Interchange (2023) 54:203–227
https://doi.org/10.1007/s10780-023-09488-6

Educational institutions selection using Analytic Hierarchy Process based on National Institutional Ranking Framework (NIRF) criteria

Mitul Kumar Ahirwal[1] · Prabhat Kumar[2]

Received: 23 February 2022 / Accepted: 29 March 2023 / Published online: 13 April 2023

Abstract
Nowadays, with increasing competitiveness in every field, securing a good job may be difficult. In this connection, students aiming to get into the best educational institution (EI) would give them their best chance of quality education and good job opportunities. Institutional evaluation and selection are complex tasks that must simultaneously include different aspects and evaluation criteria. This work addresses the EI selection dilemma by formulating a multi-criteria decision-making computational model. This work utilizes the National Institutional Ranking Framework approved by the Ministry of Human Resource Development India to rank higher education institutions in India. The problem was converted into a multi-criteria decision-making (MCDM) model based on the accumulated criteria. This MCDM problem was further solved with the help of the Analytic Hierarchy Process by formulating a multi-criteria decision-making model for EI/university selection. Further, a new technique based on separated criteria benefits and recommendations (SCBR) has been incorporated with AHP, resulting in the advancement of the basic AHP method. The proposed technique allows comprehensibility of the qualitative method while maintaining the precision of the quantitative methodology for institutional selection of undergraduate and postgraduate students. This work is beneficial not only for the students but also for the academic job aspirants for choosing the appropriate institution. The proposed work is also applicable as a tool for assessing the effectiveness of higher education institutions.

Keywords Prioritization · Educational Institution · Multi-criteria decision making · Analytic hierarchy process

Abbreviations

AI	Academic institution
AHP	Analytic Hierarchy Process

✉ Prabhat Kumar
prabhat.kumar1@nift.ac.in

Extended author information available on the last page of the article

ANP	Analytic network process
PHSE	Combined % for Placement, Higher Studies, and Entrepreneurship
PU	Combined metric for Publications
QP	Combined metric for Quality of Publications
COMP	Competitiveness
CI	Consistence index
ESCS	Economically and Socially Challenged Students
EI	Educational institution
ELECTRE	Elimination and choice translating reality
PCS	Facilities for Physically Challenged Students
FQE	Faculty with PhD (or equivalent) and Experience
FSR	Faculty-student ratio
F	Fee
FMCDM	Fuzzy logic based multi-criteria decision-making
GP	Goal programming
GO	Graduation Outcome
H	High
IPR	Intellectual property rights
IPRP	IPR and Patents
L	Low
MS	Median Salary
M	Medium
EIE	Metric for EI Examinations
GSATOP	Metric for Graduating Students Admitted into Top Universities
PHDG	Metric for Number of Ph.D. Students Graduated
MHRD	Ministry of Human Resource Development
MAUT	Multi-attribute utility theory
MCDM	Multi-criteria decision-making
NIRF	National Institutional Ranking Framework
Cn	N^{th} Criteria
Sn	N^{th} Sub-Criteria
OI	Outreach and Inclusivity
PPA	Peer Perception: Academics
PPERI	Peer Perception: Employers and Research Investors
PSOS	Percent Students from other states/countries
PW	Percentage of Women
P	Perception
PR	Perception
PROMETHEE	Projects and Professional Practice and Executive Development
PPPED	Projects and Professional Practice and Executive Development
PPER	Public Perception
RI	Random inconsistency
RD	Region Diversity
RP	Research and Professional Practice
RPPCF	Research Professional Practice and Collaborative Performance
S	Score matrix

SCBR	Separated criteria benefits and recommendations
SAW	Simple Additive Weighting
SS	Student Strength
TLR	Teaching, Learning and Resources
TOPSIS	Technique for order preference by similarity to ideal solutions
TBU	Total Budget and Its Utilization:
WSM	Weighted sum method

Introduction

Higher education is an essential tool for the overall development and growth of the nation. Generally, a developed country is a trained citizenry. The traditional educational institution (EI) are established as teaching institutions to study the arts and the higher disciplines of theology, law, and medicine. Modern educational and research institutions emerged in the nineteenth century to promote scientific and technical knowledge, wherein research became a core activity of EI. Since independence, the Indian higher education panorama has experienced rapid development. The number of higher educational institutions, student enrollment, teaching and non-teaching staff members, infrastructure, technology, vocational and professional education, and education management has improved considerably. After the USA and China, India have the most extensive higher education system globally (Madeshia & Verma, 2020). As per the all India survey on higher education (2018–19), the government of India 2018–19, in India, there are 993 Universities, 39,931 Colleges, and 10,725 independent Institutions; 385 universities in this list are privately managed. There are 548 generals, 142 technical, 63 agricultures and allied, 58 medicals, 23 law, 13 Sanskrit, and 9 language universities. The rest 106 universities are from other categories. India is the second most populated country globally, with an estimated 150 million young people between 18 and 23. Accordingly, several educational institutes are being established to impart knowledge and training in various fields to produce professional leaders to serve society and the nation's development. In India, multiple categories of higher educational institutes, i.e., central and state universities, private universities, deemed universities, open universities, institutes of national importance, an institute under the state legislature act, and others for various levels of the educational program, i.e., under-graduate (UG) degree, post-graduate (PG) degree, M.Phil., Ph.D., post graduate diploma, diploma, integrated/dual degree, and other certificates, etc.

Nowadays, in India, a range of choices are available, from small to big universities, and each has some excellence. Due to many available alternatives, EI or university selection is a high-risk decision from the prospective student's career. This selection process requires extensive effort to evaluate and understand various choice factors and preferences. It is also a time-consuming and puzzling decision-making process as multiple institutes are available, along with different positive and negative criteria that complicate the institution's selection decision. Some institutes are good at "Teaching and Learning," whereas some are good at "Research and Professional Practices." Job and Sriraman (2013) highlighted severe consequences for students when the selected institutions deliver programs or degrees that are deficient in quality. Therefore, the motive of the presented work was to understand and explore the process of EI selection and its solution in a consumer decision-making framework has been done.

