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Integrating Fuzzy Decision-making Model for e-teaching Adoption for the Education Sector

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Abstract. The COVID-19 pandemic has altered educational ideologies all over the world. The educational system has shifted drastically away from traditional teaching methods to online teaching mechanisms. Nowadays, e-teaching is rapidly developing as a part of education for social advancement and wellness care. There are numerous factors influencing the adoption of e-teaching in developing countries. The purpose of this study is to determine the factors that influence adoption in the education sector. We investigate the factors from the systematic literature in order to develop a new decision-making model. Therefore, we have adopted an integrated fuzzy approach with Decision Making Trial and Evaluation Laboratory (DEMATEL) and Fuzzy Order of Preference by Similarity to Ideal Solution (Fuzzy TOPSIS), to reveal the interrelationships between the factors and determine their relative importance in the decision-making model. The findings of this study will allow relevant parties in the education sector to potentially assign development or quality of education in developing countries.

Keywords: e-teaching, e-teaching adoption, DEMATEL, fuzzy TOPSIS, decision-making model

1. Introduction

In early 2020, the COVID-19 pandemic was declared a national emergency in the majority of countries. These pandemic compelled counties all over the world to implement a series of emergency management procedures [1]. The government of various countries-initiated measures such as city lockdowns, the closure of educational institutions, and the implementation of strict social distancing measures. In addition, approximately 1.482 billion learners were impacted by the closure of educational institutions in response to the pandemic until March 2021. According to UNESCO monitoring, 149 countries have implemented nationwide academic institution closures and 8 have implemented local closures, affecting about 79 percent of the world's student population (UNESCO Report, 2021) [2]. The Chinese Government started a strategic maneuver known as “Suspending Classes without Stopping Learning”, and later followed by governments of other countries to transition to e- teaching while educational institutions were closed. In the past, infectious illness epidemics such as swine flu have forced massive universities closings around the globe, with varying levels of effectiveness [3]. The education instantiations closures that occur later in the course of a pandemic, are less effective and should not have any impact in the least. Additionally, in exceptional instances, the reopening of educational institutions after a period of closure has resulted in higher infection rates. As closures often occur in tandem with other interventions, such as public gathering bans, it is often difficult to live the precise impact of institutions’ closures.

The present research is an effort to determine the factors which influence the adoption of e-teaching at the time of the post-COVID-19 pandemic. COVID-19 pandemic motivated academic institutions and educational institutions to go online. The teachers and students are exposed to new platforms such as Zoom, Google Hangouts, and others. In order to conduct classes smoothly, proper protocols and directions were given to the students as well as parents to facilitate the adoption of this novel channel of learning [4]. Several previous research studies have empirically validated factors leading to online platforms but the majority of these studies have focused on higher education before the COVID-19 pandemic [5]. There are negligible studies focusing on the adoption of e-teaching. To the best of the author’s understated, this is the first study in the Indian context to understand the factors influencing e-teaching adoption and developing the new decision-making model.

2. Literature Review

2.1. Previous works on e-teaching

Barhoumi et al., [6] looked into and examined the individual aspects that influence teachers' attitudes towards e-teaching and learning delivery. The data were subjected to the optimal scaling analysis technique. It was discovered that there is a link between physical teaching environment preferences and the conceptions of e-teaching motivation. [3] studied on the factors that influence network teaching. The analysis was carried out using structural equation modelling. It was shown that pupils who choose different adoption methods have different persuasive qualities. Regardless of students' learning preferences and the impact of utility value on web-based education, there is a stronger link between the learning task and the career prospects in the present and future periods. [7] focused studied how negative impressions can lead to poor e-teaching adoption outcomes, such as a lack of motivation and persistence. A comprehensive study of the literature was conducted. It was stressed that the student is responsible for rereading course/study material, passing examinations at predetermined intervals, and other responsibilities, all of which demand adequate self-direction skills for online platforms. [1] examined the proof of e-effectiveness teaching's by establishing and briefing the results as well as unwanted, random, and useless findings. As a result, this research analyses the criteria for e-teaching adoption in the education sector and provides a decision-making model.

There are several challenges from the perspectives of teachers and students to move a physical class to the online class mode of learning [8]. Another stumbling factor in the deployment of e-teaching in rural-based educational organizations is engaging teachers and delighting them in instructional advancement [9]. The necessity of the hour is to provide content that not only covers the curriculum but also engages teachers and students. Furthermore, while e-teaching adoption is commendable during COVID-19, it is equally critical to create and improve the teaching quality and subject matter given during the epidemic. To deliver e-teaching, an operational, competent, and resourceful educational system is required. There are numerous technical challenges, such as internet issues, technology installation issues, downloading issues, inaudible video and voice, and so on [10]. E-classes are also uninteresting for pupils because there is less physical interaction. As a result, the current study was conducted to better understand professors' and teachers' perspectives so that adequate efforts might be made to improve delivery, evaluation, and interaction between teachers and students. However, at this stage of the epidemic, the current study may provide important information to educational organizations for e-teaching implementation.

