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MODELING FUNDING ALLOCATION PROBLEMS VIA AHP-FUZZY TOPSIS

Joshua Ignatius[1,*], Adli Mustafa[1] and Mark Goh[2,3]

[1]School of Mathematical Sciences
University Sains Malaysia
11800 Minden, Penang, Malaysia
*Corresponding author: josh@usm.my

[2]NUS Business School
National University of Singapore
No. 21, Lower Kent Ridge Road, Singapore 11907, Singapore

[3]School of Management
University of South Australia
GPO Box 2471, Adelaide, SA, Australia

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Abstract. *This paper treats the project funding allocation problem using a combination of AHP and fuzzy TOPSIS: one which occurs when the subjects of evaluation are provided a chance to agree on the intensity and importance of the criteria while the assessment is treated by a separate set of evaluators or decision makers (DMs). The assumptions made are similar to a double blind review process; that is, the identities of both parties (evaluators and subjects) are only known to the facilitator, and the evaluators are allowed to provide ratings in linguistic terms (e.g., 'poor', 'good', 'very good'). This paper provides a novel integration and an unbiased method in reaching a transparent decision making outcome for the funding allocation of projects. The differences in implementation between the AHP-fuzzy TOPSIS and other similar applications are discussed. Finally, the evaluation process is illustrated with values derived from a university resource allocation exercise.*

Keywords: AHP, Fuzzy TOPSIS, Multiple criteria, Group-decision making, Decision analysis, Linguistic modeling

1. Introduction.

Funding allocation exercises in higher education institutions is a process that has complex and sensitive issues. This is exacerbated when disputes occur in the promotion and tenure of faculty members [1], and whether their funding allocation is a fair reflection of their performance. The challenge is to consolidate and integrate the decisions from the various stakeholders to achieve outcomes that are desirable for all. The methods available in handling this situation can be drawn from the vein of multi-criteria decision making (MCDM) covering models such as AHP, TOPSIS, and PROMETHEE (see [2,3] for examples of applications). In the technical front, decision models have undergone extensions for reasons such as the type of data elicited, ability to synthesize a partial to full set of evaluation criteria across various stakeholders, the various utility functions representing the assessors' expertise and preference, and the application context.

However, the applications of such methods in group-ranking decisions have their drawbacks, including the well established techniques [4]. The analytic hierarchy process (AHP) developed by Saaty [5] has undergone the rank reversal phenomenon, where the immediate inclusion of a redundant alternative (or evaluation objects) results in a change of order preferences. The need to conduct pairwise comparisons for all alternatives and evaluation criteria is a limitation of AHP. Similarly, the Technique for Order Performance by Similarity to Ideal Solutions (TOPSIS) encounters rank reversal issues when subject to a small number of criteria [6].

Hence, there is a need to integrate some of these techniques to better apply to practical problems. For instance, rank reversals could be easily worked around, should a proper method of consensus be generated during the decision making process, thus removing any redundant and ill-defined criteria. Also, a proper subset of the alternatives should be presented to the decision makers (DMs) for the evaluation process. Thus, it is imperative that the DMs know about the alternatives under evaluation.

This paper highlights how AHP and fuzzy TOPSIS can be combined and applied to a double blind evaluation process, for assessment in a university resource allocation exercise. The two techniques are used as AHP provides a consistency measure to gauge the quality of the decision making process, while TOPSIS can handle a larger number of alternatives.

Our treatment to the decision making problem in this paper is carved under the rubric of a two-tier decision making process. This situation is divided into objects that are being evaluated (i.e., research area) and the set of reviewers. We assume that the proponents for the objects under evaluation (researchers) are competing with each other, but mutually agree on the evaluation criteria and outcome. Next, in a double blind review, a committee of experts is formed to evaluate the research areas. The decision-making problem is narrowly partitioned, to allow the reviewers to maintain their status as "experts" and carry out the assessment with some degree of suitable judgment. In other words, comparing the viability of proposals between extremely distant disciplines such as physics and archeology would be inappropriate under our approach.

One might argue that a completely double blind review process is highly unlikely under certain circumstances, where the pursuit is confined to a select few niche areas. In such cases, the reviewers or assessors may know identity of the person behind the proposed niche area. Nonetheless, at best, it still remains a guess, if the review is conducted within a short notice and a stipulated time frame. We also provide a real context application to the problem.