Begičević et al. (2010) highlighted several factors that contain different criteria for which students prefer to select EI or college. Clayton et al. (2018) presented various reasons for choosing a learning environment. However, this work utilizes the NIRF criteria developed by the committee and approved by the Ministry of Human Resource Development Government of India to rank higher education institutions in India. Multiple Criteria Decision Making (MCDM) techniques are very useful in solving the EI selection decision-making problem consisting of multiple and usually conflicting criteria. Shayganmehr and Montazer (2020) highlight that MCDM methods empower decision-makers to examine alternatives from various viewpoints, giving optimum results. Therefore, the presented work is the development and demonstration of a novel MCDM method i.e., an Analytical Hierarchy Process (AHP) based algorithm that utilizes the concept of separated criteria (S), the range for benefits (B), and the number of recommendations (R) abbreviated as AHP-SBR for institutes selection decision decision-making problem. The proposed AHP-SBR algorithm may also be helpful in solving other multi-criteria decision-making problems. The proposed algorithm enables users or decision-makers to set their preferences one by one and restricts unwanted output by considering a range of benefits and a number of recommendations. The remainder of this paper is structured as follows. Sect. "Literature review" offered a literature review, highlighted the NIRF and MCDM–AHP techniques, and revealed gaps in the existing literature. In Sect. "The AHP procedure for EI selection", the AHP method for EI selection decisions is explained. Sect. "Proposed method and implementation" presented the proposed method and implementation with intermediate results. The final results and conclusion are presented in Sects. "Final result" and "Conclusion".

Literature review

An educational institution (EI) is a place where individuals gain knowledge, skills and cultural values and earned a degree or certification. The degree or certification is a serious training choice where individuals pick a domain of study. Learners who join higher education programs that lack quality may encounter dilemmas in the job market. Therefore, EI selection is a necessary decision-making process for students involved a complex decision process due to multiple factors/benefits/qualities associated with various institutes. Begičević et al. (2010) mentioned several criteria students generally use to select a suitable institution. Lapan (1996) explored the situations faced by the students and factors affecting the student's decision those are looking at self-efficacy and vocational interests in the science or mathematics area. Kaynama and Smith (1996) explored the "influence of others" over the decision-making process and final selection of EI. Gabrielsen (1992) focuses on the factors like perception/image, reputation, and prestige of an institute as essential criteria for its selection. Dawes and Brown (2002) develop and test a model about the factors that affect undergraduate student search processes in their choice of an EI. Soutar and Turner (2002) highlighted the number of factors that students might consider when choosing the college, i.e. course suitability, academic reputation, campus atmosphere, quality of teaching staff, job prospects, etc. They also highlighted personal criteria such as distance from home, family and friend's perception, etc., for determining their preference for the particular EI. Based on the existing literature, Ancheh et al. (2007) identified a total of 26 factors which influence the student's choices and their decision for selection of institute. The factors considered are arranged as six main criteria as, (i) financial attractiveness, (ii) programs/courses appropriateness and availability, (iii) ease/flexibility of enrolment procedure, (iv) future scope and ease of employment after graduating, (v) attractiveness of institutions, and (vi) quality reputation. Proboyo and Soedarsono (2015) suggested that the student's interest, the ability of the student to complete the courses, along with parent's support/advice were the most significant factors influencing the selection of higher education institution after passing high school exam by the student.

Winchester (1992) indicated that universities are often claimed to be elite institutions, yet they admit less than elite students, and sometimes their faculty are often ordinary. Therefore, it is argued that there is a dilemma between the elite and ordinary universities. A few years ago, the Government of India launched the National Institutional Ranking Framework (NIRF) under the Ministry of Human Resource Development (MHRD) to rank its higher education institutions (Vikaspedia, 2021). Under this framework, a methodology was developed for providing ranking to the institutions in India. Several parameters/factors are identified and defined for ranking of institutions by the core committee members of the NIRF. Teaching, Learning and Resources (TLR), Research and Professional Practice (RP), Graduation Outcomes (GO), Outreach and Inclusivity (OI), and Perception (PR) are the five main parameters under the NIRF framework. At present, NIRF ranking is beneficial for various purposes, i.e., government funding, placement drives, serious research, etc. It has been also observed that some of the institutes that were top in the NIRF framework, also held top ranking across the globe. This similarity indicates the ranking parameters of NIRF are sufficiently competent according to the world ranking process. Nowadays, students are also using this EI ranking information to decide on the most suitable EI selection.

To solve decision-making problems problem, as per the available literature, generally applied methods are goal programming (GP), weighted sum method (WSM), multi-attribute utility theory (MAUT), elimination and choice translating reality (ELECTRE), preference ranking organization method for enrichment evaluation (PROMETHEE), technique for order preference by similarity to ideal solutions (TOPSIS), analytic network process (ANP), and analytical hierarchy process (AHP) (Kumar & Tandon, 2017, 2021; Kumar & Tiwari, 2021). Salimi and Rezaei (2015) formulated an EI selection procedure as a model by considering multiple characteristics of the universities as selection criteria. They proposed a new method based on fuzzy logic and AHP. Budiyanto (2017) proposed MCDM based AHP-TOPSIS model to select a new EI and predict future employment. Kiani et al. (2019) explored different activities of universities as criteria with the help of fuzzy logic-based multi-criteria decision-making (FMCDM) techniques.

The decision making in an uncertain environment, fuzzy logic is the most popular tool addressing the level of uncertainty, complexity, or nonlinearity under conflicting objectives. Biswas and Das (2019) presented the MCDM technique for ranking the seven newly-established Indian institutes of technology (IITs) in India by using modified Simple Additive Weighting (SAW). Begičević et al. (2010) presented a decision-making method by prioritizing projects running in higher education institutions through ANP. Kramulová and Jablonský (2016) applied the AHP method in finding the ranking of some selected countries; raking is based on various indicators, absolute measurement, and expert evaluation. Kumar and Tandon (2019) have employed AHP to capture the degree of importance of customer requirements. Mousavi et al. (2013) presented multi-criteria decision-making for plant location selection, where AHP was employed to analyze the structure of the plant location selection problem and obtain weights of the selected criteria. Ardeshir et al. (2014) applied the AHP technique in civil construction work also, i.e., selecting a bridge construction site. Agha et al. (2013) emphasized AHP technique facilitates decision-making through a realistic description of the problem by incorporating all aspects in the hierarchy. Smutny and Schreiberova (2020) highlighted that AHP is a structured procedure for organizing and examining complex decisions involving qualitative and quantitative considerations. The above studies show that the AHP acts as the primary tool for modeling, solving, and analyzing the problems of different domains as decision-making problems. According to Goraya and Singh (2021), Multi-criteria decision-making (MCDM) methods are trendy for solving decision-making problems with multiple conflicting attributes. Mardani et al. (2015) reviewed 393 articles on MCDM domain and its applications from the year 1994 up to 2014. However, significantly fewer applications are present in the literature that covers applications of MCDM in EI selection and related educational decisions. Hence, in this study, AHP-based multi-criteria decision-making method, specifically AHP, has been used to analyze the problems faced by students in EI selection. Further, a new technique, SBR-AHP, has also been developed by utilizing five broad criteria of the NIRF framework. The proposed technique will definitely be helpful for students and their parents and new teaching aspirants for EI selection.