2.2. Proposed model for e-teaching adoption

Based on previous research, we can conclude that the majority of studies in e-teaching have been conducted from individual perspectives [11]. Furthermore, it is discovered that institutional and teacher readiness for developing countries is not investigated. Many educational institutions in developing countries are still in the early stages of implementing e-teaching. However, according to this study, the success of educational institutions in adopting e-learning is related to an organization's readiness to provide online services. As a result, the purpose of this research is to close this gap by developing a tripod readiness model for e-teaching adoption in India. The readiness of educational institutions for online services is critical, as its adoption is still far from its full potential due to a variety of readiness issues.

The hierarchical model, as shown in Fig. 1, has three levels: the goal (decision to adopt), the criteria levels (technological, institutional, teacher readiness, and environmental factors), and the sub-criteria level, which includes 12 factors [12]. The goal is to determine which readiness criteria can have a significant impact on educational institutions adopting e-learning. Furthermore, as stated in the research model, finding the interrelationships between these readiness criteria will be a contribution of this research.

3. Methodology

In this study, we use DEMATEL and Fuzzy TOPSIS techniques to analyze data in order to determine the importance levels of factors and the relationships between them in the model. Therefore, Fuzzy TOPSIS and DEMATEL were used in this study to identify the most important factors and analyze the interrelationships among factors for e-teaching adoption for educational institutes in India. The methodology used is described in detail in the following sections.

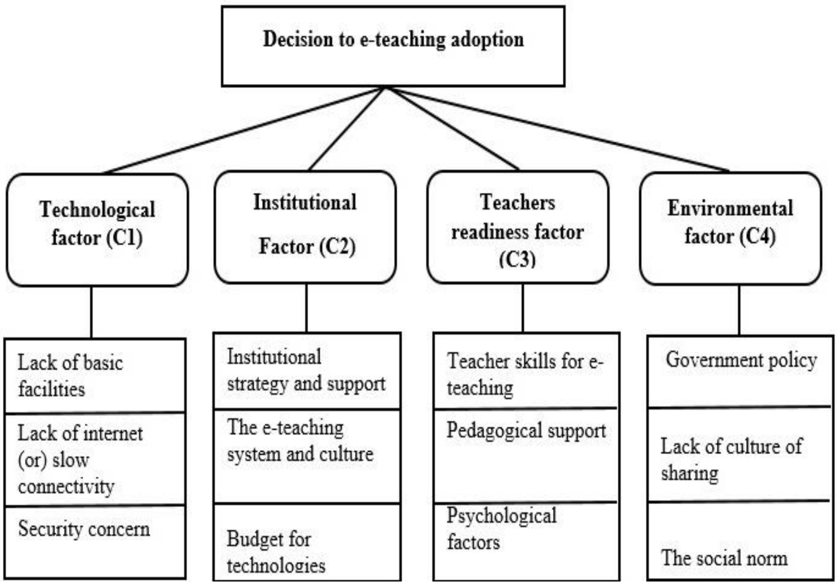

Fig. 1: Proposed model for e-teaching adoption

3.1. Fuzzy TOPSIS Analysis

In decision-making problems, multi-criteria decision-making approaches are widely used [8]. The Fuzzy TOPSIS technique has been successful in finding the best solution under uncertainty through expert opinion as a multi-criteria decision-making approach. The Fuzzy TOPSIS scales are used to collect data as shown in Table 2. The following steps are performed to find the best criteria for k decision-makers Dr (*r* = 1, 2..., k) and a decision-making problem with m criteria and n alternatives Ai (i = 1, 2..., *n*).

Step 1: The weights of criteria and alternative ratings are aggregated using the following Eqs. (1 and 2):

$$w_j = \frac{1}{k}\left[w_j^1 + w_j^2 + \cdots + w_j^k\right] \quad (1)$$

$$x_{ij} = \frac{1}{k}\left[x_{ij}^1 + x_{ij}^r + \cdots + x_j^k\right] \quad (2)$$

where the weight of the *j*th criterion (C_j) is expressed by W_r^j.

