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Prioritization of University Choice Dimensions using Fuzzy DEMATEL

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Abstract

Marketing in higher education has yet to prove its mettle in its theoretical models applications albeit, instances of application of marketing concepts are growing. This study is an effort to present an application of consumer choice behavior model in higher education with one of the tools of Fuzzy Multiple-Criteria Decision-Making (FMCDM) sphere, specifically, Fuzzy Decision Making Trial and Evaluation Laboratory (DEMATEL) method was used. Five university choice dimensions, based on consumer choice model in the realm of higher education in Pakistan, were chosen for the purpose of prioritization of these dimensions from the higher management perspective of several local and regional universities. The resultant digraph of fuzzy DEMATEL method showed that "University Competence" as a dimension was highest on importance axis and "University History" was the lowest as a dimension. On relationship axis of digraph, all the four dimensions "University Competence", "Market Worth", "Value-added Activities", and "Amenities Offered" were the causal factors having a concomitant effect on the fifth dimension "University History". The importance with cause and effect relationship digraph also enabled us to look into the structural framework that was inherent by studying the cause and effect groups of university choice dimensions. The prioritization of criteria/dimensions also elicits the steering factors for higher management of any university as what dimensions must be concentrated and focused on while formulating and implementing marketing strategies in higher education domain.

Keywords: Decision Making Trial and Evaluation Laboratory (DEMATEL), University Choice, Consumer Choice Behavior Model, Fuzzy MCDM.

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INTRODUCTION

Every year, since generations, a perplexing ritual of choosing a university is performed by young students and this ritual, no doubt, is a very important rite of passage for them. The choice behavior of aspiring students is simultaneously important for them as well as for universities to attract these prospective students. Delving deep into any prospective student's psyche to better understand their decision-making process by virtue of that student's choice behavior model (innately shaped by certain influencing factors), is therefore, fruitful for universities (Alonderiene and Klimaviciena, 2013). The better the knowledge a university gains by understanding the complex consumer choice behavior model, the better a university's marketing and admission departments would work.

For any university to understand the confusing scenario that any student undergoes while latently implementing on the choice behavior model, the decision-making process must be deciphered in operational terms. The higher management of a university must endeavor to comprehend the complex causal relationship of customer choice behavior with a pertinent solution to capitalize the inherent opportunities in consumer decision-making process based on choice behavior. The multiplicity of criteria, decision-makers, and dimensions latently influenced by multiple factors makes the undertaking of comprehension of the process, a multi-dimensional problem. Moreover, as the identification of any multi-criteria decision making dimensions remains fuzzy (in contrast to straight, unidirectional and crisp 'yes' or 'no' decisions) while evaluation, a fuzzy multiple-criteria decision-making (FMCDM) system would be a panacea to the problem. Among other equally sophisticated FMCDM techniques, fuzzy DEMATEL (Decision Making Trial and Evaluation Laboratory) method is a structural modeling approach about a problem (Chen-Yi et al., 2007). The cause-and-effect problems could easily be solved by employing this technique. The business situation in our environment are made by human beings and they themselves think in fuzzy terms. The decision support systems developed by them give out crisp values while identifying the structural model. The crisp values given by these systems are inadequate to replicate the decision-making process of a human being (e.g. a decision maker). Thus the application of fuzzy theory along with DEMATEL for FMCDM situation deems fit for the cause.

With above preamble, in this study, we tried to provide a fuzzy DEMATEL framework that incorporates the factors (or criteria dimensions) and graph theory together as an empirical way of solving the students' purchase-decision problems reflected as an outcome of choice behavior while choosing a university. The focus of the study is to facilitate the higher management of a university to evaluate the criteria dimensions and operationalize marketing strategies to capitalize on the outcomes.

BACKGROUND

Consumer's Choice Behavior

Despite the original ideas' proposition of the choice set concept in 60's, same is still valid as the proliferation of brands have grown tremendously and likewise the competition among them have also grown multi-fold ever since. Howard and Sheth (1969) explained the set of brands as a choice set available for customers. The eminent work by Shocker et al., (1991) defined that choice set comprises the attainable alternatives for a customer. Explaining the evoked set size of choice, Reilly and Parkinson (1985) highlighted that size of the set (number of brands in the set) generally relies on each consumer and the undertaken product category. It has now become imperative for marketing managers to ascertain the inclusion of their brands in the choice set of consumers as a plethora of alternative brands are available in current markets. This particular business need has given rise to several past studies which concentrated on the identification of certain marketing variables that elucidated the right choice significantly when consumer choice behavior was implemented.