THE AHP procedure for EI selection

The proposed process and steps of AHP are given below for the EI selection problem:

Step 1. Identify a set of available EI

This step involves making a list of EI where the desired subject/branch is available for higher study. The list preparation for the desired EI requires thorough research considering course content, financial aspects, accommodation, scholarships, etc.

The EI and subject-specific rankings can be beneficial ways to find suitable EI that match the interests.

Step 2. Select a number of relevant important criteria.

This step involves identifying the relevant attributes of the EI choice problem, such as criteria and sub-criteria. The possible evaluation criteria for the EI choice problem are the broad range of factors depending on needs and situation, such as location, size, expenses, academic quality, campus safety, choice of majors, and other factors that are important to you personally.

Step 3. Evaluate the EI based on the selected criteria

Stage 1: *Construction of paired comparison matrix for EI evaluation criteria*

A set of 'n' customer needs for EI criteria is pairwise compared and their relative degree of importance, in terms of weights a_{ij} (on a scale of 1 to 9) is evaluated.

Stage 2:
Estimation of the weight/importance degrees of EI evaluation criteria.

To find the importance degree of each criteria, normalization metric is generated as:

$$(N_{\mathrm{ij}}) = \frac{a_{\mathrm{ij}}}{\frac{\sum_{\mathrm{i}=1}^{n} a_{\mathrm{ij}}}{n}} \mathrm{i}, \mathrm{j} = 1, 2, \ldots, n \tag{1}$$

The weight or importance degree of criteria (w_c) are generated with the help of

$$\left(w_c\right) = \frac{\sum_{j=1}^{n} N_{ij}}{n} i = 1, 2, \ldots, n \tag{2}$$

Stage 3: Calculation of consistence index(CI).

Stage 4: *Calculation of the ultimate weight*

After this procedure is performed for all the pairwise comparison matrices of the alternatives, we form the score matrix S as follows:

$$\mathrm{S} = s_1 s_2 \ldots s_n \tag{5}$$

Thereafter, the priority criteria and local alternative priorities are combined to calculate the global alternative priorities.

Accordingly, as per the weight the ranking of *EI* decided and the ultimate weights of the alternatives value are taken as the best.

Saaty (1987) had proposed that consistency ratios having values less than 0.1 are considered acceptable, and values greater than 0.1, at any level, indicates reexamination of the judgment. To test the consistency, CI is determined first by:

$$\mathrm{CI} = \frac{\lambda_{\max} - n}{n - 1} \tag{3}$$

where, $\lambda_{\max}$ is the maximum eigenvalueand accordingly, the consistency ratio (ξ) is evaluated as,

$$\xi = \frac{CI}{RI} \tag{4}$$

where, *RI* is random inconsistency indices and given by Saaty (1987).

Above all steps are repeated for sub-criteria and finally, each sub-criterion is weighted as per its main criteria.

Step 4. Ranking of the EI based on criteria weight

Finally, the ranking is derived by ordering the global alternative priorities in decreasing order for the academic institution (AI) selection decision making.

Proposed method and implementation

This section presents the proposed methodology and implementations for educational institute (EI) selection by formulating a multi-criteria decision-making problem and solve with the help of the Analytic Hierarchy Process (AHP). The steps involved are as under:

Step 1 Identified a set of available EI.

For this study, a total of 20 educational institutes (EI) are initially listed as alternatives. Further, for the third phase, a list of 50 aspired EI prepared based on considering course content, financial aspects, accommodation, scholarships, etc.

Step 2 Selected number of relevant important criteria for the EI selection.

In this step, the decision problem “Selection of EI” decomposed into five constituent criteria. A questionnaire consisting of all strategic factors related to criteria and sub-criteria is designed to collect pair-wise comparison judgments. This work utilizes the NIRF criteria for the EI decision-making problem based on all India survey on the higher education government of India (2018–19). As the NIRF is approved by the Ministry of Human Resource Development (MHRD) and parallel ranking parameters to world ranking parameters, this work utilizes the same NIRF criteria for the EI choice problem. The fee is included as a new criterion in this work because each EI has a different fee structure and significantly fluctuates EI selection decisions. The five constituent criteria are further decomposed into various sub-criteria, as shown below:

C_1: **Teaching Learning and Resources (TLR)**—Teaching Learning and Resources (TLR)—The TLR criteria is considered as the heart of any EI. Further, TLR criteria is organized into the following sub-parameters:

1. Student Strength including Doctoral Students (SS)
2. Faculty-student ratio with emphasis on permanent faculty (FSR)
3. Combined metric for Faculty with PhD (or equivalent) and Experience (FQE)
4. Total Budget and Its Utilization: (TBU)

C_2: **Research Professional Practice and Collaborative Performance (RPPCF)**—The criteria measure the quantity and quality of research output. The criteria further organized into the following sub-parameters:

1. Combined metric for Publications (PU)
2. Combined metric for Quality of Publications (QP)
3. Intellectual property rights (IPR) and Patents: Filed, Published, Granted and Licensed (IPRP)
4. Footprint of Projects and Professional Practice and Executive Development (PPPED)

C_3: **Graduation Outcome (GO)**—The criteria aim to gather statistics on graduates' employment and higher study activities and their salary.

1. Combined % for Placement, Higher Studies, and Entrepreneurship (PHSE)
2. Metric for EI Examinations (EIE)
3. Median Salary (MS)
4. Metric for Graduating Students Admitted into Top Universities (GSATOP)
5. Metric for Number of Ph.D. Students Graduated (PHDG)

C_4: **Outreach and Inclusivity (OI)**—This emphasizes the representation of women and socially challenged persons in student and/or faculty populations and on outreach activities of the institution. The criteria further organized into the following sub-parameters:

1. Percent Students from other states/countries (PSOS)
2. Region Diversity (RD)

3. Percentage of Women (PW)
4. Economically and Socially Challenged Students (ESCS)
5. Facilities for Physically Challenged Students (PCS)

C_5: **Perception (P)**—The criteria give significant importance to the perception of the institution by its stakeholders. This will be accomplished through Stakeholder Surveys. The criteria further organized into the following sub-parameters:

1. Peer Perception: Employers and Research Investors (PPERI)
2. Peer Perception: Academics (PPA)
3. Public Perception (PPER)
4. Competitiveness (COMP)

C_6: **Fee (F)**—Nowadays, education fees also increase drastically according to the popularity of an institution and the kind of degree one wants. Each institute has a different fees structure, and students prefer to enroll in a prestigious institution for a good education with low fees. The criteria further organized into the following sub-parameters:

1. High (H)
2. Medium (M)
3. Low (L)

Step 3. Evaluate the EI based on the selected criteria.

