

Primary School Selection in India: An Empirical Study using Spherical Fuzzy Analytic Hierarchy Process with MARCOS Method

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Choosing the right primary school is a critical decision impacting a child's educational journey and development. This study aims to provide insights into the factors influencing parents' school selection, benefiting parents, policymakers, and school administrators in aligning education with parental expectations. Utilizing the Spherical Fuzzy Analytic Hierarchy Process (SF-AHP) and the Measurement Alternatives and Ranking according to Compromise Solution (MARCOS) method, the study employs mixed-method research, including in-depth interviews and surveys distributed across regions, focusing on 30 randomly selected parents from the Nagpur region. Key findings highlight that Safety and Security, Reputation and Reviews, School Culture, Quality of Curriculum, and Teaching Staff are the primary determinants of school choice. Furthermore, a well-rounded education, incorporating extracurricular activities and parental involvement, also holds significant importance, while student-teacher ratio, transportation facilities, and school timings are of lesser concern. This research offers comprehensive insights into school selection, aiding stakeholders in enhancing India's educational landscape for young learners by considering a broader scope of influencing factors compared to previous studies.

Keywords: Analytic hierarchy process, Fuzzy sets, Multi-criteria decision making, Ranking, Selection

Introduction

In the pursuit of providing children with a solid foundation for their educational journey, selecting the most suitable primary school is of paramount importance.¹ School selection is a critical decision for parents and guardians, as it directly influences a child's academic and personal development. The decision-making process in such context involves numerous complex factors, often influenced by subjective preferences and uncertain information.^{2,3} Over the years, researchers have delved into various methods and techniques to aid in the school selection process, with a focus on optimizing the decision-making process and accommodating diverse criteria. To address the challenges associated with primary school selection, researchers have explored various decision-making methodologies that can effectively accommodate uncertainty and subjective judgments.⁴⁻⁷

One prevalent approach used in decision-making is the Analytic Hierarchy Process (AHP).^{8,9} The AHP facilitates the hierarchical structuring of decision criteria and enables decision-makers to compare and rank alternatives based on pairwise comparisons of criteria. While AHP has been extensively applied in

school selection studies, it encounters challenges in handling uncertain and imprecise information. To address the limitations of traditional AHP, researchers have explored the integration of fuzzy logic to accommodate uncertainty.¹⁰⁻¹³ Fuzzy AHP extends the conventional AHP framework by employing fuzzy sets to represent vague or imprecise information. However, the standard fuzzy AHP method still faces challenges in managing complex decision problems with multiple criteria and sub-criteria, where dependencies and interactions exist among the elements.

In recent years, Spherical Fuzzy Sets (SFS) have gained attention for their capability to model uncertainty more effectively.¹⁴⁻¹⁶ The SFS provides a more flexible representation of uncertainty, allowing the membership values of elements to be defined on the surface of a unit sphere, resulting in a better representation of subjective judgments and uncertain information.¹⁷⁻²⁰

The MARCOS method represents a novel approach to multi-criteria analysis, designed to address complex real-world business challenges. It is particularly tailored for solving intricate problems in various sectors, such as the medical industry. This method stands out due to its foundation in hierarchical and methodological procedures, which enable a systematic examination of alternatives against a set of ideal values.²¹ The