Step2: Using the following Eqs. (3 and 4), create the fuzzy decision matrices for the criteria and the alternative (D).

$$W = [w_1 + w_2 + \cdots + w_m] \quad (3)$$

$$D = \begin{matrix} A_1 \\ A_j \\ A_n \end{matrix}\begin{bmatrix} X_{11} & X_{12} & X_{1j} & X_{1m} \\ . & . & . & . \\ . & . & . & . \\ X_{n1} & X_{n2} & X_{nj} & X_{nm} \end{bmatrix} \quad (4)$$

Step 3: Using the following Eqs. (5, 6 and 7), construct the normalized fuzzy decision matrix R:

$$R = [r_{ij}]_{m\times n} \quad (5)$$

$$r_{ij} = \left(\frac{l_{ij}}{u_{ij}^+}, \frac{m_{ij}}{u_j^+}, \frac{u_{ij}}{u_j^+}\right) \text{ and}$$

$$u_j^+ = max_i u_{ij} (\text{benefit criteria}) \quad (6)$$

$$r_{ij} = \left(\frac{l_j^-}{u_{ij}}, \frac{l_j^-}{m_{ij}}, \frac{l_j^-}{l_{ij}}\right) \text{ and}$$

$$l_j^- = max_i l_{ij} (\text{cost criteria}) \quad (7)$$

Step 4: Using the following Eq. (8), construct the weighted normalize decision matrix V.

$$V = [v_{ij}]_{m\times n,} v_{ij} = X_{ij} \times w_j \quad (8)$$

Step 5: Compute the Fuzzy Negative Ideal (FNIS, A^{-}) and the Fuzzy Positive Ideal Solution (FPIS, A^{+}) through the following Eqs. (9) and (10):

$$A^{+} = \{v_1^{+}, v_j^{+}, \dots, v_m^{+}\} \quad (9)$$

$$A^{-} = \{v_1^{-}, v_j^{-}, \dots, v_m^{-}\} \quad (10)$$

where $v_j^{+} = (1,1,1)$ and $v_j^{-} = (0,0,0)$.

Step 6: Compute the distances indicated of each alternative from v_j^{+} and v_j^{-} using the following Eqs. (11,12 and 13):

$$d_i^{+} = \sum_{j=1}^{n} dv(v_{ij}, v_j^{+}) \quad (11)$$

$$d_i^{-} = \sum_{j=1}^{n} dv(v_{ij}, v_j^{-}) \quad (12)$$

$$d(x,z) = \sqrt{\frac{1}{3}[(l_x - l_z)^2 + (m_x - m_z)^2 + (u_x - u_z)^2} \quad (13)$$

Using the following Eq. (14), compute the closeness coefficient CC_i:

$$CC_i = \frac{d_i^{-}}{d_i^{+} + d_i^{-}} \quad (14)$$

Step 8: in decreasing order, compute the ranks of the alternatives based on CC_i.

3.2. DEMATEL Analysis

In addition, DEMATEL is one of the most effective techniques for determining and analyzing the interdependence of system factors. This method converts the causal relationships between the indicator factors into a measurable structural model. The DEMATEL technique divides the factors into two groups based on cause and effect. The steps of DEMATEL analysis is a follow [9]:

Step1: Generating the direct-relation matrix (A)

After compiling a list of relevant criteria or factors based on the DEMATEL scale, each expert is asked to make pairwise comparisons between one factor and another. Then, using Eq., any individual options and assessments about the causality between one factor and another factor obtain each export's initial-relation matrix (15). Table 3 illustrates the inter-relationship between factors using a scale ranging from 0 to 4, which is very high influence, high influence, low influence, very low influence, and no influence. As shown in Eq. (15) the same method would be used to fill out all exports. There are p exports where p = 1, 2, 3... n. The equation is as follows:

$$A_p = \begin{bmatrix} 0 & a_{12} & a_{13} & \dots & .a_{1(n-1)} & a_{1n} \\ a_{21} & 0 & a_{23} & \dots & a_{2(n-1)} & a_{2n} \\ \dots & \dots & \dots & \dots & \dots & \dots \\ \dots & \dots & \dots & \dots & \dots & \dots \\ a_{(n-1)1} & a_{(n-1)2} & a_{(n-1)3} & \dots & 0 & a_{(n-1)n} \\ a_{n1} & a_{n2} & a_{n3} & \dots & a_{n(n-1)} & 0 \end{bmatrix} \dots \quad (15)$$

Here, A_p identify each export interactions option among factors

Step2: Normalizing the direct-relation matrix (X)

The normalizing direct-relation matrix (X) is computed in this step of the process. It is possible to do so by using the formula in the following Eqs. (16 and 17):

$$X = k \cdot A \quad (16)$$

$$\text{Here } k = \frac{1}{\max_{1<i<n} \sum_{j=1}^{n} a_{ij}}, \text{ i, j=1, 2,….,n} \quad (17)$$

'A' denotes the initial-relation matrix as defined by Eq. (15), 'k' the average of all experts' aij, and 'X' the normalized direct-relation matrix. It should be noted that the number of columns in the normalized direct-relation matrix must be less than one for the DEMATEL approach to be feasible.