(A) First phase implementation.

Stage 1: Construction of paired comparison matrix for EI criteria.

In this work, Saaty (1987) AHP Scale (1 to 9) is utilized for paired comparison, where, 1 is equal importance, 3 represented moderate importance, 5 was strong importance, 7 denoted very strong importance and 9 was "extreme importance". To construction of paired comparison matrix for EI criteria, the survey of the focus group was employed. This focus group included ambitious students and their parents. Accordingly, the focus group performed the pairwise comparisons of each factor and the results for the EI selection is shown in Table 1.

Stage 2: Estimation of the weight/importance degrees of criteria weight

The importance degree of each criteria weight, normalization metric is generated using equation (1). The, normalized pair-wise matrix is calculated as given in Table 2.

Thereafter, the weight or importance degree of CR (w_c) are generated with the help of Eq. (2). Accordingly, the weight of each criteria$C_1$to C_6 are calculated and shown in Table 3.

Stage 3: *Calculation of consistence index (CI).*

Now, we perform a consistency check on the pairwise comparison matrix of the criteria. Here, λ_{max} = 6.445 calculated and the $n=6$ now using Eqs. (3) and (4) to calculate CR as follows:

$$CI= \frac{6.445409-6}{6-1} = 0.891$$

RI is random inconsistency indices as given by Saaty (1987) for the n = 6 is 1.24.

CR = CI/RI = 0.89082/1.24 = 0.07184.

CR is calculated as 0.07184 that is below 0.1; therefore, paired comparison matrix for EI criteria is acceptable. Similar comparisons for each sub criterion will calculated in below section.

Calculation for each of the sub-criteria weights:

a. Teaching Learning and Resources (TLR)

Table 1 Pair-wise comparison matrix for criteria

Criteria	C_1	C_2	C_3	C_4	C_5	C_6
C_1	1	2	1	3	1/5	2
C_2	1/2	1	1/5	1/5	1/7	1
C_3	1	4	1	1	1	1
C_4	1/3	4	1	1	1/6	2
C_5	4	7	1	4	1	6
C_6	1/2	1	1	1/2	1/6	1

C_1: TLR, C_2: RPPCF, C_3: GO, C_4: OI, C_5: P, C_6: F

Table 2 Normalized matrix for criteria

Criteria	C_1	C_2	C_3	C_4	C_5	C_6
C_1	0.14	0.11	0.19	0.31	0.07	0.15
C_2	0.07	0.05	0.04	0.02	0.05	0.08
C_3	0.14	0.21	0.19	0.10	0.37	0.08
C_4	0.05	0.21	0.19	0.10	0.06	0.15
C_5	0.55	0.37	0.19	0.41	0.37	0.46
C_6	0.07	0.05	0.19	0.05	0.06	0.08

C_1: TLR, C_2: RPPCF, C_3: GO, C_4: OI, C_5:P, C_6: F

The paired comparison matrix for Teaching Learning and Resources (TLR) is given in Table 4.

As in the previous step, the weights for each of the sub-criteria $S_1$to S_4 are computed as provided in Table 5

Next, CR is calculated as 0.083using Eqs. (3) and (4). In this work CR ≤ 0.1, therefore the pair-wise comparison matrix of the criteria is consistent.

b. Research Professional Practice and Collaborative Performance (RPPCF)

The resulting pair-wise comparison matrix of the sub-criteria for "RPPCF" is provided in Table 6.

As in the previous step, the weights for each of the criteria are calculated and provided in Table 7.

Next, CR is calculated as 0.367 using Eqs. (3) and (4). Here, CR ≤ 0.1, therefore the pair-wise comparison matrix of the criteria is consistent.

Table 3 Weights for each criterion

Criteria		Weight in %
C_1	Teaching Learning and Resources (TLR)	16.196
C_2	Research Professional Practice and Collaborative Performance (RPPCF)	5.169
C_3	Graduation Outcome (GO)	18.215
C_4	Outreach and Inclusivity (OI)	12.792
C_5	Perception (P)	39.229
C_6	Fee (F)	8.398

c. Graduation Outcome (GO)

The resulting pair-wise comparison matrix of the sub-criteria "GO" is provided in Table 8.

As in the previous step, the weights for each of the criteria are calculated and provided in Table 9.

Next, CR is calculated as 0.0776 using Eqs. (3) and (4). Hence, CR ≤ 0.1, therefore the pairwise comparison matrix of the criteria is consistent.

d. Outreach and Inclusivity (OI)

The pair-wise comparison matrix of the sub criteria "OI" is provided in Table 10.

Same as previous step, the weights for each of the criteria are calculated and provided in Table 11.

Table 4 Pair-wise comparison matrix for "TLR" sub-criteria

Criteria	SS	FSR	FQE	TBU
SS	1	1/4	5	3
FSR	4	1	6	4
FQE	1/5	1/6	1	1/3
TBU	1/3	1/4	3	1

Table 5 Weights for each "TLR" sub-criterion

Style Sub-Criteria		Weight in %
S_1	Student Strength including Doctoral Students (SS)	25.60
S_2	Faculty-student ratio with emphasis on permanent faculty (FSR)	55.07
S_3	Combined metric for Faculty with PhD (or equivalent) and Experience (FQE)	6.07
S_4	Total Budget and Its Utilization: (TBU)	13.25

Table 6 Pair-wise comparison matrix for "RPPCF" sub-criteria

RPPCF	PU	QP	IPRP	PPPED
PU	1	1/2	1/4	3
QP	2	1	1/4	1/4
IPRP	4	4	1	3
PPPED	1/3	4	1/3	1

Next, CR is calculated as 0.061 using Eqs. (3) and (4). As CR ≤ 0.1, therefore the pairwise comparison matrix of the criteria is consistent.

e. Perception (P)

The pairwise comparison matrix of the sub criteria "P" is provided in Table 12.

Same as previous step, the weights for each of the criteria for sub criteria "P" are calculated and presented in Table 13.