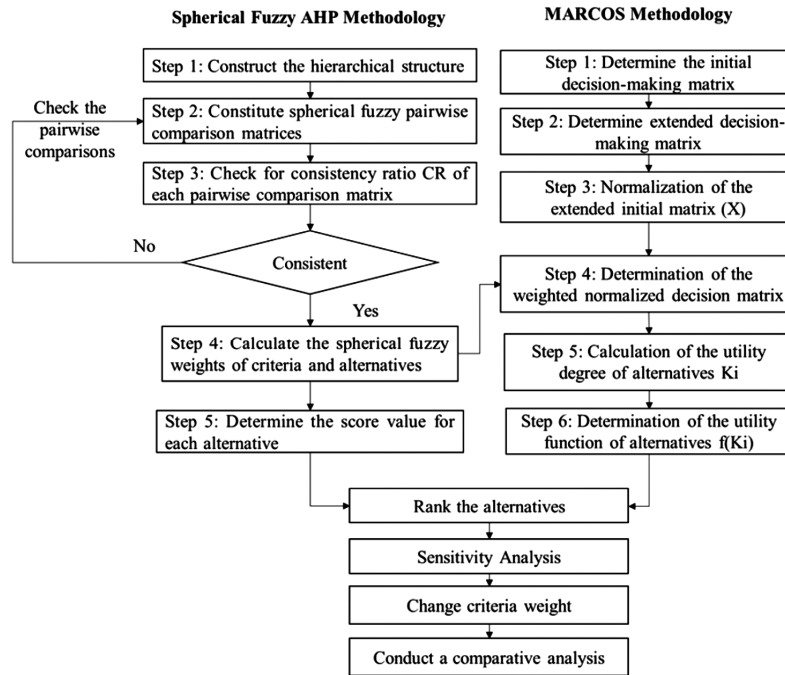


Fig. 1 — Research methodology

MARCOS method offers a structured framework for decision-making. By rigorously evaluating alternatives against established criteria, it provides a rational and comprehensive methodology. The outcome of this process is a ranking of alternatives, allowing for easy classification from the most favourable to the least desirable options based on sustainability considerations.²² While its initial application is in the medical sector, its adaptable nature makes it suitable for tackling multi-criteria analysis problems in various industries. Its flexibility empowers decision-makers, offering them an efficient means of addressing complex problems by employing the prioritized ranking of alternatives. A notable feature of the MARCOS method is its emphasis on practical applicability.²³ By offering a clear and concise ranking of alternatives, it provides valuable insights for managers and decision-makers.²⁴

Drawing inspiration from the advancements in fuzzy logic and MCDM, this study combines the SFAHP with the MARCOS method to tackle the primary school selection problem in India. By leveraging the capabilities of SFS and MARCOS, this approach aims to provide a more comprehensive and robust evaluation of primary schools, considering various factors.

Methodology

A preliminary investigation was carried out, involving the collection of data from 30 parents who

live in Nagpur city. The objective was to uncover the key factors that influence their choice of primary schools for their children. Very negligible relevant literature is available in research papers. With the opinions received from the parents, total 11 important contributing factors were identified.

The combined methodology, consisting of spherical fuzzy AHP and MARCOS approach, used for school selection problem is shown in Fig. 1.

Spherical fuzzy sets (SFS)

SFS is an extension of fuzzy sets that combines Pythagorean Fuzzy Sets (PFS) and Neutrosophic sets.^{25,26} The various parameters definitions are as follows.

Definition 1. A SFS \tilde{A}_S of a universe of discourse P can be stated as Eqs. (1 & 2)

$$\tilde{A}_S = \{ \langle p, \mu_{\tilde{A}_S}(p), \nu_{\tilde{A}_S}(p), \pi_{\tilde{A}_S}(p) \mid p \in P \rangle \}, \quad \dots (1)$$

where,

$$\begin{aligned} \mu_{\tilde{A}_S}(p): P \rightarrow [0,1], \nu_{\tilde{A}_S}(p): P \rightarrow [0,1], \pi_{\tilde{A}_S}(p): P \rightarrow [0,1] \\ \text{and} \quad \dots (2) \\ 0 \leq \mu_{\tilde{A}_S}^2(p) + \nu_{\tilde{A}_S}^2(p) + \pi_{\tilde{A}_S}^2(p) \leq 1, \forall p \in P \end{aligned}$$

The membership degree, non-membership degree, and hesitancy degree of p to \tilde{A}_S are denoted by $\mu_{\tilde{A}_S}(p)$, $\nu_{\tilde{A}_S}(p)$, and $\pi_{\tilde{A}_S}(p)$, respectively, for each p in P. Numerical operations have been developed by examining the relationship between SFS and PFS.

Definition 2. The following definitions pertain to basic operators for two spherical fuzzy sets (SFSs) (Eq. (3–6)) from universes of discourse P_1 and P_2 , represented as $\tilde{A}_S = (\mu_{\tilde{A}_S}, v_{\tilde{A}_S}, \pi_{\tilde{A}_S})$ and $\tilde{B}_S = (\mu_{\tilde{B}_S}, v_{\tilde{B}_S}, \pi_{\tilde{B}_S})$, respectively, in this research paper. Let P_1 and P_2 denote the two universes of discourse:

Addition

$$\tilde{A}_S \oplus \tilde{B}_S = \left\{ \left(\mu_{\tilde{A}_S}^2 + \mu_{\tilde{B}_S}^2 - \mu_{\tilde{A}_S}^2 \mu_{\tilde{B}_S}^2 \right)^{\frac{1}{2}}, v_{\tilde{A}_S} v_{\tilde{B}_S}, \left((1 - \mu_{\tilde{A}_S}^2) \pi_{\tilde{A}_S}^2 + (1 - \mu_{\tilde{B}_S}^2) \pi_{\tilde{B}_S}^2 - \pi_{\tilde{A}_S}^2 \pi_{\tilde{B}_S}^2 \right)^{\frac{1}{2}} \right\} \dots(3)$$

Multiplication

$$\tilde{A}_S \otimes \tilde{B}_S = \left\{ \mu_{\tilde{A}_S} \mu_{\tilde{B}_S}, \left(v_{\tilde{A}_S}^2 + v_{\tilde{B}_S}^2 - v_{\tilde{A}_S}^2 v_{\tilde{B}_S}^2 \right)^{\frac{1}{2}}, \left((1 - v_{\tilde{A}_S}^2) \pi_{\tilde{A}_S}^2 + (1 - v_{\tilde{B}_S}^2) \pi_{\tilde{B}_S}^2 - \pi_{\tilde{A}_S}^2 \pi_{\tilde{B}_S}^2 \right)^{\frac{1}{2}} \right\} \dots(4)$$