University Choice Factors

The ubiquity of literature available on university choice factors are mostly directed towards the factors for a particular geographic place where an institution is located or exclusively focused on a certain institution. Table 1 summarizes a brief extant literature on university choice factors.

Table 1: Extant literature on university choice factors

No.	Research Author(s)	Focused on	Factors as result
1.	Brown et al (2009)	University course selection and services marketing	Organization of quality open days, enabled communication with university, admission requirements, reputation etc.
2.	Hagel & Shaw (2010)	Importance of study mode in university choice	On-campus face-to-face vs. online
3.	Joseph et al (2005)	Service quality of a university	Study programs, courses, costs, scholarships, campus, reputation etc.
4.	Maringe (2006)	Study program and university	Career and employment opportunities, elements of study program, price factors etc.
5.	Price et al (2003)	Infrastructure factors	Study program, teaching reputation, computer classrooms, quality of library infrastructure, quiet learning zones, and common learning zones etc.
6.	Reza S. & Nawaz R. R. (2014)	Brassington and Pettitt (2006) theoretical model	Several indigenous dimensions identified in Quetta, Pakistan context.
7.	Veloutsou et al (2004)	Need and importance of information	Structure of study program, information related to career opportunities, business contacts, It and library infrastructure, faculty, reputation etc.

Marketing in higher education domain

Albeit, Hemsley-Brown and Oplatka, (2006) identified that the domain of marketing in higher education is deficient in theoretical models being applied by the universities, they acknowledged that the instances of application of marketing concepts are growing. There has been numerous studies highlighting various marketing concepts applications in higher education ever since Hemsley-Brown and Oplatka (2006) study surfaced. Durkin et al., (2012) and Moogan, (2010) studies are comparatively new with the trending patterns of marketing concepts applicable to a university.

Multi-criteria Multi-decision Fuzzy Set Theory

Professor Lotfi A. Zadeh (1965) founded the fuzzy set theory at University of California at Berkeley. Professor Zadeh (1965) posited that usually human beings does not absorb stern and precise numerical information as input but rather use the mechanism of their own to interpret these in imprecise approximations as they feel easy to comprehend them. Precise numerical information portrays the crisp values that could only be either 0 or 1. But on the other hand, fuzzy logic approximate reasoning with the use of linguistic variables that are more close to human thinking while evaluating or decision making. Fuzzy logic starts where the classical logic ends to encompass the vagueness of language, reasoning based on common-sense and heuristics involved in finding the solution, on a day-to-day basis, of a problem faced by human beings (Bojadziev and Bojadziev 2007).

Defining Fuzzy Sets

An object could be or could not be member of a set and this is a stern precise concept. So the membership rule of that object belonging to a set has only two crisp values 1 or 0. Object being the member of a set acquires value 1 or 0 being not the member of a set. At any given instant, an object membership function can only take one value from the two crisp values. Zadeh, (1965) presented the idea of intermediate degrees of membership between these two crisp values 0 and 1. These degrees of membership between the crisp values actually conceptualized the term fuzzy in contextual and functional terms as partial membership (contrary to either is or not) of an object to a set.

Triangular Fuzzy Numbers (TFNs)

Tzeng and Huang (2011) presented the definition of a triangular fuzzy number (TFN) according to Laarhoven and Pedrycz, (1983) as a fuzzy number A with a membership function μA(x) is a TFN and is equal to:

$$\mu_A(x) = \begin{cases} \frac{x-l}{m-l}, & l \le x \le m \\ \frac{r-x}{r-m}, & m \le x \le r \\ 0, & otherwise \end{cases}$$

Where, l and r denotes the lower and upper bounds respectively of the fuzzy number A, and m denotes the modal value (Figure 1) and the triangular fuzzy number (TFN) can be denoted by A = (l, m, r).