Next, CR is calculated as 0.0467that is less from 0.1, therefore the pairwise comparison matrix of the criteria is consistent.

f. Fee (F)

Table 7 Weights for each "RPPCF" sub-criteria

RPPCF Sub-Criteria		Weight in %
PU	Combined metric for Publications	25.60
QP	Combined metric for Quality of Publications	55.07
IPRP	IPR and Patents: Filed, Published, Granted and Licensed	6.07
PPPED	Footprint of Projects and Professional Practice and Executive Development Programs	13.25

Table 8 Pair-wise comparison matrix for "GO" sub-criteria

GO	PHSE	EIE	MS	GSATOP	PHDG
PHSE	1	5	5	1	2
EIE	1/5	1	1/4	1/3	1/2
MS	1/5	4	1	¼	1/2
GSATOP	1	3	4	1	3
PHDG	1/2	2	2	1/3	1

Table 9 Weights for each "GO" sub-criterion

Graduation Outcome Sub-Criteria		Weight in %
PHSE	Combined % for Placement, Higher Studies, and Entrepreneurship	34.29
EIE	Metric for EI Examinations	6.83
MS	Median Salary	11.48
GSATOP	Metric for Graduating Students Admitted into Top Universities	32.85
PHDG	Metric for Number of Ph.D. Students Graduated	14.52

Table 10 Pair-wise comparison matrix for "OI" sub-criteria

OI	PSOS	RD	PW	ESCS	PCS
PSOS	1	1/3	1/5	1/5	1/5
RD	3	1	1/8	1/5	1/7
PW	5	8	1	1	1
ESCS	5	5	1	1	1
PCS	5	7	1	1	1

Table 11 Weights for each "OI" sub-criterion

Outreach and Inclusivity (OI) Sub-Criteria		Weight in %
PSOS	Percent Students from other states/countries	4.94
RD	Region Diversity	6.88
PW	Percentage of Women	30.64
ESCS	Economically and Socially Challenged Students	27.83
PCS	Facilities for Physically Challenged Students	29.71

Same as previous step, the weights for each of the criteria are calculated and provided in Table 15.

Next, CR is calculated as 0.048 using Eqs. (3) and (4). Here, CR $\leq$ 0.1, therefore the pairwise comparison matrix of the criteria is consistent. For better visualization and understanding, criteria and sub-criteria with their weighted importance are shown in Fig. 1

The final sub-criteria weights according to main criteria are calculated using Eq. (7), and displayed in Fig. 2.

$$Final\ subcriteria\ weight = \frac{Criteria\ Weight \times Sub\_Critera\ Weight}{100} \tag{7}$$

Step 4. Ranking of the EI based on criteria weight

Results of first phase: Evaluation of alternatives (EI Ranking)

In Table 17, total 20 EI are listed as alternatives for this study. These alternatives are evaluated as per obtained final weighted importance of sub-criteria matrix. The subjective rank as per user of each EI based the total weight obtained by each EI is listed in Table 16. As shown in the Table 17, among all the option, educational institute 4 is most suitable or beneficial.

Table 12 Pair-wise comparison matrix for "P" sub-criteria

P	PPERI	PPA	PPER	COMP
PPERI	1	1	5	3
PPA	1	1	5	3
PPER	1/5	1/5	1	1/4
COMP	1/3	1/3	4	1

Table 13 Weights for each "P" sub-criterion

Perception (P) sub criteria		Weight in %
PPERI	Peer Perception: Employers and Research Investors	38.42
PPA	Peer Perception: Academics	38.42
PPER	Public Perception	6.472
COMP	Competitiveness	16.69

Results of first phase: Evaluation of alternatives (EI Ranking)

(B) Second phase implementation

All the above steps are repeated as same in *second phase* for all the criteria and sub-criteria excluding fee. The changes in weights of criteria have been observed and new weights are listed in Table 18 (also satisfy the CR constraint, with CR = 0.0768and final weights of sub-criteria are shown in Fig. 3.

Table 15 Weights for each "F" sub-criterion

Price		Weight in %
H	High	11.26
M	Medium	16.84
L	Low	71.89

Results of first phase: Evaluation of alternatives (EI Ranking)

Further, for fee versus benefit analysis, fee (in INR) of EI are taken as U1f = 70,000, U2f = 50,000, U3f = 20,000, U4f = 21,000, U5f = 51,000, U6f = 19,000, U7f = 72,000, and U8f = 71,000. All the prices are converted into normalized from.

From the Fig. 4, it can be easily observed and analyzed that the U4, and U8 are almost equal in terms of benefits or status but having large fee difference. Through this approach of analysis, EI can be easily evaluated in terms of benefits and their fee. But this approach can be used on small set of EI. Following the same track, the third phase of study proceeds.

(C) Third phase implementation

In *third phase*, 50 EI have been taken. As listed in Table 19, where first column is S. No. (it may be EI_ID). Second column is C_1 having values as 1, 2, 3 and 4 for SS, FSR, FQE, and TBU, respectively. Third column is C_2 having values as 1, 2, 3 and 4 for PU, QP, IPRP, and PPPED, respectively. Fourth column is C_3 having values 1, 2, 3, 4 and 5 for PHSE, EIE, MS, GSATOP, and PHDG, respectively. Fifth column is C4 having values 1, 2, 3, 4 and 5 for PSOS, RD, PW, ESCS and PCS, respectively. Sixth column is C_5 having values 1, 2, 3 and 4 for PPERI, PPA, PPER and COMP, respectively. Seventh column is the Fee of the EI. From the Fig. 5, it is easy to select range of price or benefits to select EI as per financial status of student. It seems to be easy, but when we have more than 100 or 500 EI then it becomes difficult. For that, students/parents have been asked to provide their requirements in terms of (a) Fee, (b) benefits/Status of EI and (c) number of recommended options for EI. Based on these three inputs from user, an algorithm has been proposed to enhance the capability of AHP method.