Scalar Multiplication ($\lambda > 0$)

$$\lambda \cdot \tilde{A}_S = \left\{ \left(1 - (1 - \mu_{\tilde{A}_S}^2)^\lambda \right)^{\frac{1}{2}}, v_{\tilde{A}_S}, \left((1 - \mu_{\tilde{A}_S}^2)^\lambda - (1 - \mu_{\tilde{A}_S}^2 - \pi_{\tilde{A}_S}^2)^\lambda \right)^{\frac{1}{2}} \right\} \dots(5)$$

Power of \tilde{A}_S ($\lambda > 0$)

$$\tilde{A}_S^\lambda = \left\{ \mu_{\tilde{A}_S}^\lambda, \left(1 - (1 - v_{\tilde{A}_S}^2)^\lambda \right)^{\frac{1}{2}}, \left((1 - v_{\tilde{A}_S}^2)^\lambda - (1 - v_{\tilde{A}_S}^2 - \pi_{\tilde{A}_S}^2)^\lambda \right)^{\frac{1}{2}} \right\} \dots(6)$$

Definition 3. To facilitate aggregation, the SWAM indicating spherical weighted arithmetic means defined as given in Eq. (7) where, the $w = (w_1, w_2, \dots, w_n)$ has values in the range $[0,1]$ and satisfies the condition $\sum_{i=1}^n w_i = 1$.

$$\begin{aligned} & SWAM_w(\tilde{A}_{S1}, \tilde{A}_{S2}, \dots, \tilde{A}_{Sn}) \\ &= w_1 \tilde{A}_{S1} + w_2 \tilde{A}_{S2} + \dots + w_n \tilde{A}_{Sn} \\ &= \left[\left[1 - \prod_{i=1}^n (1 - \mu_{\tilde{A}_{Si}}^2)^{w_i} \right]^{\frac{1}{2}}, \right. \\ & \left. \prod_{i=1}^n v_{\tilde{A}_{Si}}^{w_i}, \left[\prod_{i=1}^n (1 - \mu_{\tilde{A}_{Si}}^2)^{w_i} - \prod_{i=1}^n (1 - \mu_{\tilde{A}_{Si}}^2 - \pi_{\tilde{A}_{Si}}^2)^{w_i} \right]^{\frac{1}{2}} \right] \end{aligned} \dots(7)$$

Table 1 — Linguistic measures of importance

Definition	(μ, v, π)	Score Index (SI)
Absolutely more importance (AM)	(0.9, 0.1, 0.0)	9
Very high importance (VH)	(0.8, 0.2, 0.1)	7
High importance (HI)	(0.7, 0.3, 0.2)	5
Slightly more importance (SM)	(0.6, 0.4, 0.3)	3
Equally importance (EI)	(0.5, 0.4, 0.4)	1
Slightly lower importance (SL)	(0.4, 0.6, 0.3)	1/3
Low importance (LI)	(0.3, 0.7, 0.2)	1/5
Very low importance (VL)	(0.2, 0.8, 0.1)	1/7
Absolutely low importance (AL)	(0.1, 0.9, 0.0)	1/9

Spherical fuzzy AHP

Various studies have been carried out in the past^{27,28} for technology selection, studies^{29–31} for supplier/site selection. In this research, the SF–AHP method is applied to fix the weights of the criteria. It encompasses following methodology:

Step 1: A hierarchical structure is created. The top–tier represents the model's objective, which is determined by a scoring index. The second level consists of n criteria that are utilized to evaluate the alternatives defined in the third level of the structure.

Step 2: Formulate pairwise comparison matrix using linguistic terms (as demonstrated in Table 1):

The calculation of the score indices (SI) for each alternative is performed using Eqs. (8 & 9).

$$SI = \sqrt{|100 * [(\mu_{\tilde{A}_S} - \pi_{\tilde{A}_S})^2 - (v_{\tilde{A}_S} - \pi_{\tilde{A}_S})^2]|} \dots(8)$$

for AM, VH, HI, SM, and EI.

$$\frac{1}{SI} = \frac{1}{\sqrt{|100 * [(\mu_{\tilde{A}_S} - \pi_{\tilde{A}_S})^2 - (v_{\tilde{A}_S} - \pi_{\tilde{A}_S})^2]|}} \dots(9)$$

for SL, LI, VL, and AL.

Step 3: The Consistency Ratio (CR) threshold of 10% is utilized for this purpose which is calculated using Eq. (10).

$$CR = \frac{CI}{RI} \dots(10)$$

The Consistency Index (CI) is calculated using Eq. (11) as follows:

$$CI = \frac{\lambda_{\max} - n}{n - 1} \dots(11)$$

where, λ_{\max} is eigenvalue, and n is number of criteria. The Random Index (RI) used in Eq. (10) is a standard value against each n.

Step 4: The weights of each alternative with respect to each criterion is obtained using Eq. (7).