1.1. Decision making context.

A fixed amount of funding is made available for every faculty within a university. A directive requires a faculty level committee to be formed to document the current level of competence and potential of each research area that is under consideration for the research fund. Ideally, funding should be maximized for the areas with the best potential bearing in mind that critical mass is a prerequisite for potential. In short, research departments are required to compete for a limited university budget. To avoid concerns on the lack of transparency, a special session is held to communicate the available funds. During this session, the performance evaluation structure is brainstormed, with the goal of agreeing on the best intensity ranking or weights of the evaluation criteria at the end of the session. This is an iterative process, where the deliberations take place openly and the intensity or weights of the criteria are discussed before finally reaching a consensus. Thus, when one claims that a criterion is more important than another, justifications or proof of argument need to be sought by an experienced facilitator. This process is important as it allows the participants or project proponents to possess ownership and be accountable for their decisions. Thus, we are using the project proponents to come to terms with the assessment criteria, concluding the objective of the first tier of the decision making process.

The second tier begins with the formation of an external expert group. Since the proposals are confined to a faculty, the likelihood of having a set of assessors who possess the knowledge to rate all projects is increased sufficiently. This is aided by providing a list of the impact of each project proposal under evaluation. From these, the review committee will provide linguistic ratings on the proposals under review, ranking them as ‘medium good’, ‘poor’, etc. One might still question the validity of such an approach due to the inherent variation and subjectivity of the linguistic terms across evaluators. For example, evaluator A might have a different view of the term ‘good’ than evaluator B. This ambiguity is lessened to a certain extent through the similar process described in the first tier, where evaluators need to come up with a baseline for their evaluation. As such, attached to the linguistic terms are descriptive characteristics of the criteria, which are obtained through the Delphi method.

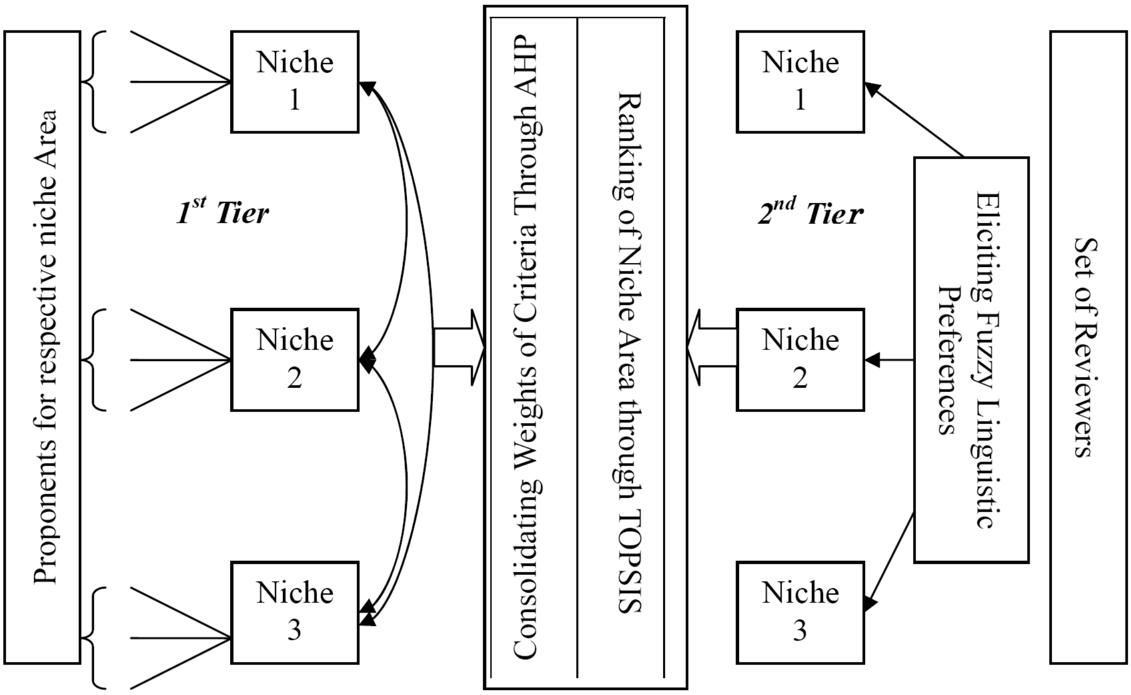

FIGURE 1. AHP-TOPSIS fuzzy framework for double-blind review process

A summary of the entire 2-tier decision making process is outlined in Figure 1 based on an actual case study. A numerical example will be provided to showcase the algorithm. We now provide an overview of AHP and fuzzy TOPSIS.

