of an advanced system of surveillance, which includes CCTV cameras, alarm systems and motion detectors, in order to monitor and safeguard the campus. This is important, especially for an enlarged or more isolated position. Unauthorized access and crime can be detected through effective surveillance and quick reactions to emergencies can be allowed. For more details: [90–92].

5.4.3 Fire Safety $(\mathscr{E}_{4C})$:

Fire safety is one of the main sub-criteria of the criteria Security and Safety $(\mathscr{E}_4)$. Fire safety is a non-passable perspective for choosing the place for an academy to secure the property as well as the lives. The site that is chosen must comply with the regulations and codes of fire safety with appropriate space for the installation of the sprinkler systems, extinguishers and fire alarms. Accessible fire trucks and emergency responders are much more crucial, multiple exits are to be allowed for safe evacuation. Propinquity to the fire station adds an extra point that certifies a quick response in the time of emergencies. The well-being of the occupants can be prioritized through a secure environment by planning the fire safety of a school. For more details: [93–95].

5.5 Site Area and Budget $(\mathscr{E}_5)$:

The primary and arguably the most important thing for a school is the land, i.e. the site area where the school is planned to be built. A school requires a significant amount of land area so that all necessary classrooms, music room, dance room, art room, computer laboratory, science laboratory, games room, teachers' rooms etc. can be situated comfortably within it. Along with the land area, the cost of the land also puts a huge significance as the development cost will be limited up to some extend. A large area will automatically increase the cost, so we have to choose a place which is significantly large in size as well as falls under the cost limitations of the budget associated with the construction. To control sustainability, the maintenance charge must need to be taken care. A lot of money will be needed for utilities, securities, manageable costs, repairing electrical and electronics items, etc. Choosing a site with comparatively low maintenance costs will allow the school to bring more advanced items and utilities for teaching the students. For more details: [96–98].

5.5.1 Area of Site $(\mathscr{E}_{5A})$:

Area of site is an important sub-criteria of the criteria Site Area and Budget $(\mathscr{E}_5)$. The current and future needs can be determined by the capacity to accommodate by considering the location of the school. The location should be spacious enough to fit in the building for academic requirements, playgrounds, parking areas, and areas for extracurricular activities. The future expansion in order to meet the demands for an increasing number of students or changes in curriculum. Building codes and standards of safety can be fostered to conduct holistic learning. For more details: [99, 100].

5.5.2 Cost of Land $(\mathscr{E}_{5B})$:

Cost of land is a vital sub-criteria of the criteria Site Area and Budget $(\mathscr{E}_5)$ for school site selection. The land's cost is a pivotal factor to be determined for the project of the school. The locational advantages along with better value for money and balancing affordability, are the required necessities for a land. A site that is cost effective must allow resource allocation to other major areas including educational activities and development in infrastructure. In contrast, land with low cost must have security, compliance accessibility and regulatory requirements. For more details: [11, 101].

5.5.3 Maintenance Charge $(\mathscr{E}_{5C})$:

In the process of school site selection Maintenance Charge is a vital sub-criteria of the criteria Site Area and Budget $(\mathscr{E}_5)$. The charges that are associated with maintenance play an important role in ensuring sustainability. Manageable costs, landscaping, utilities, securities and infrastructure repairs need to be taken care of. Choosing a site with low exposure to punitive surroundings to lower the maintenance expenditure. Decrease the ongoing charges to certify increased funds for resources of education and initiatives that are basically focused on students. For more details: [102–105].

5.6 Legal and Administrative Compliance $(\mathscr{E}_6)$:

Along with the structure of the building, the legal structure is also very crucial. The school should be compiled with all the zoning laws of that particular region. The selected location should be legally available for constructing any educational institute. Apart from land use zoning laws, Govt. approval is a major concern for constructing the school building. The approvals of local municipal officers, educational higher authorities, and other government officials are necessary to validate the school. Moreover, we have to look for the ownership status. The land should be free from any pending dues. Verification of the legal documentations should be done to avoid future potential problems. For more details: [106–108].

5.6.1 Land Use Zoning $(\mathscr{E}_{6A})$:

Land use zoning is an important sub-criteria of the criteria Legal and Administrative Compliance $(\mathscr{E}_6)$ for school site selection. One of the most crucial components for selecting a school site is Land Use Zoning, as it certifies that the location is assembled with local laws of zoning that ensure the agreement of land development. The designated location must be approved for institutes and the development of educational buildings. This will certify that the process of making school will not face any legal consequences and primarily avoid legal hindrances. Compiling with zoning laws stops the disagreements with suburban struggles. For more details: [109–111].

5.6.2 Government Approvals $(\mathscr{E}_{6B})$:

Government approvals is a vital sub-criteria of the criteria Legal and Administrative Compliance $(\mathscr{E}_6)$ for school site selection. Getting government approval is very important for the efficacious founding of the educational institute. This contains validation from local municipal officers, educational higher authorities, and different regulating bodies to certify the approval of planned projects for initializing a new school. The site should comply with all legal regulations like proximity to construction rules, pollution norms, natural disaster sensitivity and many more. Government approval minimizes all the unwanted hindrances towards the legal customs and accelerates the proceeding. For more details: [112–114].

5.6.3 Ownership Status $(\mathscr{E}_{6C})$:

For school site selection Ownership status is one of the main sub-criteria of the criteria Legal and Administrative Compliance $(\mathscr{E}_6)$. Legal disputes in future can be avoided through a few basic considerations. It is important to certify that the title of the location is clean and the property is free from any pending litigation, encumbrances and liens. In case the land is leased, the conditions need to be evaluated carefully to ensure alignment with the school's long-term goals. Verification in legalities and documentation of safeguarding the ownership and unrestricted growth and school operations. For more details: [14, 115–117].

6. Alternative Selection for School Sites

In this paper, we want to form a model to select a place in Paschim Bardhaman for establishing a new school. For this purpose, we have considered some criteria and sub-criteria, which are discussed in Section 5. Here, we have selected five places of Paschim Bardhaman, namely Durgapur, Raniganj, Asansol, Jamuria and Pandaveswar as alternatives. The geographical location of selected places is shown in Figure 4 and the Latitude and Longitude of the selected locations are also mentioned in Table 5. A brief description of the places is given as follows,

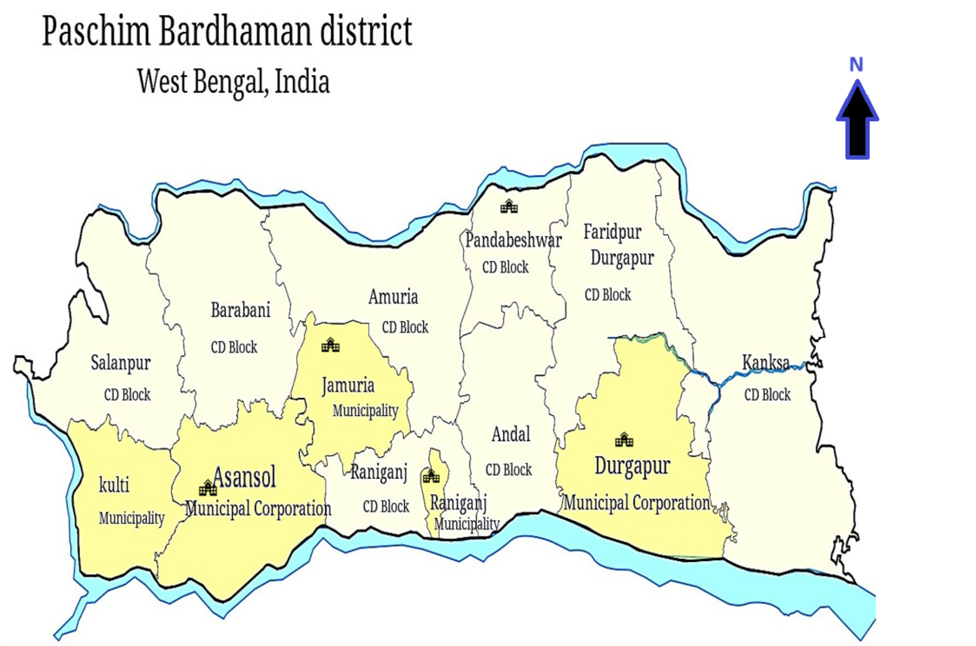

Fig. 4. Geographical position of school location of the proposed sites

Table 5
Suggested sites and their details for school location selection

School site	Latitude	Longitude
Durgapur $(\mathscr{Y}_1)$	$23°32'31''N$	$87°15'26''E$
Raniganj $(\mathscr{Y}_2)$	$23°38'19''N$	$87°04'51''E$
Asansol $(\mathscr{Y}_3)$	$23°41'31''N$	$86°52'35''E$
Jamuria $(\mathscr{Y}_4)$	$23°46'42''N$	$86°58'53''E$
Pandaveswar $(\mathscr{Y}_5)$	$23°43'01''N$	$87°16'49''E$

(i) Durgapur $(\mathscr{Y}_1)$: In West Bengal, Durgapur is known as the 'Steel City' due to multiple industrial hubs with fantastic connectivity both via roads and railways. The infrastructure of Durgapur is highly developed, with the presence of many hospitals, factories, residencies, shopping malls, etc, resulting in this city as a central location for constructing a new school. Furthermore, multiple available plots and a superior learning environment appeal to its spot for constructing a new school.

(ii) Raniganj$(\mathscr{Y}_2)$: Raniganj is the city of coal mines. Having a crowded population, different localities have a mix of urban and semi-urban populations, requiring a school for students of various cultures. Constructing a school near the National Highway could be a strategic decision, enhancing the reachability. However, we have to avoid mining areas when choosing the site, considering the safety measures of students and teachers.

(iii) Asansol $(\mathscr{Y}_3)$: Being the second largest city in West Bengal, Asansol is an industrial and financial hub. It provides fine connections with surrounding areas both by road and railways. Having financial affordability and a high qualification rate makes it a suitable choice for constructing the new school. Asansol provides a highly considerable foundation for an efficient educational environment.