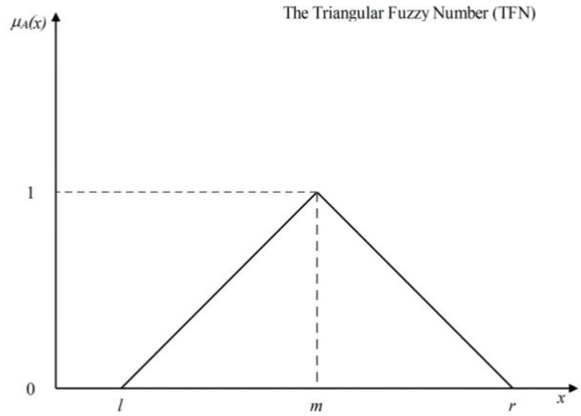

Figure 1: Triangular Fuzzy Number

Linguistic Variables

Zimmermann, (1991) defined linguistic variables are the manifestations of words, phrases, or sentences used in a natural language and not presented in numbers. Linguistic variables may have their own term-set which defines its complete range (Zadeh 1975, 1997). Usually in fuzzy logic based research, researchers employ language connectives (and, or, either, neither etc.), negation (not, no), and hedges (very, more, less, absolutely, weakly, moderately, greatly etc.). Zadeh, (1975, 1997) proposed that connectives along with hedges used as nonlinear operators and they change the meaning of their operands. In our study "Influence" is used as a linguistic variable and we adopted five linguistic terms proposed by Li, (1999) as connectives and hedges by suffixing words like "Very High", "High", "Low", "Very Low", and "No" to the linguistic variable "Influence". Following Li's (1991) five linguistic terms are presented (Table 2) in positive triangular fuzzy numbers (lij, mij, rij).

Table 2: Five levels of fuzzy linguistic scale for fuzzy DEMATEL

Linguistic Terms		Triangular Fuzzy Numbers
Very High Influence	(VHI)	(0.75, 1.0, 1.0)
High Influence	(HI)	(0.5, 0.75, 1.0)
Low Influence	(LI)	(0.25, 0.5, 0.75)
Very Low Influence	(VLI)	(0, 0.25, 0.5)
No Influence	(NI)	(0, 0, 0.25)

Fuzzy DEMATEL Method Process

The acronym DEMATEL means the Decision Making Trial and Evaluation Laboratory. This method was developed between 1972 and 1976 in Geneva research centre by Battelle Memorial Institute's Science and Human Affairs Program. DEMATEL's inception was operationalized for researching and solving complex and intertwined group decision making scenarios by gathering group knowledge, analyzing the intertwined attributes or criteria and gives output in shape of structural cause-effect relationship diagram (Fontela and Gabus, 1974, 1976; Warfield, 1976). The DEMATEL methodology brings forward the interdependence of multi-criteria or multi-attributes that reflect the characteristics of the system under study (Hori and Shimizu, 1999). Usually in everyday scenario, business decision makers make their preferential judgments which are often vague, unclear as their judgments are difficult to translate in to exact numerical values but still they are generally represented by crisp values. This particular aspect itself justifies the use of fuzzy logic for tackling issues and problems encompassed by imprecise and vague representation of human judgments (Chang et al., 1998; Chen and Chiou, 1999). For fuzzy environment like any given day we spend in life full of opinions and judgments not based on crisp values like 0 or 1 but instead use fuzzy estimations between these crisp values. For better decision making in fuzzy environments many researchers employ DEMATEL technique with fuzzy concepts (Jeng and Tzeng, 2012; Zhou et al., 2011; Chang et al., 2011; Wu and Lee, 2007). The end result of using DEMATEL analytical process is in a shape of graphical visual representation mapping the minds of individuals in group-decision making exercise.

METHODOLOGY

Wu and Lee, (2007) posited the following steps of fuzzy DEMATEL method:

Step 1: Identifying the decision goal and committee formation.

First, identification of decision goal is done and then a committee of experts is formed for collecting group knowledge for tackling the problem at hand.

Step 2: Developing evaluation criteria/attributes and designing the fuzzy linguistic scale.

Important attributes and criteria sets are necessarily developed in this step. A structural model should be developed in such a way that it should bifurcate the model into two aspects viz. cause group and effect group of criteria/attributes undertaken for evaluation for reaching the decision goal. The DEMATEL method must be operationalized for the purpose. While designing the fuzzy linguistic scale, which actually reflects the fuzziness of human judgments, the linguistic variable "influence" is utilized with its five linguistic levels (Li, 1999). These five levels are shown in Table 2 with their respective positive triangular numbers (lij, mij, rij).