Step 5: At this point, there are two effective methods for performing the calculation. The first method uses the score function described in Eq. (12) to break down the criteria weights and derive a crisp value.

$$S(\tilde{w}_j^s) = \sqrt{\left| 100 * \left[\left(3\mu_{\tilde{A}_s} - \frac{\pi_{\tilde{A}_s}}{2} \right)^2 - \left(\frac{v_{\tilde{A}_s}}{2} - \pi_{\tilde{A}_s} \right)^2 \right] \right|} \dots (12)$$

Next, the normalization of criteria weights is carried out using Eq. (13), followed by the application of spherical fuzzy multiplication described in Eq. (14).

$$\bar{w}_j^s = \frac{s(\tilde{w}_j^s)}{\sum_{j=1}^n s(\tilde{w}_j^s)} \dots (13)$$

$$\tilde{A}_{S_{ij}} = \bar{w}_j^s * \tilde{A}_{S_i} = \left(1 - \left(1 - \mu_{\tilde{A}_{S_i}}^2 \right)^{\bar{w}_j^s} \right)^{1/2}, v_{\tilde{A}_{S_i}}' \left(\left(1 - \mu_{\tilde{A}_{S_i}}^2 \right)^{\bar{w}_j^s} - \left(1 - \mu_{\tilde{A}_{S_i}}^2 - \pi_{\tilde{A}_{S_i}}^2 \right)^{\bar{w}_j^s} \right)^{1/2} \dots (14)$$

The final score (\tilde{F}) is calculated using Eq. (15).

$$\tilde{F} = \sum_{j=1}^n \tilde{A}_{S_{ij}} = \tilde{A}_{S_{i1}} + \tilde{A}_{S_{i2}} + \dots + \tilde{A}_{S_{in}} \dots (15)$$

In another approach spherical fuzzy global weights are determined using Eq. (16).

$$\prod_{j=1}^n \tilde{A}_{S_{ij}} = \tilde{A}_{S_{i1}} * \tilde{A}_{S_{i2}} * \dots * \tilde{A}_{S_{in}} \dots (16)$$

MARCOS Methodology

MARCOS presents an innovative approach that finds use in various contexts. This method is crafted by incorporating both ideal and anti-ideal solutions. Subsequently, it evaluates the usefulness of different options and computes diverse utility functions using their utility values. This ultimately leads to the determination of alternative priorities and their subsequent ranking. The steps required for ranking alternatives in MARCOS are taken from paper²¹ which are given below:

Step 1: Formation of initial and extended decision matrix. The initial decision matrix consists of ‘m’ criteria against ‘n’ number of alternatives. When dealing with group decision-making scenarios, matrices containing evaluations from experts are combined to form an initial matrix for group decision-making. For obtaining extended decision matrix (X), simply Anti-ideal solution (AAI) and

Ideal solution (AI) are identified for all the criteria as per Eq. (17). The AAI represents the least favourable option, whereas the AI is an alternative distinguished by its superior characteristics based on type of criteria.

$$X = \begin{matrix} AAI & C_1 & C_2 & \dots & C_n \\ A_1 & \begin{bmatrix} x_{aa1} & x_{aa2} & \dots & x_{aan} \\ x_{11} & x_{12} & \dots & x_{1n} \\ x_{21} & x_{22} & \dots & x_{2n} \\ \dots & \dots & \dots & \dots \\ x_{m1} & x_{22} & \dots & x_{mn} \\ AI & \begin{bmatrix} x_{ai1} & x_{ai2} & \dots & x_{ain} \end{bmatrix} \end{matrix} \end{matrix} \dots (17)$$

Step 2: Normalization. The normalized decision matrix is calculated using Eq (18) as follow:

$$n_{ij} = \frac{x_{ai}}{x_{ij}} \text{ if } j \in C$$

$$n_{ij} = \frac{x_{ij}}{x_{ai}} \text{ if } j \in B \dots (18)$$

where, elements x_{ij} and x_{ai} represent the elements of the matrix X.

Step 3: Weighted Matrix (v). It is calculated using Eq. (19) as follows.

$$v_{ij} = n_{ij} \times w_j \dots (19)$$

Step 4: Utility degrees are calculated using Eqs (20–21) as follows:

$$S_i = \sum_{i=1}^n v_{ij} \dots (20)$$

$$K_i^+ = \frac{S_i}{S_{ai}} \quad K_i^- = \frac{S_i}{S_{aai}} \dots (21)$$

Step 5: Utility function are calculated using Eqs (22–23).

$$f(K_i) = \frac{K_i^+ + K_i^-}{1 + \frac{1-f(K_i^+)}{f(K_i^+)} + \frac{1-f(K_i^-)}{f(K_i^-)}} \dots (22)$$

$$f(K_i^-) = \frac{K_i^+}{K_i^+ + K_i^-} \quad f(K_i^+) = \frac{K_i^-}{K_i^+ + K_i^-} \dots (23)$$

Step 6: Ranking. The ranking is derived from the utility function values obtained in previous step.