(iv) Jamuria $(\mathscr{Y}_4)$: Jamuria is a semi urban town with some major mining locations. It has a mix of urban and rural properties. The increasing number of residential apartments and enlarging economic situations set a valuable significance for constructing a new school over here. But, mining areas could be a potential hindrance in some locations. However, the inexpensiveness shows a good perspective for the potential future of the site.

(v) Pandaveswar $(\mathscr{Y}_5)$: Pandaveswar is mainly famous due to the presence of coalfields inside it. The town is an evolving area with a good requirement for educational institutions. The location is connected well with surrounding cities, securing good approachability for students as well as staff. Being a semi-urban site, the locality offers affordability, taking account of the future urbanization providing supportable growth.

7. Model structured

There are six criteria and several sub-criteria considered for the school site selection in the Paschim Bardhaman district, West Bengal, India. Elaborate discussion on the important criteria and their sub-criteria are described in Section 5. Also, five different sites are taken as alternatives which are discussed in Section 6. The graphical structure of this work is represented in Figure 5. And, from the above criteria and alternatives, there are 5×6, 5×3, 5×3, 5×4, 5×3, 5×3 and 5×3 order decision matrix formulate. In this problem for collecting the data set we have considered two unbiased, experienced decision experts. They are,

DM1: A senior government officer who works in the education department.

DM2: An educational policy maker with more than 15 years of experience.

8. Data collection

Data are collected from the DMs in Linguistic terms and further converted into Neutrosophic Numbers (NNs) using Table 6. The decision matrix formed by using opinions of DMs between criteria and alternatives is shown in Table 7. The decision matrix between sub-criteria of the criteria Location and Accessibility $(\mathscr{E}_1)$ and alternatives are displayed in Table 8. The decision matrix between sub-criteria of the criteria Environmental Factors $(\mathscr{E}_2)$ and alternatives is illustrated in Table 9. The decision matrix

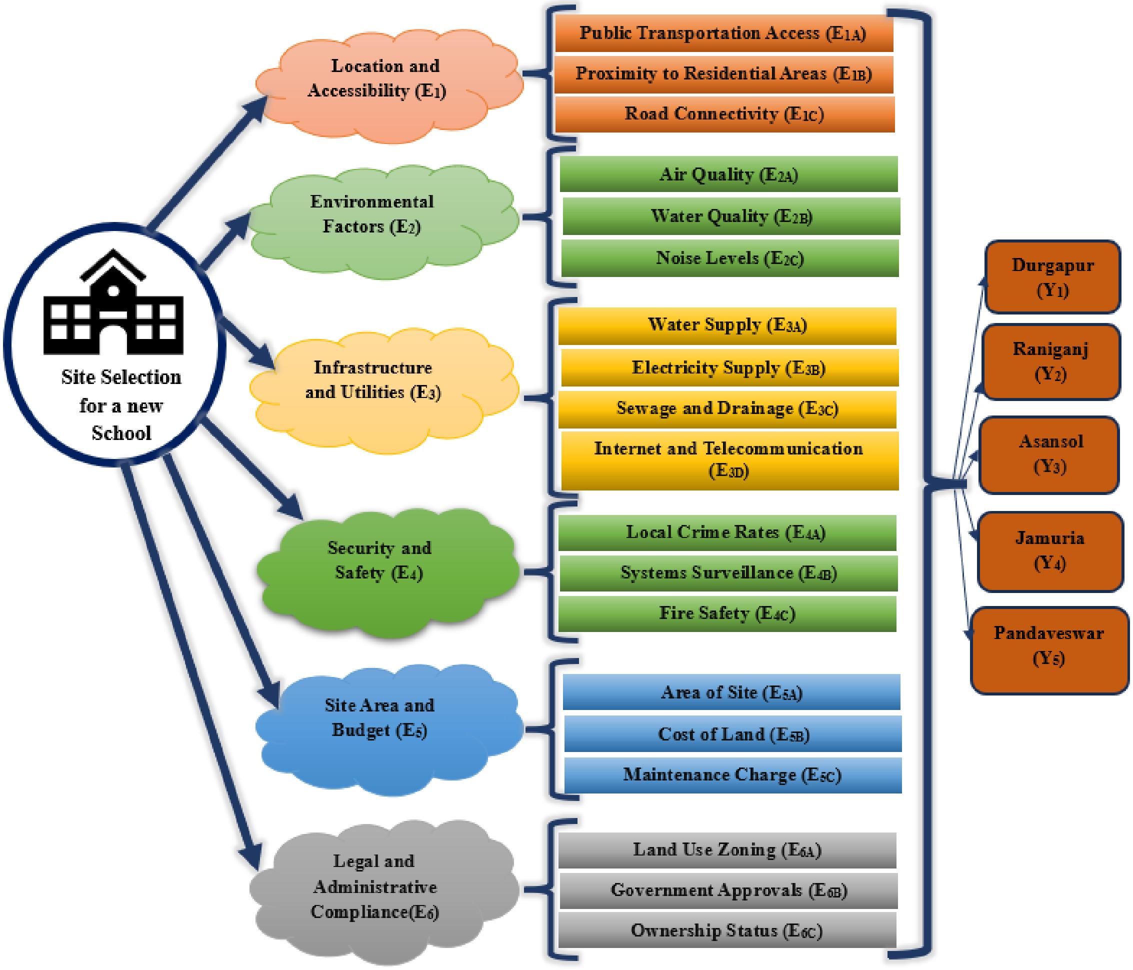

Fig. 5. Structural flowchart of the suggested model

between sub-criteria of the criteria Infrastructure and Utilities $(\mathscr{E}_3)$ and alternatives is provided in Table 10. Table 11 represents the decision matrix between the Sub-criteria corresponding to the criteria Security and Safety $(\mathscr{E}_4)$ and alternatives. Table 12 illustrates the decision matrix between sub-criteria of the criteria Site Area and Budget $(\mathscr{E}_5)$ and alternatives. The decision matrix between sub-criteria of the criteria Legal and Administrative Compliance $(\mathscr{E}_6)$ and alternatives are shown in Table 13.

Table 6
Comparison table between linguistic terms and the NNs

Linguistic Terms	Neutrosophic numbers (NNs)	Score Value	Accuracy Value
Absolutely Vital (AV)	$\{0.90, 0.05, 0.10\}$	1.8	3.55
Strongly Vital (SV)	$\{0.85, 0.10, 0.15\}$	1.7	3.30
Very Vital (VV)	$\{0.80, 0.15, 0.20\}$	1.6	3.05
Equally Vital (EV)	$\{0.75, 0.20, 0.25\}$	1.5	2.80
Weakly Vital (WV)	$\{0.70, 0.25, 0.30\}$	1.4	2.55
Low Vital (LV)	$\{0.65, 0.30, 0.35\}$	1.3	2.30
Poorly Vital (PV)	$\{0.60, 0.35, 0.40\}$	1.2	2.05

Table 7
Decision matrix in linguistic terms given by two DMs

	Criteria vs Alternatives	$\mathscr{E}_1$	$\mathscr{E}_2$	$\mathscr{E}_3$	$\mathscr{E}_4$	$\mathscr{E}_5$	$\mathscr{E}_6$
DM 1	Durgapur ($\mathscr{Y}_1$)	AV	SV	EV	VV	SV	VV
	Raniganj ($\mathscr{Y}_2$)	LV	PV	WV	PV	VV	EV
	Asansol ($\mathscr{Y}_3$)	SV	WV	VV	EV	EV	SV
	Jamuria ($\mathscr{Y}_4$)	EV	VV	EV	SV	SV	SV
	Pandaveswar ($\mathscr{Y}_5$)	WV	AV	LV	EV	SV	EV
	Criteria vs Alternatives	$\mathscr{E}_1$	$\mathscr{E}_2$	$\mathscr{E}_3$	$\mathscr{E}_4$	$\mathscr{E}_5$	$\mathscr{E}_6$
DM 2	Durgapur ($\mathscr{Y}_1$)	SV	AV	VV	SV	EV	VV
	Raniganj ($\mathscr{Y}_2$)	WV	PV	LV	PV	VV	EV
	Asansol ($\mathscr{Y}_3$)	AV	WV	SV	WV	SV	AV
	Jamuria ($\mathscr{Y}_4$)	WV	SV	EV	AV	SV	VV
	Pandaveswar ($\mathscr{Y}_5$)	LV	VV	WV	EV	VV	VV

Table 8
Decision matrix between sub-criteria of Location and Accessibility ($\mathscr{E}_1$) and alternatives by DMs

	Criteria vs Alternatives	$\mathscr{E}_{1A}$	$\mathscr{E}_{1B}$	$\mathscr{E}_{1C}$
DM 1	Durgapur ($\mathscr{Y}_1$)	AV	AV	SV
	Raniganj ($\mathscr{Y}_2$)	WV	PV	WV
	Asansol ($\mathscr{Y}_3$)	SV	AV	VV
	Jamuria ($\mathscr{Y}_4$)	VV	WV	WV
	Pandaveswar ($\mathscr{Y}_5$)	EV	LV	EV
	Criteria vs Alternatives	$\mathscr{E}_{1A}$	$\mathscr{E}_{1B}$	$\mathscr{E}_{1C}$
DM 2	Durgapur ($\mathscr{Y}_1$)	SV	SV	AV
	Raniganj ($\mathscr{Y}_2$)	LV	WV	LV
	Asansol ($\mathscr{Y}_3$)	AV	SV	VV
	Jamuria ($\mathscr{Y}_4$)	SV	EV	WV
	Pandaveswar ($\mathscr{Y}_5$)	EV	WV	EV

Table 9
Decision matrix between sub-criteria of Environmental Factors ($\mathscr{E}_2$) and alternatives by DMs