2. **Background and Preliminaries.**

While many multi criteria decision making models exist [7,8], AHP still stands out in terms of its context wide applicability. Pioneered by Saaty [5], AHP has been applied to aid faculty promotion and tenure decisions [9] ranking research papers [10], benchmark facilities management [11], selecting internet advertising networks [12], prioritizing various information sources for construction projects [13], evaluating human resource practices [14], and even in assessing occupational risks related to shoulder and neck pains [15].

AHP allows the decision making process to be structured by firstly arranging conceptually-related components under a higher concept dimension. The problem is decomposed in a hierarchical fashion that can be shown as a tree diagram. It begins with defining an objective, followed by the global criteria to the sub-level or local criteria. The number of levels depends on whether the decomposition can provide further meaningful differentiation on the criteria among the DMs. If a further breakdown does not provide differences in meaning, the structure is considered sufficient. Once the structure has been finalized, the decision making process starts with comparing two criteria at a time. Thus we have ${}^nC_2$ comparisons to make. The scale used in the decision making process ranges from 1 to 9 (Table 1), and allows the DMs to express their preference verbally in linguistic terms.

Table 1. AHP scale

Level of Importance/Preference	Definition
1	Equal Importance/Preference
3	Moderate Importance/Preference
5	Strong Importance/Preference
7	Very Strong Importance/Preference
9	Extremely Strong Importance/Preference
2, 4, 6, 8	Compromises in between levels

This information is translated into a pairwise comparison matrix, where the entries indicate the relative strength or dominance of one element to another. The weights of the elements are scaled in each of the hierarchy levels with respect to an element at a higher level, such that the matrix reflects the relative importance among entities at the lowest levels of the hierarchy. In short, the measures at the last tier can be interpreted as the drivers that enable the accomplishment of the overall goal of the problem.

Let $\boldsymbol{A}$ denote the pairwise comparison matrix where the element a_{ij} represents the entry of preference of i as compared to j.

$$A = \begin{bmatrix} a_{11} & a_{12} & \cdots & a_{1n} \\ a_{21} & a_{22} & \cdots & a_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ a_{n1} & a_{n2} & \cdots & a_{nn} \end{bmatrix} \tag{1}$$

The principal eigenvector approach is used to extract the priority weights $\boldsymbol{w}$ by solving

$$(A - \lambda_{\max} I)w = 0 \tag{2}$$

Due to the inconsistency that may arise from the subjective assessment, Saaty [5] suggests using a consistency index ($C.I. = \dfrac{\lambda_{\max} - n}{n-1}$) to test the inconsistency of the intuitive judgment, where a value below 0.1 is deemed satisfactory.

2.1. **Fuzzy TOPSIS.** Being a distance-based method, TOPSIS, developed by Hwang and Yoon [16], seeks to illustrate the ranking of a set of alternatives through their distances from the most optimistic (positive ideal) to pessimistic (negative or anti-ideal) points. TOPSIS has been integrated with grey relation [17,18], analytic network process for vendor selection problems [19], and is used to solve large scale multi-objective programming problems that involve fuzzy parameters [20]. In addition, Chen [21] and Jahanshahloo et al. [22] have extended TOPSIS for group-decision making under a fuzzy environment.

This paper uses fuzzy TOPSIS to ease the burden of having to assign subjective ratings to numerous criteria. This action also avoids pairwise comparisons for the alternatives, and is useful when the number of alternatives is large. Until recently, there are only a few studies incorporating both techniques (i.e., AHP and TOPSIS), with applications in airlines [23], transshipment site selection [24], mobile phones [25], sourcing for partners in logistics value chains [26], and determining product design characteristics for competitive benchmarking [27].