Results and Discussion

In the present study, primary school selection problem is handled. Through survey and expert opinion, eleven factors are finalized (Table 2). The

Table 2 — Details of factors identified

Criteria	Criteria Type	Criteria Description
Location (C1)	Min	The school's location is important for parents who want their children to be close to home or who want their children to attend a school in a specific neighborhood.
Tuition Fees (C2)	Min	The school's affordability is important for parents who have a limited budget.
Student–Teacher Ratio (C3)	Min	Smaller class sizes and a low teacher-student ratio enhance personalized attention and student engagement.
School Timings (C4)	Min	Too early timings or too much span is a factor for parents
Quality of Curriculum and Teaching staff(C5)	Max	The school's curriculum is important for parents who want their children to receive a particular type of education, such as a bilingual education or a STEM education. The school's teaching staff is important for parents who want their children to be taught by qualified and experienced teachers.
Extracurricular activities (C6)	Max	The school's extracurricular activities are important for parents who want their children to be involved in sports, arts, or other activities.
School culture (C7)	Max	The school's culture is important for parents who want their children to attend a school that has a particular atmosphere, such as a school that is known for its academic rigor or its emphasis on community service.
Reputation and Reviews (C8)	Max	Seek feedback from other parents, educators, and online reviews to understand the school's reputation and community perception.
Safety and Security (C9)	Max	Ensure that the school maintains a safe and secure environment for students, with proper safety protocols in place.
Infrastructure/Transportation facilities (C10)	Max	The quality of the school's infrastructure, including classrooms, libraries, laboratories, and sports facilities, and transportation services including bus/auto etc is a consideration for parents.
Parent involvement (C11)	Max	Parents want to be involved in their children's education. They want to make sure that the school has a parent–teacher association or other opportunities for parents to get involved.

Table 3 — Spherical Fuzzy Pairwise Comparison Matrix

	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11
C1	EI	SM	VH	AM	LI	EI	VL	VL	AL	EI	SL
C2	SL	EI	SM	HI	SL	HI	LI	VL	VL	HI	HI
C3	VL	SL	EI	EI	LI	VL	LI	AL	LI	LI	VL
C4	AL	LI	EI	EI	LI	SL	LI	AL	AL	LI	VL
C5	HI	SM	HI	HI	EI	HI	EI	SL	SL	SM	EI
C6	EI	LI	VH	SM	LI	EI	SL	LI	LI	SM	EI
C7	VH	HI	HI	HI	EI	SM	EI	EI	SL	SM	SL
C8	VH	VH	AM	AM	SM	HI	EI	EI	SL	SM	SL
C9	AM	VH	HI	AM	SM	HI	SM	SM	EI	HI	HI
C10	EI	LI	HI	HI	SL	SL	SL	SL	LI	EI	EI
C11	SM	LI	VH	VH	EI	EI	SM	SM	LI	EI	EI

corresponding objective function of the criteria is also identified having either minimization or maximization function.

In this case, experts are the parents who can afford to select all the schools listed in the alternatives for the study. Data in the form of pairwise comparison matrix based on the linguistic scale, as mentioned in Table 1, is gathered from 30 such parents in a Google Forms/printed sheets. The mode of the values is taken for further evaluation. The obtained data in Table 3 represents the SPF pairwise comparison matrix. The consistency check was performed which resulted into 0.089 consistency ratio. The consistency index

less than or equal to 0.1 is acceptable for further proceeding with the investigation.³²

The linguistic variables are converted into Spherical fuzzy numbers as shown in Table 4. For example EI is replaced with 0.5|0.4|0.4 representing (μ, ν, π) terms. Following the further steps of SPF–AHP, final ‘Membership’, ‘Non membership’, and ‘Degree of Hesitancy’ is obtained as shown in Table 5. The spherical values are then defuzzified and respective criteria weights were obtained.

The criteria are listed in descending ordered of their weight, ‘Safety and Security (C9)’, ‘Reputation and Reviews (C8)’, ‘School culture (C7)’,