Step3: Calculate the total-relation matrix (T)

The total-relation matrix (T) is evaluated in this step using the following Eq (18):

$$T = X\,(I - X)^{-1} \quad (18)$$

In this Eq. (16), 'I' stands for identity matrix, 'T' stands for total-relation matrix, and 'X' stands for normalizing matrix.

Stage 4: Draw a causal diagram

The total-relation matrix ‘T' computes the sum of a number of rows (D) and the sum of a number of columns (R). D and R are calculated in the ‘T’ matrix with the use of the following Eqs. (19 and 20).

$$(D) = [d_{ij}]_{n \times 1} = \left[\sum_{j=1}^{n} d_{ij} \right]_{n \times 1} \quad (19)$$

$$(R) = [r_{ij}]_{1 \times n} = \left[\sum_{i=1}^{n} r_{ij} \right]_{1 \times n} \quad (20)$$

Furthermore, to calculate the threshold value (α), all elements of the averages contained in the matrix 'T' are added and divided by the number of elements in the matrix. This calculation is carried out using the following Eq. (21):

$$\alpha = \frac{\sum_{j=1}^{n} \sum_{i=1}^{n} r_{ij}}{n^2} \quad (21)$$

Here, the total number of elements in the total relation matrix ‘T' is represented by n2. As the number of barriers =n, so, number of total elements in matrix T= $n \times n = n^2$

The linking diagram is created in the future by plotting the values of (R+D) and (R - D). The Y-axis in this diagram represents the values of (R-D), while the X-axis represents the values of (R+D). The interrelationships between the factors are described using a driven graph. Values in the 'T' matrix that match or exceed α are considered to have a high level of influence. The influential strength matrix is used to generate the directed graph.

Table 1: Assessment of data collection in present study

Reason	Sample size	Sample characteristics				
		Institution category		Education level (majority)	Work experience	Working on e-teaching
		Schools	Universities			
Fuzzy TOPSIS	42	23	19	Graduated	>10 years	<2 years
DEMATEL	27	16	11	Graduated	>10 years	<2 years

3.3. Data Collection

In this study, the authors were collected the data to perform Fuzzy TOPSIS and DEMATEL using random sampling techniques from the educational organizations in India as shown in Table 1. The scale for data collection is shown in Tables 2 and 3. Moreover, it is showing that the decision-makers come from primary and secondary schools and universities. Most of the decision-makers have worked on e-teaching for less than two years and a majority of them had more than ten years of working experience as a teacher in their respective organizations. In addition, all decision-makers were graduated from well-known universities in India. Based on the decision maker’s assessment, this study analyzes the factors by using fuzzy TOPSIS and DEMATEL analysis.

Table 2: The correspondence of fuzzy TOPSIS Scale

Linguistic terms	Fuzzy value
Very High	(0.85,0.95,1)
High	(0.70,0.80,0.90)
Medium High	(0.50,0.65,0.80)
Medium	(0.30,0.50,0.70)
Medium Low	(0.20,0.35,0.50)
Low	(0.10,0.20,0.30)
Very Low	(0,0.05,0.15)

Table 3: The correspondence of DEMATEL Scale

Linguistic terms	Numerical value
Very high influence	4
High influence	3
Low influence	2
Very low influence	1
No influence	0

4. Results

In the first step of data analysis, the Fuzzy TOPSIS questionnaire was designed based on a 7 scale and distributed. The experts provided the importance of each factor of the decision-making model based on these linguistic scales. Then, the average scores and linguistic terms corresponding to the average fuzzy scores of the readiness factors were then computed. Table 4 shows the results final ranking of the Fuzzy TOPSIS analysis.

In addition, questionnaires for the DEMATEL survey were distributed. The purpose of this study was to discover the interrelationships between four readiness criteria and to determine the value of each element in instructors' decisions to use e-teaching in India. The influence rates of teachers factor on technological, institutional, and environmental aspects are T = 0.73, T = 0.72, and T = 0.66, respectively as shown in Fig. 2. Furthermore, the technological component has a T = 0.71 and T = 0.73 influence rate on institutional and teachers' aspects, respectively. The findings also show that there is a considerable relationship between teachers and institutional elements, with a T = 0.72 effect rate.