Step 3: Acquiring and aggregating the assessments of decision makers.

In this step a group of decision makers (experts) is asked to mark their pair-wise judgments based on influences and directions between every single pair of evaluation attributes or criteria C = {Ci | i = 1, 2, 3, …, n}. The fuzzy data entered in to the matrix is converted into crisp scores by using the CFCS (Converting Fuzzy to Crisp Scores) method. The CFCS method involves five step algorithms which makes the fuzzy judgments and evaluations simultaneously de-fuzzified and aggregated with an output of a crisp value, zij. So a new matrix is created by virtue of crisp values calculated by using formulas (2)-(9), which is called the initial direct-relation matrix usually denoted by Z = [zij]nxn.

The five step algorithms of CFCS are given below

The fuzzy judgments usually are presented by formula (1)

$$\tilde{z}_{ij}^{k} = \left(z_{lij}^{k}, z_{mij}^{k}, z_{rij}^{k}\right) \quad (1)$$

And let the evaluators be k (k = 1, 2, 3, …, p) which marks their judgments as degree of influence in which criterion i (row) inflects the criterion j (column).

Normalization is achieved by using following equations

CFCS Step-1

$$x^k_{lij} = \frac{z^k_{lij} - \min z^k_{lij}}{\max z^k_{rij} - \min z^k_{lij}} \quad (2)$$

$$x^k_{mij} = \frac{z^k_{mij} - \min z^k_{lij}}{\max z^k_{rij} - \min z^k_{lij}} \quad (3)$$

$$x^k_{rij} = \frac{z^k_{rij} - \min z^k_{lij}}{\max z^k_{rij} - \min z^k_{lij}} \quad (4)$$

Then calculate left side and right side normalized values by using:
CFCS Step-2

$$x^k_{leftside\ ij} = \frac{x^k_{mij}}{(1 + x^k_{mij} - x^k_{lij})} \quad (5)$$

And

$$x^k_{rightsideij} = \frac{x^k_{rij}}{(1 + x^k_{rij} - x^k_{mij})} \quad (6)$$

The total normalized crisp value is calculated by:

CFCS Step-3

$$x^k_{ij} = \frac{\left[x^k_{leftsideij}\left(1 - x^k_{leftsideij}\right) + \left(x^k_{rightsideij}\right)^2\right]}{\left[1 - x^k_{leftsideij} + x^k_{rightsideij}\right]} \quad (7)$$

Crisp values calculation is done by:

CFCS Step-4

$$z^k_{ij} = \min z^k_{lij} + x^k_{ij}\left(\max z^k_{rij} - \min z^k_{lij}\right) \quad (8)$$

And then finally integrating the crisp values by using equation below:

CFCS Step-5

$$z^k_{ij} = \frac{1}{p}\left(z^1_{ij} + z^2_{ij} + z^3_{ij} + \ldots + z^p_{ij}\right) \quad (9)$$

Step 4: Establishing and analyzing the structural model.

From step 3 above, we develop the initial direct-relation matrix Z = [zij]nxn. Once this is done we then convert initial direct-relation matrix to normalized direct-relation matrix X = [xij]nxn , where 0 ≤ xij ≤ 1 and i, j = 1, 2, 3, …, n , by using formula (10)

$$X = \frac{1}{\max_{0 \le i \le 1} \sum_{j=1}^{n} z_{ij}} Z \quad (10)$$

After applying above, T, total-relation matrix is developed by formula (11)

$$T = X(I - X)^{-1} \quad (11)$$

Where I is identity matrix.

Next the causal diagram is developed by estimating the values from following formulas (12)-(13)

$$T = t_{ij}, \qquad i, j = 1, 2, 3, \ldots, n$$

$$D = \sum_{j=1}^{n} t_{ij} \quad (12)$$

$$R = \sum_{i=1}^{n} t_{ij} \quad (13)$$

The causal digraph is developed by having two axes as horizontal axis i.e. (D + R) which highlights the importance of the criteria/attributes under study and the vertical axis as (D - R) which divides the criteria/attributes into two groups viz. cause group and effect group.

So it is very evident from the above procedure that complex and intertwined causal relationships of criteria/dimensions can easily be visualized through construction of causal digraph which depicts a visible structural model bringing impending knowledge for solution of the problem under study.