Table 4 — Aggregated evaluations of the decision makers

	C1			C2			C3			C4			C5			C6			C7			C8			C9			C10			C11		
C1	0.50	0.40	0.40	0.60	0.40	0.30	0.80	0.20	0.10	0.90	0.10	0.00	0.30	0.70	0.20	0.50	0.40	0.40	0.20	0.80	0.10	0.20	0.80	0.10	0.10	0.90	0.00	0.50	0.40	0.40	0.40	0.60	0.30
C2	0.40	0.60	0.30	0.50	0.40	0.40	0.60	0.40	0.30	0.70	0.30	0.20	0.40	0.60	0.30	0.70	0.30	0.20	0.30	0.70	0.20	0.20	0.80	0.10	0.20	0.80	0.10	0.70	0.30	0.20	0.70	0.30	0.20
C3	0.20	0.80	0.10	0.40	0.60	0.30	0.50	0.40	0.40	0.50	0.40	0.40	0.30	0.70	0.20	0.20	0.80	0.10	0.30	0.70	0.20	0.10	0.90	0.00	0.30	0.70	0.20	0.30	0.70	0.20	0.20	0.80	0.10
C4	0.10	0.90	0.00	0.30	0.70	0.20	0.50	0.40	0.40	0.50	0.40	0.40	0.30	0.70	0.20	0.40	0.60	0.30	0.30	0.70	0.20	0.10	0.90	0.00	0.10	0.90	0.00	0.30	0.70	0.20	0.20	0.80	0.10
C5	0.70	0.30	0.20	0.60	0.40	0.30	0.70	0.30	0.20	0.70	0.30	0.20	0.50	0.40	0.40	0.70	0.30	0.20	0.50	0.40	0.40	0.40	0.60	0.30	0.40	0.60	0.30	0.60	0.40	0.30	0.50	0.40	0.40
C6	0.50	0.40	0.40	0.30	0.70	0.20	0.80	0.20	0.10	0.60	0.40	0.30	0.30	0.70	0.20	0.50	0.40	0.40	0.40	0.60	0.30	0.30	0.70	0.20	0.30	0.70	0.20	0.60	0.40	0.30	0.50	0.40	0.40
C7	0.80	0.20	0.10	0.70	0.30	0.20	0.70	0.30	0.20	0.70	0.30	0.20	0.50	0.40	0.40	0.60	0.40	0.30	0.50	0.40	0.40	0.40	0.50	0.40	0.40	0.60	0.30	0.60	0.40	0.30	0.40	0.60	0.30
C8	0.40	0.60	0.30	0.80	0.20	0.10	0.90	0.10	0.00	0.90	0.10	0.00	0.60	0.40	0.30	0.70	0.30	0.20	0.60	0.40	0.30	0.60	0.40	0.30	0.50	0.40	0.40	0.60	0.30	0.60	0.40	0.30	0.40
C9	0.50	0.40	0.40	0.80	0.20	0.10	0.70	0.30	0.20	0.90	0.10	0.00	0.60	0.40	0.30	0.70	0.30	0.20	0.60	0.40	0.30	0.60	0.40	0.30	0.50	0.40	0.40	0.70	0.30	0.20	0.70	0.30	0.20
C10	0.20	0.80	0.10	0.30	0.70	0.20	0.70	0.30	0.20	0.70	0.30	0.20	0.40	0.60	0.30	0.40	0.60	0.30	0.40	0.60	0.30	0.40	0.60	0.30	0.70	0.20	0.50	0.40	0.40	0.40	0.50	0.40	0.40
C11	0.30	0.70	0.20	0.30	0.70	0.20	0.80	0.20	0.10	0.80	0.20	0.10	0.50	0.40	0.40	0.50	0.40	0.40	0.60	0.40	0.30	0.60	0.40	0.30	0.70	0.20	0.50	0.40	0.40	0.40	0.50	0.40	0.40

Table 5 — Results from the SF–AHP model

Criteria	Spherical Fuzzy Weights			Defuzzified values	Crisp Weights
	Membership	Non–Membership	Degree of Hesitancy		
C1	0.572	0.441	0.251	15.895	0.097
C2	0.549	0.463	0.248	15.243	0.093
C3	0.329	0.662	0.251	8.613	0.053
C4	0.321	0.676	0.248	8.395	0.051
C5	0.595	0.388	0.294	16.367	0.100
C6	0.511	0.478	0.292	13.872	0.085
C7	0.611	0.374	0.285	16.915	0.104
C8	0.686	0.318	0.237	19.408	0.119
C9	0.696	0.298	0.239	19.689	0.121
C10	0.478	0.519	0.282	12.920	0.079
C11	0.573	0.411	0.289	15.734	0.096

Table 6 — Extended initial decision matrix

	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11
AAI	1.635	1.737	3.100	3.866	5.058	3.533	3.445	1.141	3.356	5.116	3.508
A1	5.610	3.892	5.094	5.979	8.113	5.002	5.099	8.798	5.331	7.970	7.874
A2	8.103	8.041	3.100	7.478	7.193	3.896	7.023	5.382	5.748	7.936	5.860
A3	1.635	3.778	7.320	5.297	8.029	7.059	3.595	5.424	3.356	9.000	3.508
A4	3.411	1.795	7.012	3.866	8.698	7.646	5.756	8.358	5.307	9.000	5.157
A5	7.339	5.850	3.151	7.420	5.744	5.118	3.889	1.678	5.809	5.116	3.777
A6	5.306	3.629	5.123	5.218	7.734	5.774	3.445	5.434	3.665	5.322	5.915
A7	5.983	1.737	7.113	5.882	9.000	7.210	5.330	9.000	5.403	7.655	5.035
A8	3.422	7.353	5.981	5.953	5.058	3.533	5.450	1.141	3.914	5.250	3.927
AI	8.103	8.041	7.320	7.478	9.000	7.646	7.023	9.000	5.809	9.000	7.874

‘Quality of Curriculum and Teaching staff (C5)’, ‘Location (C1)’, ‘Parent involvement (C11)’, ‘Tuition Fees (C2)’, ‘Extracurricular activities (C6)’, ‘Infrastructure/ Transportation facilities (C10)’, ‘Student–Teacher Ratio (C3)’, and ‘School Timings (C4)’. It is observed that that the decision makers are giving more importance to safety, school’s reputation, culture, and of course the quality of curriculum and staff than tuition fees, facilities, student teacher ratio and school timings. This shift is may be due to improved standard of living, development and availability of transportation mediums. During a conversation with parents, it came to light that they actively involve their children in extracurricular activities before or after school. As a result, they

perceive less necessity for these activities to be provided within the school curriculum.