There are variations to the way AHP and TOPSIS are integrated in the above studies, with some incorporating fuzzy set theory [28]. For instance, in Tsaur et al. [23] the DMs are allowed to specify a fuzzy triangular function to the alternative. A triangular fuzzy number $\tilde{A}$ in Figure 2 is shown as (L, M, U), with membership function $\mu\tilde{A}(x)$ akin to:

$$\mu\tilde{A}(x) = \begin{cases} 0, & x < L, \\ \dfrac{x-L}{M-L}, & L \le x \le M, \\ \dfrac{U-x}{U-M}, & M \le x \le U, \\ 0, & x > U \end{cases} \tag{3}$$

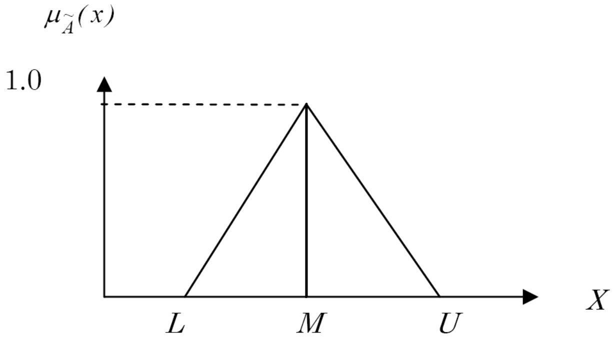

Figure 2. Triangular fuzzy number $\tilde{A}$

In evaluating the alternatives, Tsaur et al. [23] allow the differing attachment of L^k, M^k and U^k values on the linguistic concepts (e.g., fair, satisfied, very satisfied) across the K DMs. Since the DMs can subjectively assume their personal range of linguistic variables, the same concept might hold different values as depicted in Figure 3.

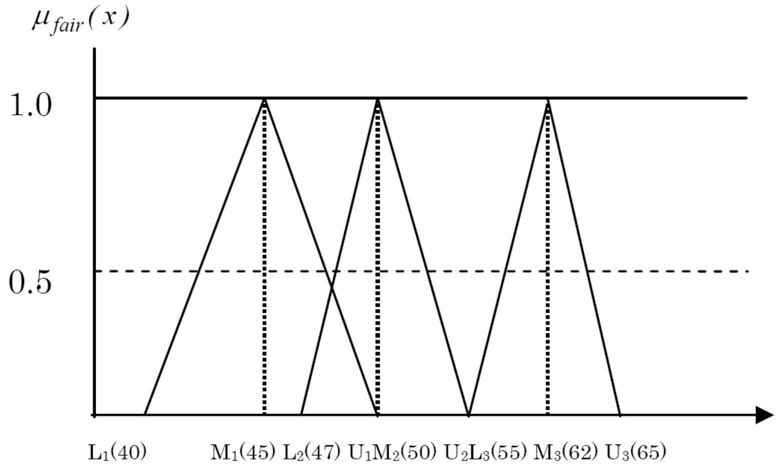

Figure 3. Triangular fuzzy linguistic term for "fair" among DMs

Hence, the values attached on the final rankings might be biased and unable to reflect the collective preferences of the DMs. A prudent approach would be to standardize the linguistic concepts among the DMs (Figure 4). Chen [21] extends TOPSIS to cater for group decision making under a fuzzy environment using fuzzy linguistic criteria. In this paper, these linguistic concepts are standardized through the Delphi approach. To avoid ambiguity, the terms of 'poor', 'good', etc. undergo a few rounds of calibration until a consensus is reached. For instance, in our example, when evaluating *International Funding*, a range of between US100 and US150 thousand is finally agreed to denote 'good'.