	Criteria vs Alternatives	$\mathscr{E}_{2A}$	$\mathscr{E}_{2B}$	$\mathscr{E}_{2C}$
DM 1	Durgapur ($\mathscr{Y}_1$)	SV	SV	VV
	Raniganj ($\mathscr{Y}_2$)	PV	LV	PV
	Asansol ($\mathscr{Y}_3$)	VV	WV	WV
	Jamuria ($\mathscr{Y}_4$)	EV	VV	SV
	Pandaveswar ($\mathscr{Y}_5$)	AV	SV	SV
	Criteria vs Alternatives	$\mathscr{E}_{2A}$	$\mathscr{E}_{2B}$	$\mathscr{E}_{2C}$
DM 2	Durgapur ($\mathscr{Y}_1$)	VV	AV	AV
	Raniganj ($\mathscr{Y}_2$)	PV	LV	PV
	Asansol ($\mathscr{Y}_3$)	SV	WV	LV
	Jamuria ($\mathscr{Y}_4$)	VV	VV	SV
	Pandaveswar ($\mathscr{Y}_5$)	SV	AV	AV

9. Numerical Illustration and Discussion

In this section, we will discuss the numerical results. At first, the weight of Criteria and Sub-criteria are evaluated by using CRITIC method which is discussed in Section 4.1. Using the formulae of the CRITIC method, we have found the weight of each criteria and for each individual sub-criteria, we

Table 10

Decision matrix between sub-criteria of Infrastructure and Utilities ($\mathscr{E}_3$) and alternatives by DMs

	Criteria vs Alternatives	$\mathscr{E}_{3A}$	$\mathscr{E}_{3B}$	$\mathscr{E}_{3C}$	$\mathscr{E}_{3D}$
DM 1	Durgapur ($\mathscr{Y}_1$)	SV	AV	EV	AV
	Raniganj ($\mathscr{Y}_2$)	PV	PV	VV	PV
	Asansol ($\mathscr{Y}_3$)	LV	WV	SV	VV
	Jamuria ($\mathscr{Y}_4$)	VV	SV	WV	WV
	Pandaveswar ($\mathscr{Y}_5$)	SV	AV	LV	LV
	Criteria vs Alternatives	$\mathscr{E}_{3A}$	$\mathscr{E}_{3B}$	$\mathscr{E}_{3C}$	$\mathscr{E}_{3D}$
DM 2	Durgapur ($\mathscr{Y}_1$)	AV	VV	SV	AV
	Raniganj ($\mathscr{Y}_2$)	LV	EV	AV	LV
	Asansol ($\mathscr{Y}_3$)	WV	EV	VV	VV
	Jamuria ($\mathscr{Y}_4$)	VV	LV	LV	WV
	Pandaveswar ($\mathscr{Y}_5$)	SV	WV	WV	WV

Table 11

Decision matrix between sub-criteria of Security and Safety ($\mathscr{E}_4$) and alternatives by DMs

	Criteria vs Alternatives	$\mathscr{E}_{4A}$	$\mathscr{E}_{4B}$	$\mathscr{E}_{4C}$
DM 1	Durgapur ($\mathscr{Y}_1$)	PV	SV	VV
	Raniganj ($\mathscr{Y}_2$)	AV	VV	WV
	Asansol ($\mathscr{Y}_3$)	EV	SV	WV
	Jamuria ($\mathscr{Y}_4$)	PV	EV	WV
	Pandaveswar ($\mathscr{Y}_5$)	PV	EV	WV
	Criteria vs Alternatives	$\mathscr{E}_{4A}$	$\mathscr{E}_{4B}$	$\mathscr{E}_{4C}$
DM 2	Durgapur ($\mathscr{Y}_1$)	PV	VV	VV
	Raniganj ($\mathscr{Y}_2$)	SV	SV	LV
	Asansol ($\mathscr{Y}_3$)	VV	VV	EV
	Jamuria ($\mathscr{Y}_4$)	LV	WV	WV
	Pandaveswar ($\mathscr{Y}_5$)	WV	EV	EV

Table 12

Decision matrix between sub-criteria of Site Area and Budget ($\mathscr{E}_5$) and alternatives by DMs

	Criteria vs Alternatives	$\mathscr{E}_{5A}$	$\mathscr{E}_{5B}$	$\mathscr{E}_{5C}$
DM 1	Durgapur ($\mathscr{Y}_1$)	AV	AV	VV
	Raniganj ($\mathscr{Y}_2$)	VV	SV	AV
	Asansol ($\mathscr{Y}_3$)	VV	SV	SV
	Jamuria ($\mathscr{Y}_4$)	WV	WV	LV
	Pandaveswar ($\mathscr{Y}_5$)	PV	WV	LV
	Criteria vs Alternatives	$\mathscr{E}_{5A}$	$\mathscr{E}_{5B}$	$\mathscr{E}_{5C}$
DM 2	Durgapur ($\mathscr{Y}_1$)	AV	SV	SV
	Raniganj ($\mathscr{Y}_2$)	SV	VV	VV
	Asansol ($\mathscr{Y}_3$)	VV	VV	SV
	Jamuria ($\mathscr{Y}_4$)	WV	LV	WV
	Pandaveswar ($\mathscr{Y}_5$)	PV	PV	LV

have evaluated the local and global weight. The weight corresponding to each Criteria is shown in Table 14. Further, we calculated the local and global weight of each sub-criteria, which is provided in Table 15.

Table 13
Decision matrix between sub-criteria of Legal and Administrative Compliance ($\mathscr{E}_6$) and alternatives by DMs

	Criteria vs Alternatives	$\mathscr{E}_{6A}$	$\mathscr{E}_{6B}$	$\mathscr{E}_{6C}$
DM 1	Durgapur ($\mathscr{Y}_1$)	VV	AV	SV
	Raniganj ($\mathscr{Y}_2$)	EV	VV	VV
	Asansol ($\mathscr{Y}_3$)	AV	SV	VV
	Jamuria ($\mathscr{Y}_4$)	WV	WV	PV
	Pandaveswar ($\mathscr{Y}_5$)	LV	LV	WV
	Criteria vs Alternatives	$\mathscr{E}_{6A}$	$\mathscr{E}_{6B}$	$\mathscr{E}_{6C}$
DM 2	Durgapur ($\mathscr{Y}_1$)	SV	AV	AV
	Raniganj ($\mathscr{Y}_2$)	VV	VV	VV
	Asansol ($\mathscr{Y}_3$)	VV	SV	SV
	Jamuria ($\mathscr{Y}_4$)	WV	EV	PV
	Pandaveswar ($\mathscr{Y}_5$)	WV	PV	LV

Table 14
Criteria weight evaluated by CRITIC methodology

Criteria	Weight
Location and Accessibility ($\mathscr{E}_1$)	0.187
Environmental Factors ($\mathscr{E}_2$)	0.139
Infrastructure and Utilities ($\mathscr{E}_3$)	0.133
Security and Safety ($\mathscr{E}_4$)	0.115
Site Area and Budget ($\mathscr{E}_5$)	0.287
Legal and Administrative Compliance ($\mathscr{E}_6$)	0.139

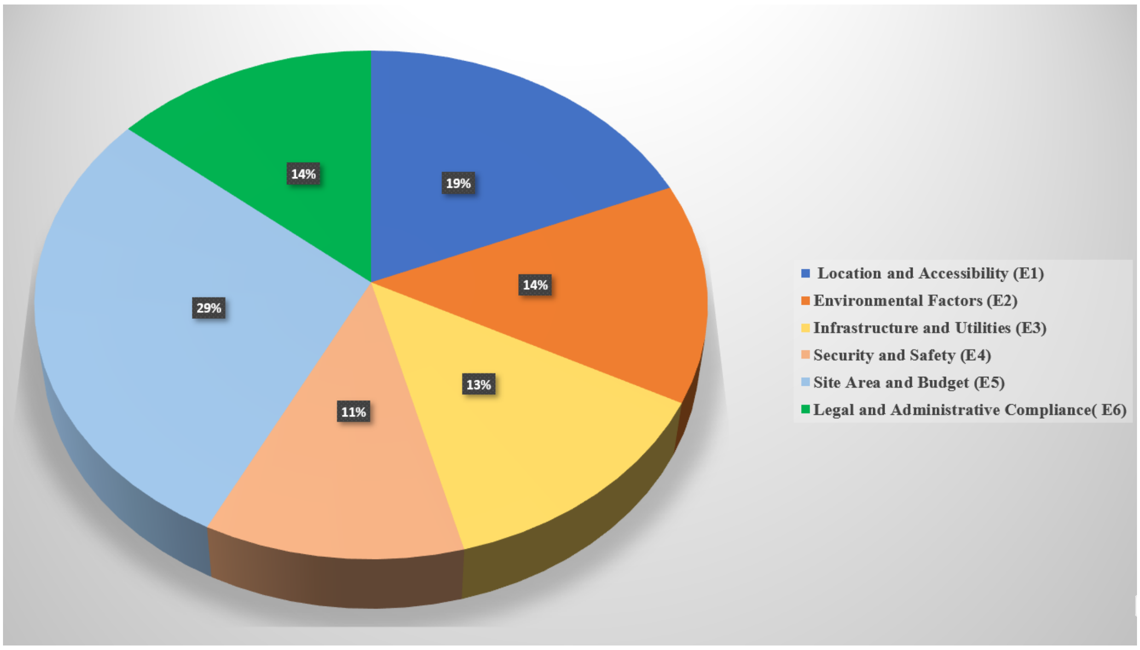

Fig. 6. Pi diagram of the criteria weight (using CRITIC methodology)

Remark 1. *From the above Table 14 and Figure 6, it is clear that the criteria "Site Area and Budget ($\mathscr{E}_5$)" obtained the highest weight in this school site selection problem. The criteria "Location and*

Accessibility" $(\mathscr{E}_1)$ *got the second highest weight and the criteria "Security and Safety"* $(\mathscr{E}_4)$ *got the lowest weight among all criteria.*