After obtaining the criteria preferences, the next step was to rank the available alternatives. Ranking of the alternatives was accomplished by the MARCOS method. Experts were asked to give rating based on 5 degrees’ scale. The rating scale used was as follows: 1 = Very poor, 3 = Poor, 5 = Average, 7 = Good and 9 = Excellent. There were a total of eight schools under evaluation, with assessment being conducted by thirty decision–makers (DMs). The ratings were averaged and initial decision matrix was formed. Depending on the type of criteria, ideal and inti–ideal solution was identified and represented (Table 6) in the form of extended initial decision matrix. The

Table 7 — Normalized decision matrix

	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11
AAI	0.202	0.216	0.424	0.517	0.562	0.462	0.491	0.127	0.578	0.568	0.446
A1	0.692	0.484	0.696	0.800	0.901	0.654	0.726	0.978	0.918	0.886	1.000
A2	1.000	1.000	0.424	1.000	0.799	0.510	1.000	0.598	0.989	0.882	0.744
A3	0.202	0.470	1.000	0.708	0.892	0.923	0.512	0.603	0.578	1.000	0.446
A4	0.421	0.223	0.958	0.517	0.966	1.000	0.820	0.929	0.913	1.000	0.655
A5	0.906	0.728	0.430	0.992	0.638	0.669	0.554	0.186	1.000	0.568	0.480
A6	0.655	0.451	0.700	0.698	0.859	0.755	0.491	0.604	0.631	0.591	0.751
A7	0.738	0.216	0.972	0.787	1.000	0.943	0.759	1.000	0.930	0.851	0.640
A8	0.422	0.914	0.817	0.796	0.562	0.462	0.776	0.127	0.674	0.583	0.499
AI	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000

Table 8 — Weighted normalized matrix

	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11
AAI	0.020	0.020	0.022	0.026	0.056	0.039	0.051	0.015	0.070	0.045	0.043
A1	0.067	0.045	0.037	0.041	0.090	0.056	0.076	0.116	0.111	0.070	0.096
A2	0.097	0.093	0.022	0.051	0.080	0.043	0.104	0.071	0.120	0.070	0.071
A3	0.020	0.044	0.053	0.036	0.089	0.078	0.053	0.072	0.070	0.079	0.043
A4	0.041	0.021	0.051	0.026	0.097	0.085	0.085	0.111	0.111	0.079	0.063
A5	0.088	0.068	0.023	0.051	0.064	0.057	0.058	0.022	0.121	0.045	0.046
A6	0.064	0.042	0.037	0.036	0.086	0.064	0.051	0.072	0.076	0.047	0.072
A7	0.072	0.020	0.051	0.040	0.100	0.080	0.079	0.119	0.113	0.067	0.061
A8	0.041	0.085	0.043	0.041	0.056	0.039	0.081	0.015	0.082	0.046	0.048
AI	0.097	0.093	0.053	0.051	0.100	0.085	0.104	0.119	0.121	0.079	0.096

Table 9 — Results of MARCOS method

Ai	Si	Ki ⁻	K ⁺	f(K ⁻)	f(K ⁺)	f(Ki)	Rank	Rank with TOPSIS method	Rank with VIKOR method
A1	0.804	1.973	0.806	0.290	0.710	0.721	2	4	2
A2	0.823	2.018	0.824	0.290	0.710	0.737	1	1	1
A3	0.637	1.562	0.638	0.290	0.710	0.570	7	7	6
A4	0.769	1.885	0.770	0.290	0.710	0.689	4	2	3
A5	0.641	1.573	0.643	0.290	0.710	0.575	6	6	7
A6	0.646	1.586	0.648	0.290	0.710	0.579	5	5	5
A7	0.803	1.969	0.804	0.290	0.710	0.719	3	3	4
A8	0.577	1.415	0.578	0.290	0.710	0.517	8	8	8

values in extended initial decision matrix are normalized by dividing it with AI values. The normalized decision matrix is shown in Table 7. The normalized matrix is then multiplied with criteria weights obtained using SPF-AHP method and weighted normalized decision matrix is obtained (Table 8). The sum of AI and AAI was calculated for further processing. Row wise sum of weighted normalized matrix was taken to obtain the values of Si. The values for K⁻, K⁺, f(K⁻), and f(K⁺) was also calculated using respective formulae provided in methodology section. The alternatives are ranked using the values of f(Ki). The details are furnished in Table 9. The ranks obtained are as follows:

$$A2 > A1 > A7 > A4 > A6 > A3 > A5 > A8$$

The results were confirmed by addressing the same problem with the two most widely used distance-

based MCDM methods, TOPSIS and VIKOR. Despite minor differences in the rankings, alternative A2 consistently emerged as the top choice in all three methods. This affirms that the solution provided by the combined spherical fuzzy AHP and MARCOS method is both reasonable and acceptable.