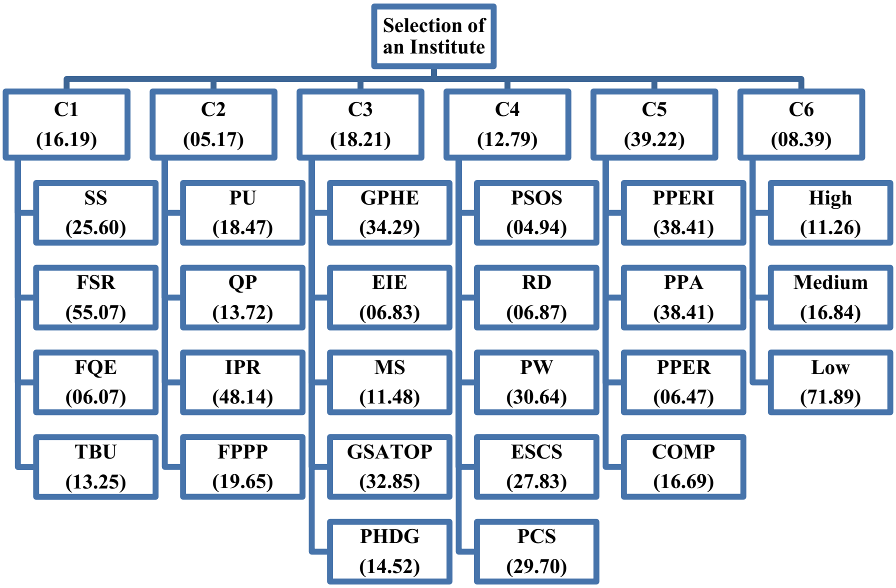

Fig. 1 Criteria and sub-criteria with weighted importance in percentage

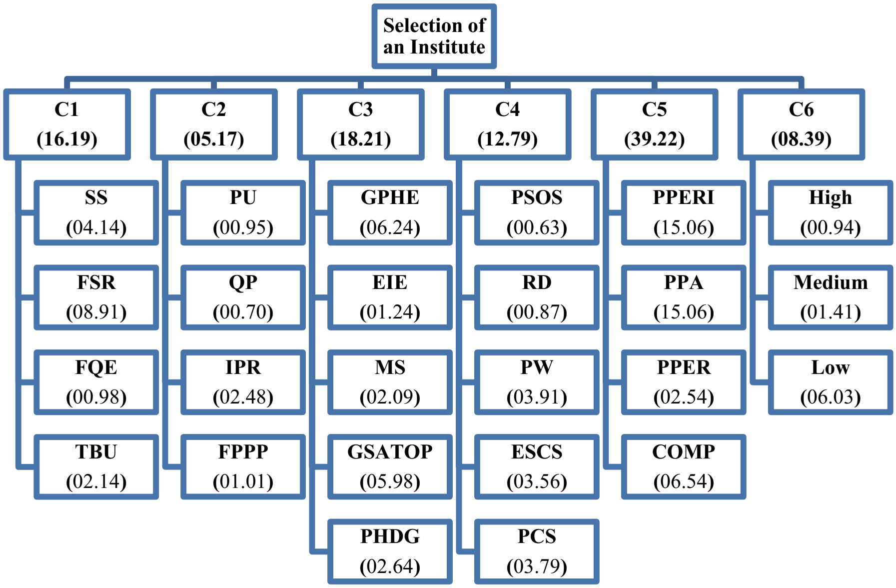

Fig.2 Final sub-criteria weights according to main criteria

Table 16 EI with their specifications as criteria and respective sub-criteria

EI Option	TLR	RPPCF	GO	OI	P	F
U1	SS	PU	PHSE	PCS	PPERI	H
U2	SS	FPP	EIE	RD	COMP	M
U3	TBU	IPRP	MS	PW	PPER	L
U4	FSR	FPP	GSATOP	ESCS	COMP	L
U5	FQE	FPP	PHDG	PCS	COMP	M
U6	FQE	QP	MS	PSOS	PPA	L
U7	TBU	PU	PHDG	PSOS	COMP	H
U8	FQE	QP	PHSE	RD	PPA	H

Table 17 Ranks of EI after evaluation through criteria and respective sub-criteria

EI Option	TLR	RPPCF	GO	OI	P	F	Total Weight	Rank
U1	4.15	0.96	6.25	3.80	15.07	0.95	31.17	II
U2	4.15	1.02	1.24	0.88	6.55	1.41	15.25	VIII
U3	2.15	2.49	2.09	3.92	2.54	6.04	19.23	V
U4	8.92	1.02	5.98	3.56	6.55	6.04	32.07	I
U5	0.98	1.02	2.65	3.80	6.55	1.41	16.41	VII
U6	0.98	0.71	2.09	3.92	15.07	6.04	28.81	III
U7	2.15	0.96	2.65	3.80	6.55	0.95	17.04	VI
U8	0.98	0.71	6.25	0.63	15.07	0.95	24.59	IV

Table 18 Weights for each criterion in second phase

Criteria		Weight in %
C_1	TLR	18.02
C_2	RPPCF	05.10
C_3	GO	22.27
C_4	OI	13.68
C_5	P	40.91

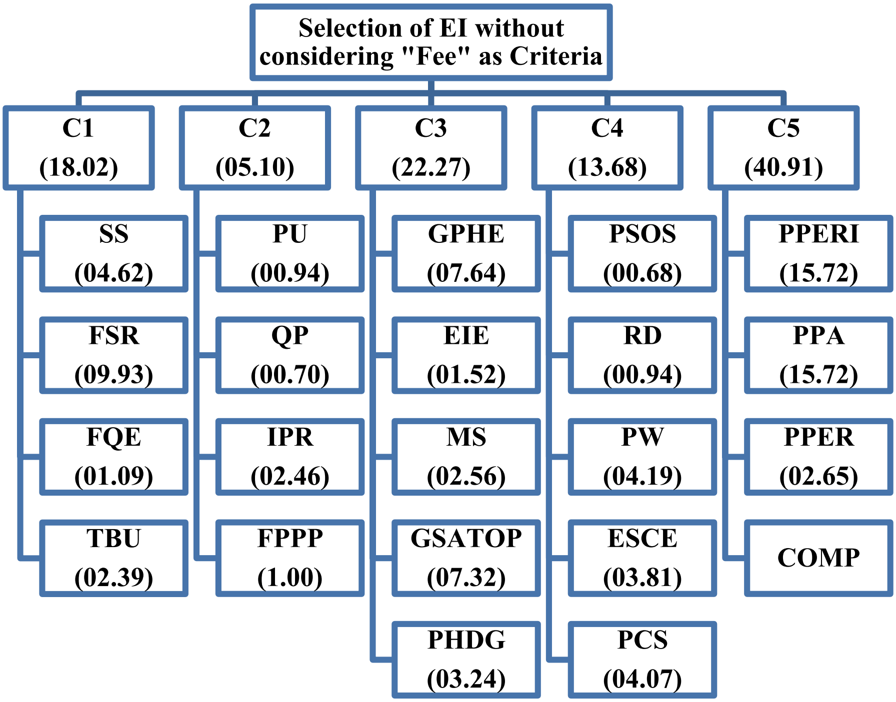

Fig.3 Final Sub-Criteria weights according to main criteria

Now, the further work flow is presented as algorithm in step wise manner. Later the working of proposed algorithm is explained with the help of above EI specifications as example. The algorithm is as follows:

Proposed algorithm

Step 1:	Model the main goal into criteria and sub-criteria
Step 2:	Separate out the criteria corresponding to investment (for example Fee or donation)
Step 3:	Apply the AHP method to calculate weights for criteria and sub-criteria expect the one which is separated in last step. Also calculate final weights for sub-criteria
Step 4:	Evaluate all the alternatives as per final weights and list out their benefits

Step 5: Take range for separated criteria (S), range for benefits (B) and number of recommendations (R) that user wants

Step 6: Identify the alternatives that satisfy the ranges of separated criteria and benefits, sort them on the basis of separated criteria and benefits as two lists

Step 7: Select same number of top alternatives as user wants from both sorted lists

Step 8: Perform the intersection in both sorted lists to identify best alternatives that satisfy both ranges

Step 9: Show the final result as identified alternatives in last step

In above algorithm, steps 5 to 9 are novel contribution to enhance the capabilities of AHP method. This algorithm is termed as AHP extension for separated criteria (S), range for benefits (B) and number of recommendations (R) method and abbreviated as AHP-SBR.