Table 15
Weight of the sub-criteria determined by CRITIC procedure

Sub-criteria	Local Weight	Global Weight
Location and Accessibility $(\mathscr{E}_1)$		
Public Transportation Access $(\mathscr{E}_{1A})$	0.335	0.062
Proximity to Residential Areas $(\mathscr{E}_{1B})$	0.305	0.057
Road Connectivity$(\mathscr{E}_{1C})$	0.360	0.067
Environmental Factors $(\mathscr{E}_2)$		
Air Quality $(\mathscr{E}_{2A})$	0.421	0.059
Water Quality $(\mathscr{E}_{2B})$	0.248	0.035
Noise Levels$(\mathscr{E}_{2C})$	0.331	0.046
Infrastructure and Utilities $(\mathscr{E}_3)$		
Water Supply $(\mathscr{E}_{3A})$	0.298	0.039
Electricity Supply $(\mathscr{E}_{3B})$	0.131	0.017
Sewage and Drainage $(\mathscr{E}_{3C})$	0.425	0.057
Internet and Telecommunication $(\mathscr{E}_{3D})$	0.145	0.019
Security and Safety $(\mathscr{E}_4)$		
Local Crime Rates $(\mathscr{E}_{4A})$	0.395	0.046
Systems Surveillance $(\mathscr{E}_{4B})$	0.232	0.027
Fire Safety $(\mathscr{E}_{4C})$	0.372	0.043
Site Area and Budget $(\mathscr{E}_5)$		
Area of Site $(\mathscr{E}_{5A})$	0.331	0.095
Cost of Land $(\mathscr{E}_{5B})$	0.182	0.052
Maintenance Charge $(\mathscr{E}_{5C})$	0.487	0.139
Legal and Administrative Compliance $(\mathscr{E}_6)$		
Land Use Zoning $(\mathscr{E}_{6A})$	0.260	0.036
Government Approvals($(\mathscr{E}_{6B})$	0.246	0.034
Ownership Status $(\mathscr{E}_{6C})$	0.494	0.069

We can easily visualize the importance of each sub-criteria along with the criteria with the help of a Pi diagram which is given in the following Figure 7.

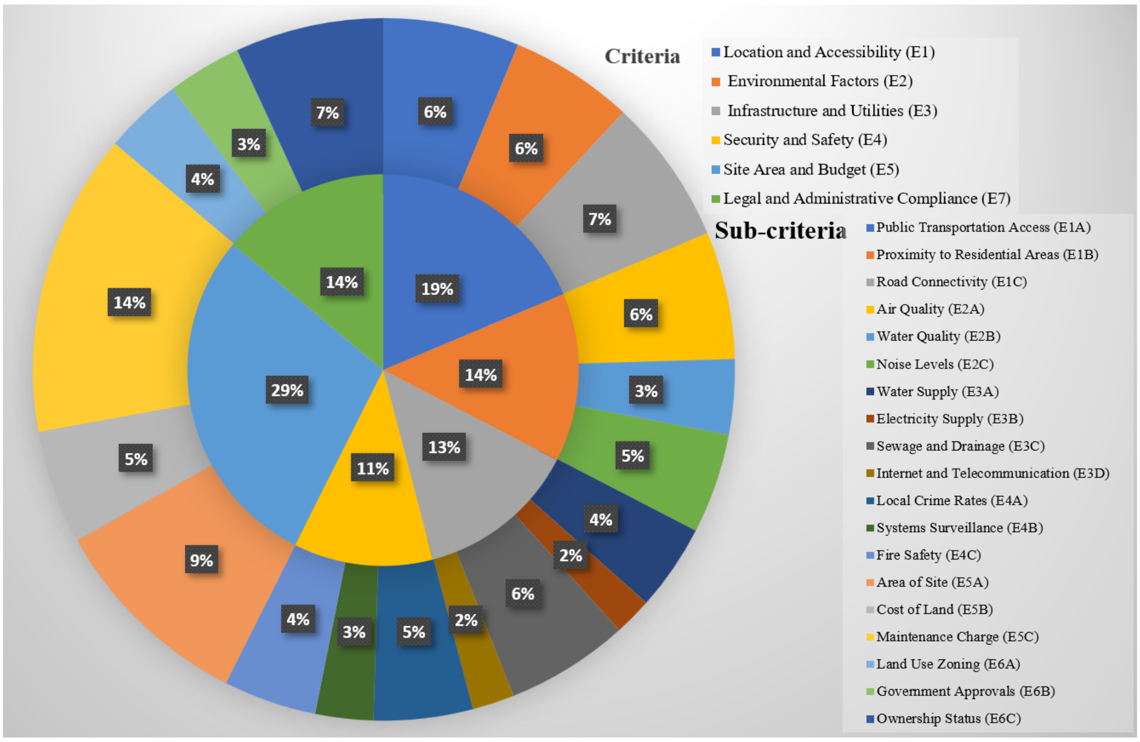

Fig. 7. Pi diagram of the criteria and sub-criteria weight

Remark 2. *Again, from Table 15 it is noted that the sub-criteria "Ownership Status" $(\mathscr{E}_{6C})$ posses the highest weight corresponding to the criteria "Legal and Administrative Compliance" $(\mathscr{E}_6)$. The sub-criteria "Road Connectivity" $(\mathscr{E}_{1C})$, "Air Quality" $(\mathscr{E}_{2A})$, "Sewage and Drainage" $(\mathscr{E}_{3C})$, "Local Crime Rates" $(\mathscr{E}_{4A})$ and "Maintenance Charge" $(\mathscr{E}_{5C})$ are the highest weighted sub-criteria among all sub-criteria corresponding to the criteria "Location and Accessibility" $(\mathscr{E}_1)$, "Environmental Factors" $(\mathscr{E}_2)$, "Infrastructure and Utilities" $(\mathscr{E}_3)$, "Security and Safety" $(\mathscr{E}_4)$ and "Site Area and Budget $(\mathscr{E}_5)$" respectively. Figure 7 also gives us a clear view of how each sub-criteria effect their corresponding criteria.*

Table 16
Ranking of the alternatives with their associated valueS by COPRAS method

Alternative	$\mathcal{S}_m^+$	$\mathcal{S}_m^-$	$\mathscr{Q}_m$	$\mathscr{P}_m$	Ranking
Durgapur $(\mathscr{Y}_1)$	19.932	4.819	24.710	100	1
Raniganj $(\mathscr{Y}_2)$	19.120	4.862	23.858	96.550	5
Asansol $(\mathscr{Y}_3)$	19.666	4.849	24.415	98.804	2
Jamuria $(\mathscr{Y}_4)$	19.260	4.746	24.114	97.586	4
Pandaveswar $(\mathscr{Y}_5)$	19.239	4.721	24.118	97.602	3
$\mathcal{S}_{\min} = \min\{\mathcal{S}_m^- : m = 1, 2, \ldots, \gamma\} = 4.721$					

Here, we have applied the COPRAS method, which is described in Section 4.2, for ranking the alternatives. In this method, we have used the weight of criteria and sub-criteria, which are given in Table 14 and Table 15, respectively. After going through some steps of the COPRAS method, we have got the Maximizing Index $(\mathcal{S}_{m+})$, Minimizing Index $(\mathcal{S}_{m-})$, Relative Weight of each alternatives $(\mathscr{Q}_m)$ and Performance Index (P_m). These values are provided in Table 16. Finally, we have got the ranking of alternatives, which is also shown in Table 16.

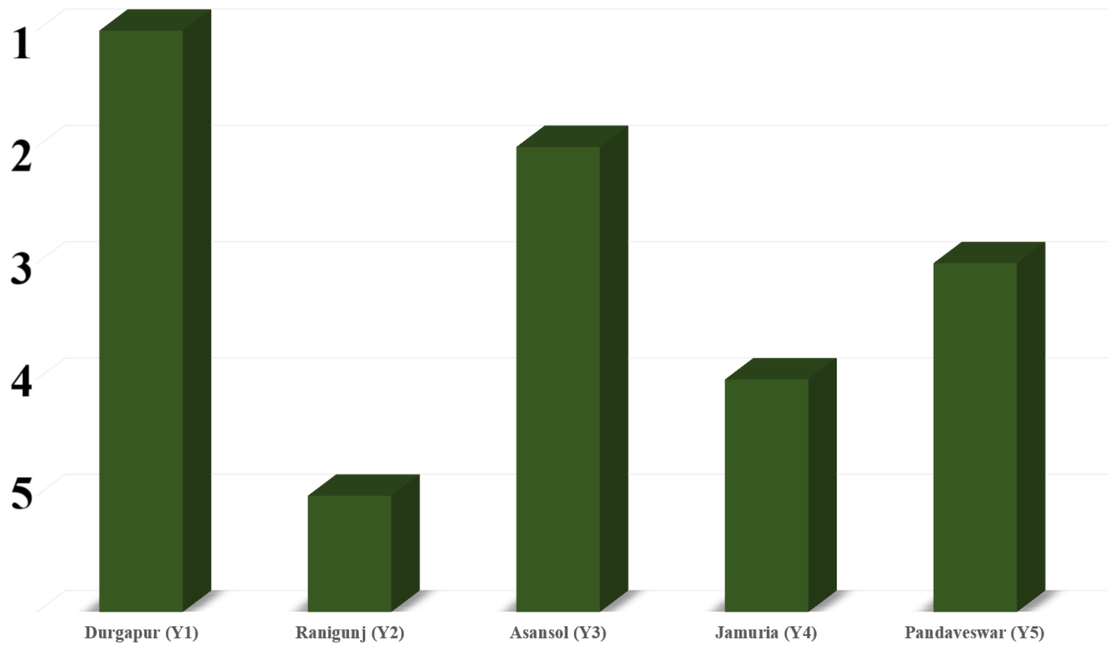

Fig. 8. Rank of Sites that Selected for a new School in Paschim Bardhaman District (West Bengal, India) according to 5 different sites with associated data (using COPRAS process)

Remark 3. *Table 16 and Figure 8 present the ranking of alternatives. Here, we can see that "Durgapur" $(\mathscr{Y}_1)$ is the best place for establishing a school, the second preferred place is "Asansol" $(\mathscr{Y}_3)$, third suitable place is Pandaveswar $(\mathscr{Y}_5)$. Alternatives "Jamuria" $(\mathscr{Y}_4)$ and Raniganj $(\mathscr{Y}_2)$ are the fourth and fifth preferred places, respectively, for establishing a new school.*

Remark 4. *This result depends on the opinions of decision experts, so the result may vary if more decision experts are considered.*

10. Sensitivity analysis and Comparative analysis

Sensitivity analysis and Comparative analysis disclose the robustness and stability of a model. In this section, we will perform the sensitivity analysis and comparative analysis of this work.