Analysis

Step 1: Identifying the decision goal.

The goal for decision making for this study was presented as “University choice factors as per aspiring students”.

Step 2: Developing evaluation criteria/attributes and designing the fuzzy linguistic scale.

The five university choice dimensions were adapted from the study of Reza S. and Nawaz R. R. (2014). The dimensions were “University Competence”, “Market Worth”, Value-added Activities”, “Amenities Offered”, and “University History” which are taken as criteria C1, C2, C3, C4, and C5 respectively in this study. Consequently, a questionnaire was developed for seeking judgments or assessments from eleven higher education academic experts on pair-wise comparisons of choice criteria/dimensions.

Table 3 is the linguistic scale that was employed in this study as defined by Li (1999). Note that the middle column contains the rating points that were used while designing the Fuzzy DEMATEL questionnaire.

Table 3: Fuzzy linguistic scale for fuzzy DEMATEL questionnaire

Linguistic Terms		Ratings	Triangular Fuzzy Numbers
Very High Influence	(VHI)	4	(0.75, 1.0, 1.0)
High Influence	(HI)	3	(0.5, 0.75, 1.0)
Low Influence	(LI)	2	(0.25, 0.5, 0.75)
Very Low Influence	(VLI)	1	(0, 0.25, 0.5)
No Influence	(NI)	0	(0, 0, 0.25)

Note: Columns linguistic terms with ratings were only used in Fuzzy DEMATEL Questionnaire

Step 3: Acquiring and aggregating the assessments of decision makers.

Influence matrices (Table 4) are constructed by using the linguistic terms as given in Table

4 and then these terms are converted in positive triangular fuzzy numbers (lij, mij, rij).

Table 4. The influence matrix (one expert only)

CRITERIA	C1	C2	C3	C4	C5
C1	0	HI	HI	LI	HI
C2	HI	0	LI	HI	LI
C3	LI	NI	0	HI	VHI
C4	HI	VHI	HI	0	HI
C5	VHI	HI	HI	LI	0

For example, following the CFCS equations (Eq.2 to Eq.8, CFCS step 1 to 4), one can obtain a matrix like Table 5 given below where the converted crisp values of influence matrix (Table 4) is shown only for Expert 1.

Table 5. Converted crisp values matrix via CFCS (one expert only)

CRITERIA	C1	C2	C3	C4	C5
C1	0	0.73333	0.73333	0.5	0.73333
C2	0.73333	0	0.5	0.73333	0.5
C3	0.5	0	0	0.73333	0.96667
C4	0.73333	0.96667	0.73333	0	0.73333
C5	0.96667	0.73333	0.73333	0.5	0

Similarly, we collected all eleven experts' influence matrices by repeatedly applying CFCS algorithm (from Eq.2 to Eq.4) for every expert's influence matrix. This resulted in all experts' individual crisp values matrices. Then we applied formula (9) to obtain the initial direct relation matrix Z = [zij]nxn (see Table 6). This matrix Z is just the average matrix of all experts' assessments/judgments on criteria under discussion.

Table 6: Initial direct relation matrix

CRITERIA	C1	C2	C3	C4	C5
C1	0	0.79	0.62	0.62	0.73
C2	0.62	0	0.68	0.73	0.56
C3	0.68	0.37	0	0.67	0.73
C4	0.62	0.62	0.50	0	0.68
C5	0.68	0.50	0.50	0.33	0

Step 4: Establishing and analyzing the structural model.

Using the initial direct relation matrix, the normalized direct-relation matrix was developed (see Table 7) by employing formula (10).

Table 7: The normalized direct relation matrix

CRITERIA	C1	C2	C3	C4	C5
C1	0	0.29	0.23	0.23	0.27
C2	0.23	0	0.25	0.27	0.21
C3	0.25	0.14	0	0.25	0.27
C4	0.23	0.23	0.19	0	0.25
C5	0.25	0.19	0.19	0.12	0

After the normalized direct relation matrix, the T, total-relation matrix is obtained (Table 8) by using the formula (11).