Final result

Evaluation of proposed AHP-SBR algorithm for EI section

Explanation of proposed algorithm with example: Suppose the student provided range of Fee 00.22 lakhs to 01.01 lakhs, benefits range 20 to 60, and number of recommendations as 4. Then the proposed system results in following options as listed in Table 20.

Total seven numbers of alternatives are there which satisfies both the ranges. On the other hand, as per the student's input only four are show in Table 20. From the above results it is easily concluding that the **EI-ID 26** is fulfilling both the

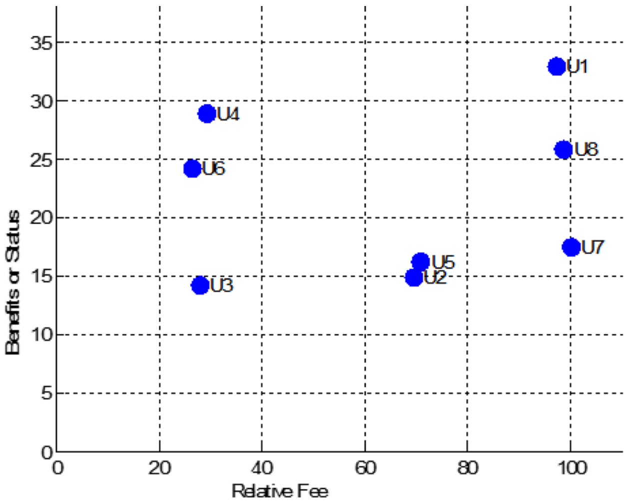

Fig.4 "Fee" Vs "Benefit" analysis for EI

Table 19 EI specifications for simulation

S. No	C_1	C_2	C_3	C_4	C_5	Fee (In INR Lakhs)
1	1	1	2	2	1	00.20
2	2	2	3	1	1	01.68
3	3	3	4	1	1	01.66
4	4	4	4	2	3	03.11
5	1	3	1	3	3	05.12
6	1	2	5	3	4	00.50
7	2	3	2	2	2	03.96
8	3	2	3	3	2	00.34
9	4	4	5	5	1	01.59
10	4	1	2	2	4	00.22
11	1	1	3	1	2	00.75
12	4	4	5	1	3	00.26
13	4	1	2	2	2	01.51
14	2	2	1	3	4	02.70
15	3	4	1	5	3	02.90
16	3	1	5	2	3	01.96
17	3	3	3	3	2	02.55
18	2	2	3	2	3	00.99
19	4	3	5	2	3	00.45
20	4	3	3	5	3	00.67
21	1	2	5	1	3	01.40
22	2	4	5	2	2	01.25
23	3	4	1	3	2	02.81
24	2	2	1	5	4	02.21
25	4	1	2	2	4	01.93
26	4	4	3	3	1	00.35
27	4	3	3	2	1	00.20
28	4	1	5	2	2	01.25
29	1	3	3	2	4	03.62
30	1	2	2	1	3	00.47
31	1	4	2	2	2	02.35
32	2	2	5	1	2	00.83
33	3	2	1	5	1	00.59
34	3	1	2	2	1	00.55
35	3	4	2	5	2	01.92
36	3	2	3	3	4	02.29
37	2	1	2	2	1	04.76
38	2	2	3	3	3	04.75
39	2	3	5	2	4	00.38
40	1	1	2	5	3	00.57
41	1	3	3	3	2	01.08
42	2	2	3	5	4	02.05

Table 19 (continued)

S. No	C_1	C_2	C_3	C_4	C_5	Fee (In INR Lakhs)
43	2	3	5	2	3	01.53
44	3	2	3	3	2	02.78
45	1	2	3	3	2	04.93
46	1	1	1	2	3	03.13
47	4	1	5	5	3	00.57
48	3	2	1	2	2	03.47
49	4	3	3	2	4	02.01
50	2	3	1	1	2	01.34

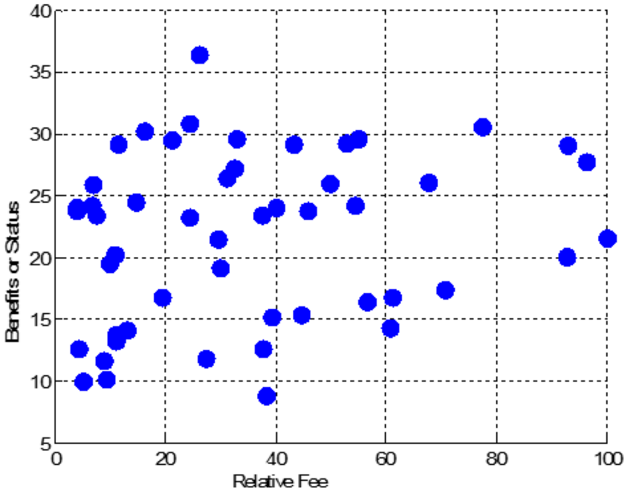

Fig. 5 "Fee" Vs "Benefit" analysis for 50 EI

student's requirements. Hence, the developed AHP-SBR algorithm with suggested approach can also be used in real life for EI selection.

Conclusion

This work demonstrated decision-making method for the EI Selection. This work presented a complex an EI selection decision-making process in which several criteria simultaneously considered. The proposed AHP-SBR algorithm is easy to implement in the EI Selection decision-making problem because it simplifies the understating of criteria, benefits, and recommendations to students and parents. The criteria adopted in this work is adequate as this work utilizes the selection criteria from the National Institutional Ranking Framework (NIRF) approved by the

Table 20 Top 4 options as per student's requirement with priority as Fee/benefit

Fee as priority			Benefit as priority		
EI ID	Fee	Benefit	EI ID	Fee	Benefit
8	0.34	24.26	32	0.83	30.25
26	**0.35**	**25.86**	33	0.59	29.21
39	0.38	23.38	**26**	**0.35**	**25.86**
34	0.55	20.21	11	0.75	24.50

Bold font indicates best common results obtained for both priority

Ministry of Human Resource Development Government of India to rank higher education institutions. The results are obtained from a simulation of over 50 educational institutes alterative that covers almost all types of fees and benefits criteria. This work enables decision-makers to structure a decision-making problem into a hierarchy and prioritizes based on their criteria relative importance weight. Hence, the approach and proposed algorithm presented would be beneficial for the students and parents as well as new teaching aspirants for the EI selection. This work also worked as a tool for assessing the effectiveness of higher education institutions. This work will also provide a direction to properly allocate funding, prioritize research and educational grants to the establishment. There are not any significant challenges or limitations of the proposed work. Further, the accuracy of the outcome of the proposed work depends on the qualitative data evaluation.