10.1 *Sensitivity analysis*

In an MCDM method, through sensitivity analysis, we can understand how the changes in input data affect the ranking of alternatives. So, this is very vital for checking the validity of the result.

10.1.1 *Case 1 [Removing Criteria Site Area and Budget $(\mathscr{E}_5)$]:*

In this case, to compute the sensitivity analysis of this school location selection problem, we remove the criteria and sub-criteria of Site Area and Budget $(\mathscr{E}_5)$.Since, sometimes the servicing fee of schools is not so high or it is paid by other organizations or institutes, so, the problem is analyzed here without these criteria. Then, based on the two DMs' wise decisions and considering the rest of the criteria, we identify that Durgapur $(\mathscr{Y}_1)$ is the ideal place for this described problem and the ranking result is identical with our main structured model.

10.1.2 Case 2 [Removing Criteria Legal and Administrative Compliance ($\mathscr{E}_6$)]:

We discuss this case except for the criteria and its sub-criteria of Legal and Administrative Compliance $\mathscr{E}_6$. As every educational institute has been formed on legal and government approved lands, and then, based on the two DMs' viewpoints, we can compute the remaining categories. And, here also, Durgapur ($\mathscr{Y}_1$) is the proper place for structuring a school.

Remark 5. *After considering these two different cases, we consider that Durgapur ($\mathscr{Y}_1$) is the best and Raniganj ($\mathscr{Y}_2$) is the worst place for this school site selection problem. Table 17 and Figure 9 visualize it specifically.*

Table 17
Alternatives ranking by removing factors in two cases by TOPSIS Methodology

Alternative	Case 1	Case 2	Main Method
Durgapur ($\mathscr{Y}_1$)	1	1	1
Raniganj ($\mathscr{Y}_2$)	5	5	5
Asansol ($\mathscr{Y}_3$)	2	2	2
Churulia/ Jamuria ($\mathscr{Y}_4$)	4	4	4
Pandaveswar ($\mathscr{Y}_5$)	3	3	3

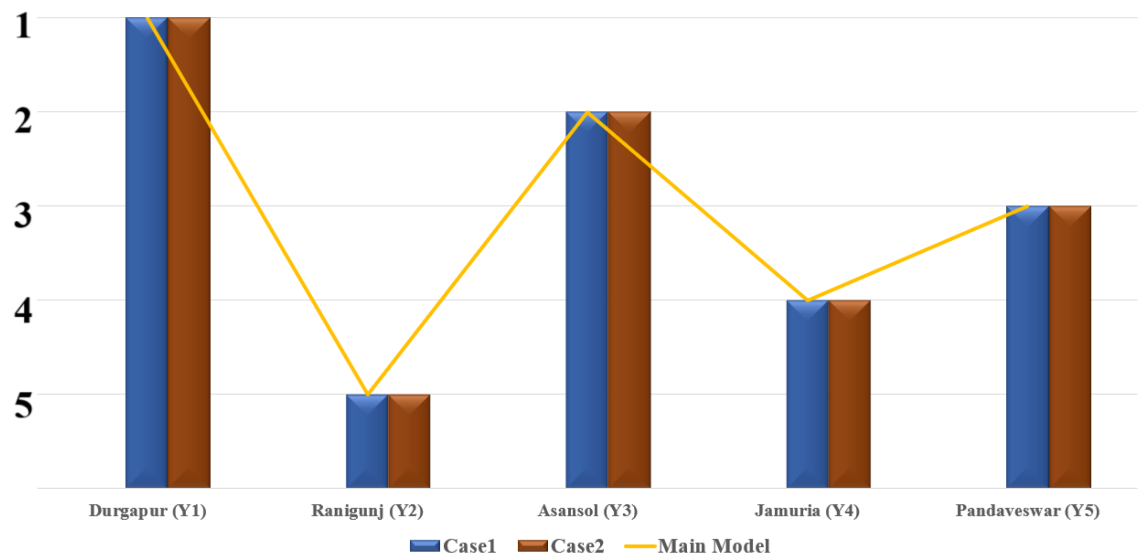

Fig. 9. Sensitivity analysis by COPRAS Process with two different cases

10.2 Comparative analysis

To assess the accuracy and validity of the given rank of the suggested location, we compute this again with another fuzzy decision making process named Technique for Order Preference by Similarity to Ideal Solution(TOPSIS) method. Table 18 presents the two results of TOPSIS and our already proposed Complex Proportional Assessment (COPRAS) methodology to develop the comparison. The graphical representation Figure 10 is explained in a more clear way.

Table 18
Ranking of suggested locations based on VIKOR and TOPSIS methods

Alternative	TOPSIS	COPRAS
Durgapur ($\mathscr{Y}_1$)	1	1
Raniganj ($\mathscr{Y}_2$)	5	5
Asansol ($\mathscr{Y}_3$)	2	2
Churulia/ Jamuria ($\mathscr{Y}_4$)	3	4
Pandaveswar ($\mathscr{Y}_5$)	4	3

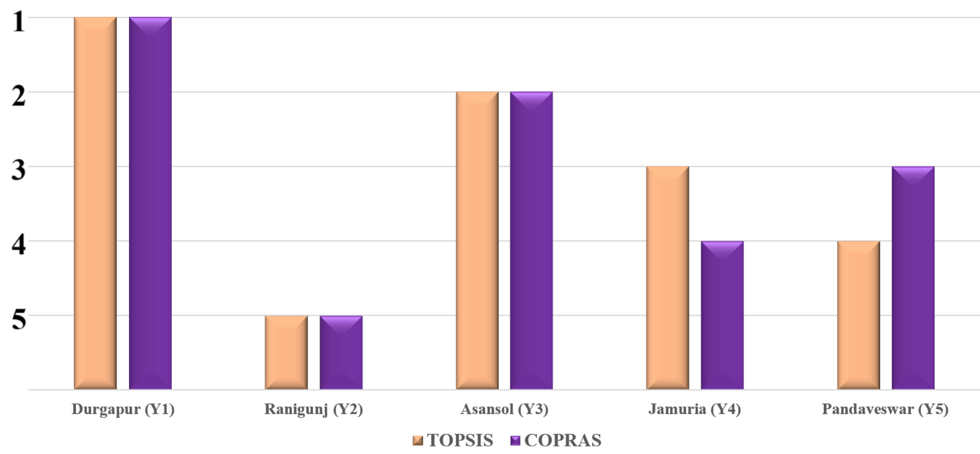

Fig. 10. Comparative analysis by TOPSIS procedure with our proposed methodology

11. Research implication

The proper location selection for a new school in Paschim Bardhaman district (West Bengal, India) has significant research implications in a number of areas, these are,

(I) **Accessibility**: Closeness to residential areas and transport facilities affects attendance and parental involvement.

(ii) **Community Effect**: A perfect-locate school can boost local progress and community cohesion.

(iii) **Environmental Objects**: Evaluation of the ideal location can avoid flood zones, pollution, and other risks, ensuring security and sustainability.

(iv) **Zoning and Regulationst**: Compliance with legal standards is essential for sustainable project completion.

(v) **Equality in Access**: Avoiding differences in school placements ensure equitable educational opportunities.

(vi) **Long-Term Development**: Effective location selection allows for future progress and flexibility.

12. Conclusions and Future Research Scope

Every developing country focuses on providing good educational facilities for all children. Schools are the places where students gain knowledge and learn various subjects. So, there is a need to establish a sufficient number of new schools so that children can easily get access to education. Site selection for establishing a new school is a complex task as many conflicting criteria are involved there.

In our problem we want to establish a new school in Paschim Bardhaman district, for this we have considered 6 criteria and total 19 sub-criteria associated to those criteria. Here, two MCDM methods, namely CRITIC and COPRAS, are used. Applying the CRITIC method we have obtained the criteria and sub-criteria weight. After that, the COPRAS method is used to rank the 5 alternatives, which are five places in West Bardhaman. In this problem, we have also developed a new score and accuracy function, which are given in Equation (11) and Equation (12). After numerical calculations, we have got the result that "Durgapur"$(\mathscr{Y}_1)$ is the best option among the five places for a new school and the second and third preferred options are "Asansol"$(\mathscr{Y}_3)$ and "Pandaveswar" ($\mathscr{Y}_5$), respectively.

There are some further research scopes discussed as follows:

(i) Here, we have considered 6 criteria and 19 sub-criteria associated with this problem. One can include more criteria like 'Social and Community factors', 'Health and Safety', etc. to get better results.

(ii) In this paper, we have applied Neutrosophic numbers to include uncertainty in data. For better results, one can use Interval Neutrosophic numbers, Bipolar Neutrosophic numbers, Multi-Dimensional Neutrosophic numbers, etc.

(iii) In this paper, the CRITIC method is used for finding criteria and sub-criteria weight and for ranking alternatives, the COPRAS method is applied. One may apply MCDM methods like ENTROPY, AHP, etc. for finding criteria and sub-criteria weight and methods like TOPSIS, WASPAS and VIKOR for alternative ranking.