Table 4: The final ranks of factors of new decision-making model

Criteria	Sub criteria	d_i^-	d_i^+	Closeness coefficient	Final rank
Technological factors (C1)	Lack of basic facilities	0.6571	4.3156	0.8094	2
	Lack of internet (or) slow connectivity	0.9654	4.896	1.1626	1
	Security concern	0.6421	4.6894	0.7790	3
Institutional factors (C2)	Institutional strategy and support	0.9156	4.0154	1.1436	1
	The e-teaching system and culture	0.6958	4.672	0.8447	2
	Budget for technologies	0.6581	4.4671	0.8054	3
Teachers readiness factors (C3)	Teacher skills for e-teaching	0.987	4.1942	1.2223	1
	Pedagogical support	0.0871	4.0103	0.1088	3
	Psychological factors	0.6428	4.5832	0.7831	2
Environmental factors (C4)	Government policy	0.7951	4.2398	0.9826	2
	Lack of culture of sharing	0.9125	4.1589	1.1319	1
	The social norm	0.6487	4.354	0.7977	3

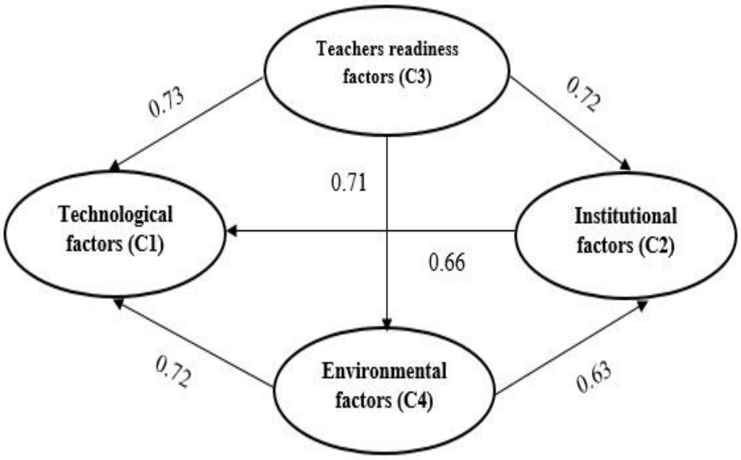

Fig. 2 Interrelationships between criteria

5. Conclusions

In this research, the attempt was made to develop a decision-making model for the adoption of e-teaching using the fuzzy integrated methodology. However, the findings of DEMATEL data analysis revealed that, from the perspectives of teachers, that technological and environmental factors are more important than teachers and institutional factors in the decision to e-teaching adoption in the educational sector. The findings also revealed that the teachers, environmental, and institutional factors all had a significant influence (net receiver factor) on the technological factor. The Fuzzy TOPSIS results revealed the significance of the criteria in each factor. The data analysis results revealed that among all readiness, teacher skills for e-teaching and a lack of internet (or) slow connectivity are more important.

The findings of this study have important implications for educational policymakers who want to encourage the adoption of e-teaching during a pandemic outbreak. The study's findings suggest that organizational administrators should improve technological expectancy because it has a significant relationship with teachers' readiness factors intention and attitude to adopt e-teaching. Teachers must be trained on the benefits and utility of online teaching if performance expectations are to be met. Furthermore, teachers who do not understand the technology's utility were unable to adopt it. Teachers who conduct classes online may be able to persuade their colleagues to adopt e-teaching. A positive incentive could also be associated with teachers who promote and motivate their colleagues to use e-teaching. These organizations could also share their experiences with teachers who are hesitant to use technology. Because facilitating conditions emerge significantly, this indicates that infrastructural support for online teaching is well established in schools, and it can enable both behavioral intention and actual use. The school administration should organize regular query handling and training sessions for teachers so that the teachers understand the intricacies of the system. During a pandemic, school officials must instill in teachers a positive attitude toward the utility of online education. COVID 19 Finally, the strong relationship between intentions and actual use suggests that an “institutional factor -environmental factors gap” is highly unlikely in the context of e-teaching adoption. This may be explained by the fact that, in contrast to other highly involved behaviors where the gap is very acute, the actual behavior under study (i.e., using e-teaching during a pandemic) is not as difficult to perform and does not necessitate as much commitment or motivation. Instead, it fits well into a wide range of lifestyles, especially given that most people now use e-teaching for a variety of purposes. This study has theoretical and methodological limitations. In this study, a limited number of readiness criteria for e-teaching adoption in India are investigated.

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