Declarations

Conflict of interest None.

References

Agha, S. R., Jarbo, M. H., & Matr, S. J. (2013). A multi-criteria multi-stakeholder industrial projects prioritization in Gaza Strip. *Arabian Journal for Science and Engineering, 38*(5), 1217–1227.

All India Survey on Higher Education (2018–2019). Government of India. Ministry of Human Resource Development. Department of Higher Education, New Delhi. Retrieved from www.mhrd.gov.in

Ancheh, K. S. B., Krishnan, A., & Nurtjahja, O. (2007). Evaluative criteria for selection of private universities and colleges in Malaysia. *Journal of International Management Studies, 2*(1), 1–11.

Ardeshir, A., Mohseni, N., Behzadian, K., & Errington, M. (2014). Selection of a bridge construction site using fuzzy analytical hierarchy process in geographic information system. *Arabian Journal for Science and Engineering, 39*(6), 4405–4420.

Begičević, N., Divjak, B., & Hunjak, T. (2010). Decision-making on prioritization of projects in higher education institutions using the analytic network process approach. *Central European Journal of Operations Research, 18*(3), 341–364.

Biswas, T. K., Chaki, S., & Das, M. C. (2019). MCDM technique application to the selection of an Indian institute of technology. *Operational Research in Engineering Sciences: Theory and Applications, 2*(3), 65–76.

Budiyanto D (2017, November) AHP-TOPSIS on selection of new university students and the prediction of future employment. Paper presented at 2017 1st International Conference on Informatics and Computational Sciences (ICICoS) pp. 125–130). IEEE

Clayton, K. E., Blumberg, F. C., & Anthony, J. A. (2018). Linkages between course status, perceived course value, and students' preference for traditional versus non-traditional learning environments. *Computers & Education, 125*, 175–181.

Dawes, P. L., & Brown, J. (2002). Determinants of awareness, consideration, and choice set size in University choice. *Journal of Marketing for Higher Education, 12*(1), 49–75.

Gabrielsen E (1992) The role of self-monitoring, conformity, and social intelligence in selection of a college major. Annual Conference of the Eastern Psychological Association.

Goraya, M. S., & Singh, D. (2021). A comparative analysis of prominently used MCDM methods in cloud environment. *The Journal of Supercomputing, 77*(4), 3422–3449.

Job, J., & Sriraman, B. (2013). A framework for quality assurance in globalization of higher education: A view toward the future. *Interchange, 43*(2), 75–93.

Kaynama, S. A., & Smith, L. W. (1996). Using consumer behavior and decision models to aid students in choosing a major. *Journal of Marketing for Higher Education, 7*(2), 57–73.

Kiani, M., Bagheri, M., Ebrahimi, A., & Alimohammadlou, M. (2019). A model for prioritizing outsourceable activities in universities through an integrated fuzzy-MCDM method. *International Journal of Construction Management*. https://doi.org/10.1080/15623599.2019.1645264

Kramulová, J., & Jablonský, J. (2016). AHP model for competitiveness analysis of selected countries. *Central European Journal of Operations Research, 24*(2), 335–351.

Kumar, P., & Tandon, P. (2017). Improvised concept development process in design through product ingredients. *International Conference on Research into Design* (pp. 453–463). Singapore: Springer.

Kumar, P., & Tandon, P. (2019). A paradigm for customer-driven product design approach using extended axiomatic design. *Journal of Intelligent Manufacturing, 30*(2), 589–603.

Kumar, P., & Tandon, P. (2021). Design Decision in the Manufacturing Environment Using an Improved Multiple-Criteria Performance Evaluation Method. Arabian Journal for Science and Engineering, 1–12.

Kumar, P., & Tiwari, A. (2021). MCDM-Based Decision Support System for Product Design and Development. *Design for Tomorrow—Volume 2* (pp. 575–584). Singapore: Springer.

Lapan, R. T. (1996). Efficacy expectations and vocational interests as mediators between sex and choice of math/ science college majors: A longitudinal study. *Journal of Vocational Behavior, 49*(3), 277–291.

Madeshia, P. K., & Verma, S. (2020). Review on higher education in India. *Journal of Critical Reviews, 7*(10), 1161–1164.

Mardani, A., & Jusoh, A. (2015). Zavadskas EK (2015) Fuzzy multiple criteria decision-making techniques and applications–Two decades' review from 1994 to 2014. *Expert Systems with Applications, 42*(8), 4126–4148.

Mousavi, S. M., Tavakkoli-Moghaddam, R., Heydar, M., & Ebrahimnejad, S. (2013). Multi-criteria decision making for plant location selection: An integrated Delphi–AHP–PROMETHEE methodology. *Arabian Journal for Science and Engineering, 38*(5), 1255–1268.

Proboyo, A., & Soedarsono, R. (2015). Influential factors in choosing higher education institution: A case study of a private EI in Surabaya. *Jurnal Manajemen Pemasaran, 9*(1), 1–7.

Saaty, R. W. (1987). The analytic hierarchy process—What it is and how it is used. *Mathematical Modelling, 9*(3–5), 161–176.

Salimi, N., & Rezaei, J. (2015). Multi-criteria university selection: Formulation and implementation using a fuzzy AHP. *Journal of Systems Science and Systems Engineering, 24*(3), 293–315.

Shayganmehr, M., & Montazer, G. A. (2020). An extended model for assessing E-services of Iranian Universities websites using Mixed MCDM method. *Education and Information Technologies, 25*(5), 3723–3757.

Smutny, P., & Schreiberova, P. (2020). Chatbots for learning: A review of educational chatbots for the Facebook Messenger. *Computers & Education, 151*, 103862.

Soutar, G. N., & Turner, J. P. (2002). Students' preferences for university: A conjoint analysis. *International Journal of Educational Management, 16*(1), 40–45.

Vikaspedia, Accessed 14 May 2021 https://vikaspedia.in/education/education-best-practices/national-institutional-ranking-framework

Winchester, I. (1992). Elite and ordinary: The essential tension in the university. *Interchange, 23*(1), 91–95.

Authors and Affiliations

Mitul Kumar Ahirwal[1] · **Prabhat Kumar**[2]

Mitul Kumar Ahirwal
ahirwalmitul@gmail.com

1 Department of Computer Science and Engineering, MANIT, Bhopal, Madhya Pradesh 462003, India

2 Department of Fashion and Lifestyle Accessories, NIFT, Bhopal, Madhya Pradesh 462016, India