Sensitivity Analysis

A sensitivity analysis was conducted to judge whether the weights of the criteria impact the ranking of the alternatives.³³ To do so, the most significant criteria was ‘C9’ having weight of 0.121. The weight of C9 was decreased by 5%. The weights of remaining criteria were adjusted using the Eq. (24).

$$\tilde{W}_{n\beta} = (1 - \tilde{W}_{n\alpha}) \frac{\tilde{W}_{\beta}}{(1 - \tilde{W}_n)} \quad \dots (24)$$

where, $\tilde{W}_{n\beta}$ represents the new value of the criteria to be evaluated, $\tilde{W}_{n\alpha}$ represents the modified value of

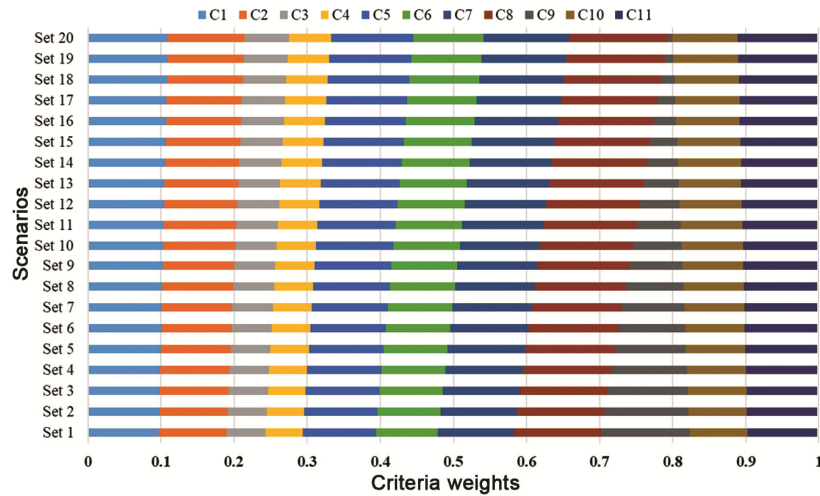


Fig. 2 — Criteria weights under 20 scenarios

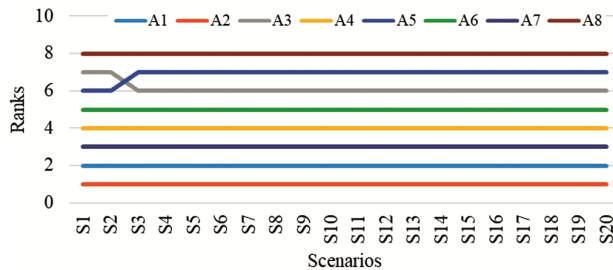


Fig. 3 — Rankings through 20 scenarios

the most significant criteria, \tilde{W}_β represents original value of criteria to be evaluated, and \tilde{W}_n represents the original value of the most significant criteria.

The criteria weights under 20 scenarios are presented in Fig. 2. Ranking through 20 scenarios is provided in Fig. 3, which clearly indicates that the proposed joint model is stable. Alternative 3 and alternative 5 exchanged their ranks for scenario S2–S3. For all the other scenarios, model is perfectly stable. The purpose of the sensitivity analysis was to steer clear of the experts' subjective assessment of the criteria.

Managerial Implications

The findings of this study offer actionable insights for school administrators and policymakers. Schools can enhance their appeal by focusing on safety and security measures, cultivating a positive reputation, fostering a supportive school culture, and maintaining a high-quality curriculum delivered by competent teaching staff. Additionally, schools should emphasize providing a well-rounded education that includes extracurricular activities and encourages parental involvement. Policymakers can use these insights to formulate guidelines and policies that

support schools in these areas, thereby improving the overall educational landscape.

Conclusions

In a landscape where choosing a primary school profoundly shapes a child's educational journey, this empirical study employs an integrated approach, combining the Spherical Fuzzy Analytic Hierarchy Process with the MARCOS method, to delve into the intricate web of factors guiding this pivotal decision for parents in India. Through a fusion of in-depth interviews and widespread surveys, the research identifies Safety and Security, Reputation and Reviews, School Culture, Curriculum Quality, and Teaching Staff as the pivotal pillars steering school preferences. Furthermore, it unveils the rising influence of a holistic education, incorporating extracurricular and parental engagement, while diminishing the significance of variables like student-teacher ratio and transportation facilities. Offering actionable insights for parents, policymakers, and school administrators, this study redefines the boundaries of prior research by embracing a comprehensive spectrum of determinants, enriching the educational landscape for the young minds of India. The study's small sample size and regional focus limit the generalizability of the findings across India. Future research should expand the sample size and geographic scope, incorporate quantitative performance measures, and explore perspectives from diverse stakeholders such as students and teachers.

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