(iv) In this paper, we developed a new Score and Accuracy function shown in Equation (11) and Equation (12). One can introduce different types of Score and Accuracy functions for comparing Neutrosophic numbers.

(v) Here, we considered opinions of 2 DMs. One may consider the opinions of a large number of decision makers for better results.

Acknowledgement

This research was not funded by any grant.

Conflicts of Interest

The authors declare no conflicts of interest.

References

[1] Ye, Z., Chen, Y., Jiang, X., Song, G., Yang, B., & Fan, S. (2022). Improving sample efficiency in multi-agent actor-critic methods. *Applied Intelligence*, 1–14. https://doi.org/10.1007/s10489-021-02554-5

[2] Zhong, S., Chen, Y., & Miao, Y. (2023). Using improved critic method to evaluate thermal coal suppliers. *Scientific reports*, *13*(1), 195. https://doi.org/10.1038/s41598-023-27495-6

[3] Lu, J., Zhang, S., Wu, J., & Wei, Y. (2021). Copras method for multiple attribute group decision making under picture fuzzy environment and their application to green supplier selection. *Technological and economic development of economy*, *27*(2), 369–385. https://doi.org/10.3846/tede.2021.14211

[4] Kundakcı, N., & Işık, A. (2016). Integration of macbeth and copras methods to select air compressor for a textile company. *Decision Science Letters*, *5*(3), 381–394. https://doi.org/10.5267/j.dsl.2016.2.003

[5] De Gennaro, G., Farella, G., Marzocca, A., Mazzone, A., & Tutino, M. (2013). Indoor and outdoor monitoring of volatile organic compounds in school buildings: Indicators based on health risk assessment to single out critical issues. *International journal of environmental research and public health*, *10*(12), 6273–6291. https://doi.org/10.3390/ijerph10126273

[6] Mukherjee, M. (2012). Do better roads increase school enrollment? evidence from a unique road policy in india. *Evidence from a Unique Road Policy in India (August 28, 2012)*. https://doi.org/10.2139/ssrn.2207761

[7] Bowers, A. J. (2015). Site selection in school district research: A measure of effectiveness using hierarchical longitudinal growth models of performance. *School Leadership & Management*, *35*(1), 39–61. https://doi.org/10.1080/13632434.2014.962500

[8] Talam, P. K., & Ngigi, M. M. (2015). Integration of gis and multicriteria evaluation for school site selection a case study of belgut constituency.

[9] Jamal, I. (2016). Multi-criteria gis analysis for school site selection in gorno-badakhshan autonomous oblast, tajikistan. *Master Thesis in Geographical Information Science*.

[10] Panahi, M., Yekrangnia, M., Bagheri, Z., Pourghasemi, H. R., Rezaie, F., Aghdam, I. N., & Damavandi, A. A. (2019). Gis-based swara and its ensemble by rbf and ica data-mining techniques for determining suitability of existing schools and site selection of new school buildings. In *Spatial modeling in gis and r for earth and environmental sciences* (pp. 161–188). Elsevier. https://doi.org/10.1016/B978-0-12-815226-3.00007-7

[11] Baser, V. (2020). Effectiveness of school site decisions on land use policy in the planning process. *ISPRS International Journal of Geo-Information*, *9*(11), 662. https://doi.org/10.3390/ijgi9110662

[12] Palm, M., & Farber, S. (2020). The role of public transit in school choice and after-school activity participation among toronto high school students. *Travel behaviour and society*, *19*, 219–230. https://doi.org/10.1016/j.tbs.2020.01.007

[13] Zaheer, N., Hassan, S.-U., Ali, M., & Shabbir, M. (2022). Optimal school site selection in urban areas using deep neural networks. *Journal of Ambient Intelligence and Humanized Computing*, 1–15. https://doi.org/10.1007/s12652-021-02903-9

[14] González-Espejo, F., Astroza, S., & Hurtubia, R. (2022). On the relation between school and residential location choice: Evidence of heterogeneous strategies from santiago de chile. *Journal of transport geography*, *102*, 103359. https://doi.org/10.1016/j.jtrangeo.2022.103359

[15] Alamin, A., Gazi, K. H., & Mondal, S. P. (2024). Solution of second order linear homogeneous fuzzy difference equation with constant coefficients by geometric approach. *Journal of Decision Analytics and Intelligent Computing*, *4*(1), 241–252. https://doi.org/10.31181/jdaic10021122024a

[16] Mishra, A. R., Liu, P., & Rani, P. (2022). Copras method based on interval-valued hesitant fermatean fuzzy sets and its application in selecting desalination technology. *Applied soft computing*, *119*, 108570. https://doi.org/10.1016/j.asoc.2022.108570

[17] Rahaman, M., Chalishajar, D., Gazi, K. H., Alam, S., Salahshour, S., & Mondal, S. P. (2025). Fractional calculus for type 2 interval-valued functions. *Fractal Fract*, *9*(2), 102. https://doi.org/10.3390/fractalfract9020102

[18] Kumari, R., & Mishra, A. R. (2020). Multi-criteria copras method based on parametric measures for intuitionistic fuzzy sets: Application of green supplier selection. *Iranian journal of science and technology, Transactions of Electrical Engineering*, *44*(4), 1645–1662. https://doi.org/10.1007/s40998-020-00312-w

[19] Alamin, A., Biswas, A., Gazi, K. H., & Mondal, S. P. (2024). Modelling with neutrosophic fuzzy sets for financial applications in discrete system. *Spectrum of Engineering and Management Sciences*, *2*(1), 263–280. https://doi.org/10.31181/sems21202433a

[20] Deli, I., & Şubaş, Y. (2017). A ranking method of single valued neutrosophic numbers and its applications to multi-attribute decision making problems. *International Journal of Machine Learning and Cybernetics*, *8*, 1309–1322. https://doi.org/10.1007/s13042-016-0505-3

[21] Abdel-Basset, M., Mohamed, M., & Sangaiah, A. K. (2017). Neutrosophic ahp-delphi group decision making model based on trapezoidal neutrosophic numbers. *Journal of Ambient Intelligence and Humanized Computing*, *9*, 1427–1443. https://doi.org/10.1007/s12652-017-0548-7

[22] Garg, H., & Nancy. (2018). New logarithmic operational laws and their applications to multiattribute decision making for single-valued neutrosophic numbers. *Cognitive Systems Research*, *52*, 931–946. https://doi.org/10.1016/j.cogsys.2018.09.001

[23] Nabeeh, N. A., Smarandache, F., Abdel-Basset, M., El-Ghareeb, H. A., & Aboelfetouh, A. (2019). An integrated neutrosophic-topsis approach and its application to personnel selection: A new trend in brain processing and analysis. *Journals & Magazines*, *7*, 29734–29744. https://doi.org/10.1109/ACCESS.2019.2899841

[24] Fan, C., Feng, S., & Hu, K. (2019). Linguistic neutrosophic numbers einstein operator and its application in decision making. *Mathematics*, *7*(5), 389. https://doi.org/10.3390/math7050389

[25] Muhamediyeva, D., & Egamberdiyev, N. (2021). An application of gauss neutrosophic numbers in medical diagnosis. *2021 International Conference on Information Science and Communications Technologies (ICISCT)*, 1–4. https://doi.org/10.1109/ICISCT52966.2021.9670195

[26] Das, S. K., & Edalatpanah, S. (2020). A new ranking function of triangular neutrosophic number and its application in integer programming. *International Journal of Neutrosophic Science (IJNS)*, *4*(2), 82–92. https://doi.org/10.5281/zenodo.3767107

[27] Biswas, A., Gazi, K. H., Bhaduri, P., & Mondal, S. P. (2024). Neutrosophic fuzzy decision-making framework for site selection. *Journal of Decision Analytics and Intelligent Computing*, *4*(1), 187–215. https://doi.org/10.31181/jdaic10004122024b

[28] Rahaman, M., Mondal, S. P., Ahmad, S., Gazi, K. H., & Ghosh, A. (2025). Study of the system of uncertain linear differential equations under neutrosophic sense of uncertainty. *Spectrum of Engineering and Management Sciences*, *3*(1), 93–109. https://doi.org/10.31181/sems31202536r

[29] Biswas, A., Gazi, K. H., Bhaduri, P., & Mondal, S. P. (2025). Site selection for girls hostel in a university campus by mcdm based strategy. *Spectrum of Decision Making and Applications*, *2*(1), 68–93. https://doi.org/10.31181/sdmap21202511

[30] Momena, A. F., Gazi, K. H., Rahaman, M., Sobczak, A., Salahshour, S., Mondal, S. P., & Ghosh, A. (2024). Ranking and challenges of supply chain companies using mcdm methodology. *Logistics*, *8*(3), 87. https://doi.org/10.3390/logistics8030087

[31] Adhikari, D., Gazi, K. H., Sobczak, A., Giri, B. C., Salahshour, S., & Mondal, S. P. (2024). Ranking of different states in india based on sustainable women empowerment using mcdm methodology under uncertain environment. *Journal of Uncertain Systems*, *17*(4), 1–52. https://doi.org/10.1142/S1752890924500107

[32] Wu, H.-W., Zhen, J., & Zhang, J. (2020). Urban rail transit operation safety evaluation based on an improved critic method and cloud model. *Journal of Rail Transport Planning & Management*, *16*, 100206. https://doi.org/10.1016/j.jrtpm.2020.100206

[33] Krishnan, A. R., Kasim, M. M., Hamid, R., & Ghazali, M. F. (2021). A modified critic method to estimate the objective weights of decision criteria. *Symmetry*, *13*(6), 973. https://doi.org/10.3390/sym13060973