Table 8: The total relation matrix

CRITERIA	C1	C2	C3	C4	C5
C1	1.96	2.00	1.96	1.98	2.25
C2	2.05	1.69	1.89	1.92	2.11
C3	1.97	1.72	1.60	1.81	2.05
C4	1.94	1.77	1.74	1.60	2.02
C5	1.72	1.53	1.53	1.50	1.57

Formulas (12) and (13) were used to acquire the columns and rows totals, respectively. Once these totals were obtained, a table was constructed (see Table 9) which gave inputs for the creation of cause and relationship digraph.

Table 9: D and R data used for creation of digraph

CRITERIA	D	R	D + R	D - R
C1	10.15	9.64	19.79	0.51
C2	9.65	8.72	18.37	0.93
C3	9.16	8.71	17.87	0.44
C4	9.07	8.82	17.89	0.25
C5	7.85	9.99	17.84	-2.14

Then the causal digraph (Figure 2) was constructed with horizontal axis (D + R) and vertical axis (D - R). The horizontal axis showed the degree of importance the dimension/criteria had and the vertical axis divided the dimensions into two groups as cause and effect groups.

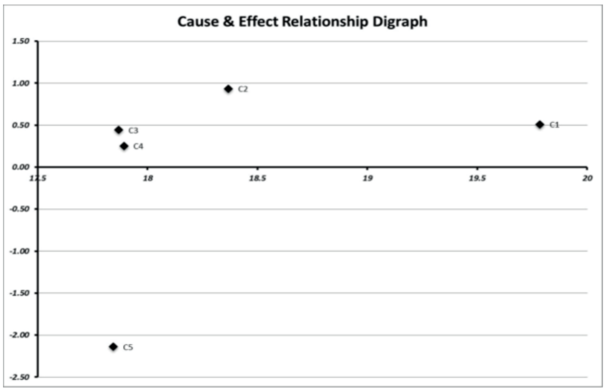

Figure 2: University choice dimensions' cause and effect digraph

RESULTS AND DISCUSSION

For a better insight and methodology for decision making, this study was an effort to present fuzzy DEMATEL as a unique and sophisticated multi-criteria/multi-attribute decision-making tool for management students, faculty and business managers. Fuzzy DEMATEL was used to prioritize the university choice latent dimensions as criteria by eleven higher education industry experts who were proactive in managing the helm of marketing affairs in their respective universities. The fuzzy DEMATEL as a tool enabled our study to develop the fuzzy DEMATEL questionnaire especially designed to acquire the assessments and judgments from these higher education experts. They analyzed the intertwined relationships among university choice dimensions as criteria. On horizontal "Importance" axis (D + R) of the digraph (Figure 2), which explains the latent importance of the dimensions undertaken in the study. "University Competence (C1)" dimension was found to be most akin with latent importance as well as "University History (C5)" dimension was latently least important among the five dimensions taken as criteria. The digraph also highlights an interesting outcome that "Value-added Activities (C3)" and "Amenities Offered (C4)" are very close in importance along with "University History (C5)" albeit, C3, is slightly being lower than the C4 but almost prioritized as equally important with C5. It is also worth noting from resultant digraph that two dimensions "Market Worth (C2) and "University Competence (C1)" clearly stand out on "Importance" axis. The vertical "Relationship" axis (D – R) of the digraph clearly exhibits that all of the dimensions "C1, C2, C3, C4 except C5 are causal factors that controls the cause and effect relationship to the "University History (C5)" dimension. The importance with cause and effect relationship digraph also enabled us to look into the structural framework that was inherent by studying the cause and effect groups of university choice dimensions. Our endeavor also highlighted that fuzzy DEMATEL is one of the appropriate tools to prioritize the selection criteria and by virtue of its methodology, provides a better visual and graphical output to understand the intertwined relationships inherent in the structure.

CONCLUSION

Results from our study portray the importance and the cause and effect visualization of university choice criteria/dimensions with the help of cause and effect relationship digraph. The extracted results show the latent ordering and prioritizing of the university choice dimensions by eleven higher education industry experts on which students decide among these dimensions while choosing a university in Pakistan. The prioritization of criteria/dimensions also elicits the steering factors for higher management of any university as what dimensions must be concentrated and focused while formulation and implementation of marketing strategies in higher education domain. These dimensions would also require the higher management to be in continuous pursuit for development, maintenance, and improvement to offer better and competitive opportunities for their sustenance.

For further research, the application of other tools of MCDM, MADM, and MODM could be used individually or in hybrid conjunction.

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