[34] Pamucar, D., Žižović, M., & Đuričić, D. (2022). Modification of the critic method using fuzzy rough numbers. *Decision Making: Applications in Management and Engineering*, *5*(2), 362–371. https://doi.org/10.31181/dmame0316102022p
[35] Haktanır, E., & Kahraman, C. (2022). A novel picture fuzzy critic & regime methodology: Wearable health technology application. *Engineering Applications of Artificial Intelligence*, *113*, 104942. https://doi.org/10.1016/j.engappai.2022.104942
[36] Puška, A., Nedeljković, M., Prodanović, R., Vladisavljević, R., & Suzić, R. (2022). Market assessment of pear varieties in serbia using fuzzy cradis and critic methods. *Agriculture*, *12*(2), 139. https://doi.org/10.3390/agriculture12020139
[37] Sharkasi, N., & Rezakhah, S. (2022). A modified critic with a reference point based on fuzzy logic and hamming distance. *Knowledge-Based Systems*, *255*, 109768. https://doi.org/10.1016/j.knosys.2022.109768
[38] Kahraman, C., Onar, S. C., & Öztayşi, B. (2022). A novel spherical fuzzy critic method and its application to prioritization of supplier selection criteria. *Journal of Intelligent & Fuzzy Systems*, *42*(1), 29–36. https://doi.org/10.3233/JIFS-219172
[39] Mishra, A. R., Chen, S.-M., & Rani, P. (2023). Multicriteria decision making based on novel score function of fermatean fuzzy numbers, the critic method, and the glds method. *Information Sciences*, *623*, 915–931. https://doi.org/10.1016/j.ins.2022.12.031
[40] Turanoglu Bekar, E., Cakmakci, M., & Kahraman, C. (2016). Fuzzy copras method for performance measurement in total productive maintenance: A comparative analysis. *Journal of Business Economics and Management*, *17*(5), 663–684. https://doi.org/10.3846/16111699.2016.1202314
[41] Kamali Saraji, M., Streimikiene, D., & Kyriakopoulos, G. L. (2021). Fermatean fuzzy critic-copras method for evaluating the challenges to industry 4.0 adoption for a sustainable digital transformation. *Sustainability*, *13*(17), 9577. https://doi.org/10.3390/su13179577
[42] Fan, J., Han, D., & Wu, M. (2022). T-spherical fuzzy copras method for multi-criteria decision-making problem. *Journal of Intelligent & Fuzzy Systems*, *43*(3), 2789–2801. https://doi.org/10.3233/JIFS-213227
[43] Naz, S., Akram, M., Al-Shamiri, M. M. A., & Saeed, M. R. (2022). Evaluation of network security service provider using 2-tuple linguistic complex q-rung orthopair fuzzy copras method. *Complexity*, *2022*(1), 4523287. https://doi.org/10.1155/2022/4523287
[44] Naz, S., Akram, M., & Muzammal, M. (2023). Group decision-making based on 2-tuple linguistic t-spherical fuzzy copras method. *Soft Computing*, *27*(6), 2873–2902. https://doi.org/10.1007/s00500-022-07644-1
[45] Zadeh, L. A. (1965). Fuzzy sets. *Information and Control*, *8*(3), 338–353. https://doi.org/10.1016/S0019-9958(65)90241-X
[46] Gazi, K. H., Biswas, A., Singh, P., Rahaman, M., Maity, S., Mahata, A., & Mondal, S. P. (2024). A comprehensive literature review of fuzzy differential equations with applications. *Journal of Fuzzy Extension and Applications*, 1–28. https://doi.org/10.22105/jfea.2024.449970.1426
[47] Singh, P., Gazi, K. H., Rahaman, M., Basuri, T., & Mondal, S. P. (2024). Solution strategy and associated results for fuzzy mellin transformation. *Franklin Open*, *7*, 100112. https://doi.org/10.1016/j.fraope.2024.100112
[48] Singh, P., Gazi, K. H., Rahaman, M., Salahshour, S., & Mondal, S. P. (2024). A fuzzy fractional power series approximation and taylor expansion for solving fuzzy fractional differential equation. *Decision Analytics Journal*, *10*(100402). https://doi.org/10.1016/j.dajour.2024.100402
[49] Ponnivalavan, K., & Pathinathan, T. (2015). Intuitionistic pentagonal fuzzy number. *ARPN Journal of Engineering and Applied Sciences*, *10*(12), 5446–5450.

[50] Chakraborty, A., Banik, B., Mondal, S. P., & Alam, S. (2020). Arithmetic and geometric operators of pentagonal neutrosophic number and its application in mobile communication service based mcgdm problem. *Neutrosophic Sets and Systems*, *32*, 61–79.
[51] Senapathi, T., & Yager, R. R. (2019). Some new operations over fermatean fuzzynumbers and application of fermatean fuzzy wpm in multiple criteria decision making. *Informatica*, *30*(2), 391–412.
[52] Gündoğdu, F. K., & Kahraman, C. (2019). Spherical fuzzy sets and spherical fuzzy topsis method. *Journal of Intelligent and Fuzzy Systems*, *36*(1), 337–352. https://doi.org/10.3233/JIFS-181401
[53] Gazi, K. H., Momena, A. F., Salahshour, S., Mondal, S. P., & Ghosh, A. (2024). Synergistic strategy of sustainable hospital site selection in saudi arabia using spherical fuzzy mcdm methodology. *Journal of Uncertain Systems*, (2450004). https://doi.org/10.1142/S1752890924500041
[54] Diakoulaki, D., Mavrota, G., & Papayannakis, L. (1995). Determining objective weights in multiple criteria problems: The critic method. *Computers & Operations Research*, *22*(7), 763–770. https://doi.org/10.1016/0305-0548(94)00059-H
[55] Al Awadh, M., & Mallick, J. (2024). A decision-making framework for landfill site selection in saudi arabia using explainable artificial intelligence and multi-criteria analysis. *Environmental Technology & Innovation*, *33*, 103464. https://doi.org/10.1016/j.eti.2023.103464
[56] Alavi, S. M. S., Maleki, A., Noroozian, A., & Khaleghi, A. (2024). Simultaneous optimal site selection and sizing of a grid-independent hybrid wind/hydrogen system using a hybrid optimization method based on electre: A case study in iran. *International Journal of Hydrogen Energy*, *55*, 970–983. https://doi.org/10.1016/j.ijhydene.2023.11.110
[57] Dehghani, A., & Soltani, A. (2024). Site selection of car parking with the gis-based fuzzy multi-criteria decision making. *International Journal of Information Technology & Decision Making*, *23*(02), 715–740. https://doi.org/10.1142/S0219622023500293
[58] Valant, J., & Lincove, J. A. (2023). Transportation inequities and school choice: How car, public transit, and school bus access affect families' options. *Educational Researcher*, *52*(9), 535–543. https://doi.org/10.3102/0013189X231189465
[59] Saini, P., & Pandit, D. (2024). Factors influencing residential location choice: Learnings from the indian context. *Open House International*, *49*(3), 514–530. https://doi.org/10.1108/OHI-02-2023-0027
[60] Moussa, M., & mostafaand Ahmed Abou Elwafa, Y. (2017). School site selection process. *Procedia Environmental Sciences*, *37*, 282–293. https://doi.org/10.1016/j.proenv.2017.03.059
[61] Zubaidah, B., Ahmad Rodzi, M., & Noordin, A. (2012). Spatial multi-criteria decision analysis for safe school site selection. *Jurnal Pengurusan dan Kepimpinan Pendidikan*, *24*(02), 91–108.
[62] Woehr, W. S. (1973). A study of the factors and procedures used for school site selection, site development, and site utilization.
[63] Osborne, S., Uche, O., Mitsakou, C., Exley, K., & Dimitroulopoulou, S. (2021). Air quality around schools: Part i-a comprehensive literature review across high-income countries. *Environmental research*, *196*, 110817. https://doi.org/10.1016/j.envres.2021.110817
[64] Zagatti, E., Russo, M., & Pietrogrande, M. C. (2020). On-site monitoring indoor air quality in schools: A real-world investigation to engage high school science students. *Journal of Chemical Education*, *97*(11), 4069–4072. https://doi.org/10.1021/acs.jchemed.0c00065
[65] Savelieva, K., Marttila, T., Lampi, J., Ung-Lanki, S., Elovainio, M., & Pekkanen, J. (2019). Associations between indoor environmental quality in schools and symptom reporting in pupil-administered questionnaires. *Environmental Health*, *18*, 1–12. https://doi.org/10.1186/s12940-019-0555-6

[66] Dobhal, R., Jeelani, N., Uniyal, D., Khandka, S., & Shrivastava, N. (2012). Water quality analysis of selected schools of kumaonregion, uttarakhand, india. *Environment Conservation Journal*, *13*(1&2), 161–167. https://doi.org/10.36953/ECJ.2012.131231
[67] Spellerberg, I., Ward, J., & Smith, F. (2004). A water quality monitoring programme for schools and communities. *Journal of Biological Education*, *38*(4), 163–166. https://doi.org/10.1080/00219266.2004.9655935
[68] Islam, M. O., & Ghorai, M. (2024). The impact of water quality on children's education: Evidence from 39 districts in the ganges basin of india. *Environment and Development Economics*, 1–20. https://doi.org/10.1017/S1355770X24000123
[69] Shimamura, Y., Shimizutani, S., Taguchi, S., & Yamada, H. (2022). The impact of better access to improved water sources on health, schooling, and water collection of girls and boys in rural zambia. *The Journal of Development Studies*, *58*(9), 1750–1771. https://doi.org/10.1080/00220388.2022.2048650
[70] Ahmed, S., Rifaat, S. M., Ahmad, M. Z., & Uddin, M. S. S. (2021). A study on comparison of noise level at educational institutions adjacent to highways connecting with dhaka city. *TECHNOLOGY*, *6*, 7.
[71] Wiater, J., & G ladyszewska-Fiedoruk, K. (2024). Analysis of noise in education buildings. *Journal of Ecological Engineering*, *25*(2). https://doi.org/10.12911/22998993/176142
[72] Vincent, J. M. (2006). Public schools as public infrastructure: Roles for planning researchers. *Journal of Planning Education and Research*, *25*(4), 433–437. https://doi.org/10.1177/0739456X06288092
[73] Kouri, C. (1999). Wait for the bus: How lowcountry school site selection and design deter walking to school and contribute to urban sprawl.
[74] El-Nwsany, R. I., Maarouf, I., & Abd el-Aal, W. (2019). Water management as a vital factor for a sustainable school. *Alexandria Engineering Journal*, *58*(1), 303–313. https://doi.org/10.1016/j.aej.2018.12.012
[75] Kumambala, P. G., & Ervine, A. (2009). Site selection for combine hydro, irrigation and water supply in malawi: Assessment of water resource availability. *Desalination*, *248*(1-3), 537–545. https://doi.org/10.1016/j.desal.2008.05.099
[76] Koima, J. (2024). School electrification and academic outcomes in rural kenya. *Journal of Development Economics*, *166*, 103178. https://doi.org/10.1016/j.jdeveco.2023.103178
[77] Welland, A. (2017). Education and the electrification of rural schools. *Smart Villages Partnership, Cambridge*.
[78] Kwak, C. (2022). Applicability analysis of trunk drainage sewer system for reduction of inundation in urban dense areas. *Water*, *14*(21), 3399. https://doi.org/10.3390/w14213399
[79] Ouattara, Z. A., Kabo-Bah, A. T., Dongo, K., & Akpoti, K. (2023). A review of sewerage and drainage systems typologies with case study in abidjan, côte d'ivoire: Failures, policy and management techniques perspectives. *Cogent Engineering*, *10*(1), 2178125. https://doi.org/10.1080/23311916.2023.2178125
[80] Saadat Foomani, M., & Malekmohammadi, B. (2020). Site selection of sustainable urban drainage systems using fuzzy logic and multi-criteria decision-making. *Water and Environment Journal*, *34*(4), 584–599. https://doi.org/10.1111/wej.12487
[81] Ghashim, I. A., & Arshad, M. (2023). Internet of things (iot)-based teaching and learning: Modern trends and open challenges. *Sustainability*, *15*(21), 15656. https://doi.org/10.3390/su152115656
[82] Dogruer, N., Eyyam, R., & Menevis, I. (2011). The use of the internet for educational purposes. *Procedia-Social and Behavioral Sciences*, *28*, 606–611. https://doi.org/10.1016/j.sbspro.2011.11.115

[83] Gu, L. (2017). Using school websites for home–school communication and parental involvement? *Nordic Journal of Studies in Educational Policy*, *3*(2), 133–143. https://doi.org/10.1080/20020317.2017.1338498

[84] Saxena, R., & Kamal, M. A. (2018). The impact of built environment on crime prevention and safety in schools: An environmental-behavior design guidelines approach. *American Journal of Civil Engineering and Architecture*, *6*(6), 260–270. https://doi.org/10.12691/ajcea-6-6-5

[85] Timm, P. (2021). *School security: How to build and strengthen a school safety program*. Butterworth-Heinemann.

[86] Seraji, H. (2006). Safety measures for terrain classification and safest site selection. *Autonomous Robots*, *21*(3), 211–225. https://doi.org/10.1007/s10514-006-9716-x

[87] Mubita, K. (2021). Understanding school safety and security: Conceptualization and definitions. *Journal of Lexicography and Terminology (Online ISSN 2664-0899. Print ISSN 2517-9306).*, *5*(1), 76–86.

[88] Perumean-Chaney, S. E., & Sutton, L. M. (2013). Students and perceived school safety: The impact of school security measures. *American Journal of Criminal Justice*, *38*, 570–588. https://doi.org/10.1007/s12103-012-9182-2

[89] Astor, R. A., Meyer, H. A., Benbenishty, R., Marachi, R., & Rosemond, M. (2005). School safety interventions: Best practices and programs. *Children & Schools*, *27*(1), 17–32. https://doi.org/10.1093/cs/27.1.17

[90] Adiyono, A., Mandasari, K., Laila, N., & Suryani, N. Y. (2024). School facility security: An evaluation of surveillance technologies and efforts to improve physical security. *International Education Trend Issues*, *2*(1), 67–79. https://doi.org/10.56442/ieti.v2i1.430

[91] Habib Ullah, K., Abbas, M., Alruwaili, O., Nazir, S., Siddiqi, M. H., & Alanazi, S. (2024). Selection of a smart and secure education school system based on the internet of things using entropy and topsis approaches. https://doi.org/10.1016/j.chb.2024.108346

[92] Birnhack, M., & Perry-Hazan, L. (2020). School surveillance in context: High school students' perspectives on cctv, privacy, and security. *Youth & Society*, *52*(7), 1312–1330. https://doi.org/10.1177/0044118X20916617

[93] Hassanain, M. A., Aljuhani, M., Hamida, M. B., & Salaheldin, M. H. (2022). A framework for fire safety management in school facilities. *International journal of built environment and sustainability*, *9*(2), 1–9. https://doi.org/10.11113/ijbes.v9.n2.901

[94] Seyedin, H., Dowlati, M., Moslehi, S., & Sakhaei, F. S. (2020). Health, safety, and education measures for fire in schools: A review article. *Journal of education and health promotion*, *9*(1), 121. https://doi.org/10.4103/jehp.jehp_665_19

[95] Nadzim, N., & Taib, M. (2014). Appraisal of fire safety management systems at educational buildings. *SHS Web of Conferences*, *11*, 01005. https://doi.org/10.1051/shsconf/20141101005

[96] Fermanich, M., Odden, A., & Archibald, S. (2000). A case study of district decentralization and site-based budgeting: Cordell place school district.

[97] Peternick, L., & Sherman, J. (1998). Site-based budgeting in fort worth, texas. *Journal of Education Finance*, *23*(4), 532–556.

[98] Conley, S. C., & Bacharach, S. B. (1990). From school-site management to participatory school-site management. *The Phi Delta Kappan*, *71*(7), 539–544.

[99] Merchant, Z., Goetz, E. T., Cifuentes, L., Keeney-Kennicutt, W., & Davis, T. J. (2014). Effectiveness of virtual reality-based instruction on students' learning outcomes in k-12 and higher education: A meta-analysis. *Computers & education*, *70*, 29–40. https://doi.org/10.1016/j.compedu.2013.07.033

[100] Proctor, A. M. (1950). Site selection and development for a secondary school plant. *The High School Journal*, *33*(2), 49–55.

[101] Miller, M. A. (2008). Planning for enrollment growth: Using land use data to determine future school sites. *Transportation Research Record*, *2074*(1), 12–20. https://doi.org/10.3141/2074-02
[102] Kazar, G., Yiğit, U., & Boyabatlı, K. E. (2024). Predicting maintenance cost overruns in public school buildings using a rough topological approach. *Automation in Construction*, *168*, 105810. https://doi.org/10.1016/j.autcon.2024.105810
[103] Obradović, D., Briš Alić, M., & Čulo, K. (2024). The issue of estimating the maintenance and operation costs of buildings: A case study of a school. *Eng*, *5*(3), 1209–1231. https://doi.org/10.3390/eng5030066
[104] Ropi, R. M., & Tabassi, A. (2014). Study on maintenance practices for school buildings in terengganu and kedah, malaysia. *MATEC Web of Conferences*, *10*, 03003. https://doi.org/10.1051/matecconf/20141003003
[105] Tijanić Štrok, K., Marenjak, S., & Car-Pušić, D. (2022). Analysis of the current maintenance management process in school buildings: Study area of primorje-gorski kotar county, republic of croatia. *Frontiers in built environment*, *8*, 912326. https://doi.org/10.3389/fbuil.2022.912326
[106] Onyinkwa, J. (2014). *Factors influencing compliance to procurement regulations in public secondary schools in kenya: A case of nyamache district, kisii county*. [Doctoral dissertation].
[107] Chogo, K. C. (2018). *Factors affecting procurement law compliance in public secondary schools in kenya (a case study of public secondary schools in kwale county)* [Doctoral dissertation].
[108] Muthiani, R. M. (2016). *Factors influencing schools compliance to safety standards guidelines in public secondary schools in kitui central sub county, kitui county* [Doctoral dissertation].
[109] Hammad, A. W., Akbarnezhad, A., Haddad, A., & Vazquez, E. G. (2019). Sustainable zoning, land-use allocation and facility location optimisation in smart cities. *Energies*, *12*(7), 1318. https://doi.org/10.3390/en12071318
[110] Bhadhane, P., Jain, R., Joshi, D. A., & Menon, R. (2020). Zoning strategies for urban land use planning. *International Journal of Engineering and Advanced Technology*, *9*(3), 4187–4190. https://doi.org/10.35940/ijeat.C5257.029320
[111] Siegel-Hawley, G. (2024). The potential for land use and housing reform to address school segregation and educational opportunity.
[112] Pat Wardlaw, H. (1952). State approval and accrediting standards for secondary schools. *The bulletin of the National Association of Secondary School Principals*, *36*(186), 198–201. https://doi.org/10.1177/019263655203618636
[113] Ennis, J. R. (1973). *Effects of approval and disapproval by the illinois school building commission on school districts*. Illinois State University.
[114] Lowrey, B. (1989). School site selection and approval guide.
[115] De Armas, J., Ramalhinho, H., & Reynal-Querol, M. (2022). Improving the accessibility to public schools in urban areas of developing countries through a location model and an analytical framework. *Plos one*, *17*(1), e0262520. https://doi.org/10.1371/journal.pone.0262520
[116] Khan, S., & Kotharkar, R. (2012). Performance evaluation of school environs: Evolving an appropriate methodology building. *Procedia-Social and Behavioral Sciences*, *50*, 479–491. https://doi.org/10.1016/j.sbspro.2012.08.052
[117] Juan, Y.-K., Hsu, Y.-C., & Chang, Y.-P. (2021). Site selection assessment of vacant campus space transforming into daily care centers for the aged. *International Journal of Strategic Property Management*, *25*(1), 34–49. https://doi.org/10.3846/ijspm.2020.13800