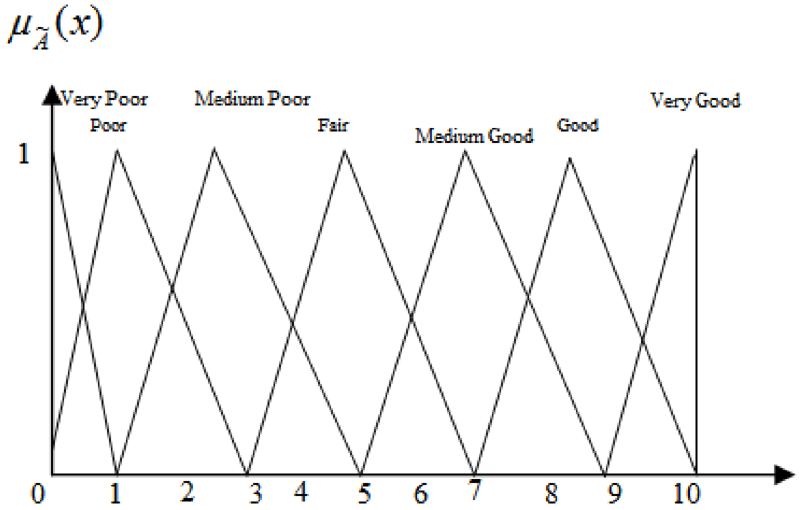

FIGURE 4. Linguistic variables for ratings

Büyüközkan et al. [26] use the same linguistic ratings for criteria evaluation, and even input the fuzzy triangular values to represent the scales of the AHP. This improves the method used in Isikar and Büyüközkan [25], where crisp ratings were used for the rating evaluation. However, this approach is criticized by Saaty and Tran [29] who argue that the pairwise comparison method and ratio of weights have inherently included the uncertainty and subjectivity of the DMs' preferences.

In this paper, the integration of AHP and fuzzy TOPSIS uses the fuzzy triangular function for the latter. Therefore, the triangular scores of their individual rating can be aggregated across the K DMs as:

$$\tilde{A}_k = \frac{1}{K}\sum_{k=1}^{K}(L_k, M_k, U_k) \tag{4}$$

Assuming that there are multiple scales across the criteria, a simple linear scale transformation can be used to standardize the comparison, where

$$\tilde{A}_{ij}^{norm} = \left(\frac{L_{ij}}{U_j^{\max}}, \frac{M_{ij}}{U_j^{\max}}, \frac{U_{ij}}{U_j^{\max}}\right), \quad j \in \text{ Benefit Criteria} \tag{5}$$

$$\tilde{A}_{ij}^{norm} = \left(\frac{L_{ij}}{L_j^{\max}}, \frac{M_{ij}}{L_j^{\max}}, \frac{U_{ij}}{L_j^{\max}}\right), \quad j \in \text{ Cost Criteria} \tag{6}$$

Subsequently, a simple additive form allows the integration between the fuzzy preferences and AHP weights:

$$\tilde{R} = \tilde{A}_{ij}^{norm} \otimes W_j^T \tag{7}$$

where

$$\tilde{A}_{ij}^{norm} = \begin{bmatrix} \tilde{x}_{11} & \tilde{x}_{12} & \cdots & \tilde{a}_{1n} \\ \tilde{x}_{21} & \tilde{x}_{22} & \cdots & \tilde{x}_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ \tilde{x}_{m1} & \tilde{x}_{m2} & \cdots & \tilde{x}_{mn} \end{bmatrix}, \text{ and } W_j = [w_1\ w_2\ w_3\ w_4] \tag{8}$$

As the elements of $\tilde{R}$ are [0 1], the fuzzy positive ideal (B^*) and anti-deal (B^-) solution can be expressed as:

$$B^* = (\tilde{b}_1^*, \tilde{b}_2^*, \ldots, \tilde{b}_n^*), \text{ and } B^- = (\tilde{b}_1^-, \tilde{b}_2^-, \ldots, \tilde{b}_n^-), \tag{9}$$

where $\tilde{b}_j^*$ and $\tilde{b}_j^-$ are $(1, 1, 1)$ and $(0, 0, 0)$, respectively for $j = 1, 2, \ldots, n$.

Hence, the distance between each alternative i to B^* and B^- can be calculated as:

$$d_i^* = \left\{ \sum_{j=1}^{n} \left(\tilde{b}_{ij} - \tilde{b}_j^* \right)^2 \right\}^{1/2} \text{ and } d_i^- = \left\{ \sum_{j=1}^{n} \left(\tilde{b}_{ij} - \tilde{b}_j^- \right)^2 \right\}^{1/2}, \quad \forall i \tag{10}$$

The relative closeness to the ideal solution can then be interpreted through

$$RC_i = d_i^- \Big/ \left(d_i^* + d_i^- \right), \quad \forall i \tag{11}$$

The relative closeness coefficients can further be scaled to:

$$\sum_{i}^{m} RC_i = 1, \quad i = 1, \ldots, m. \tag{12}$$

where

$$RC_{scaled\,i} = RC_i \Big/ \sum_{i}^{m} RC_i, \quad \forall i \tag{13}$$

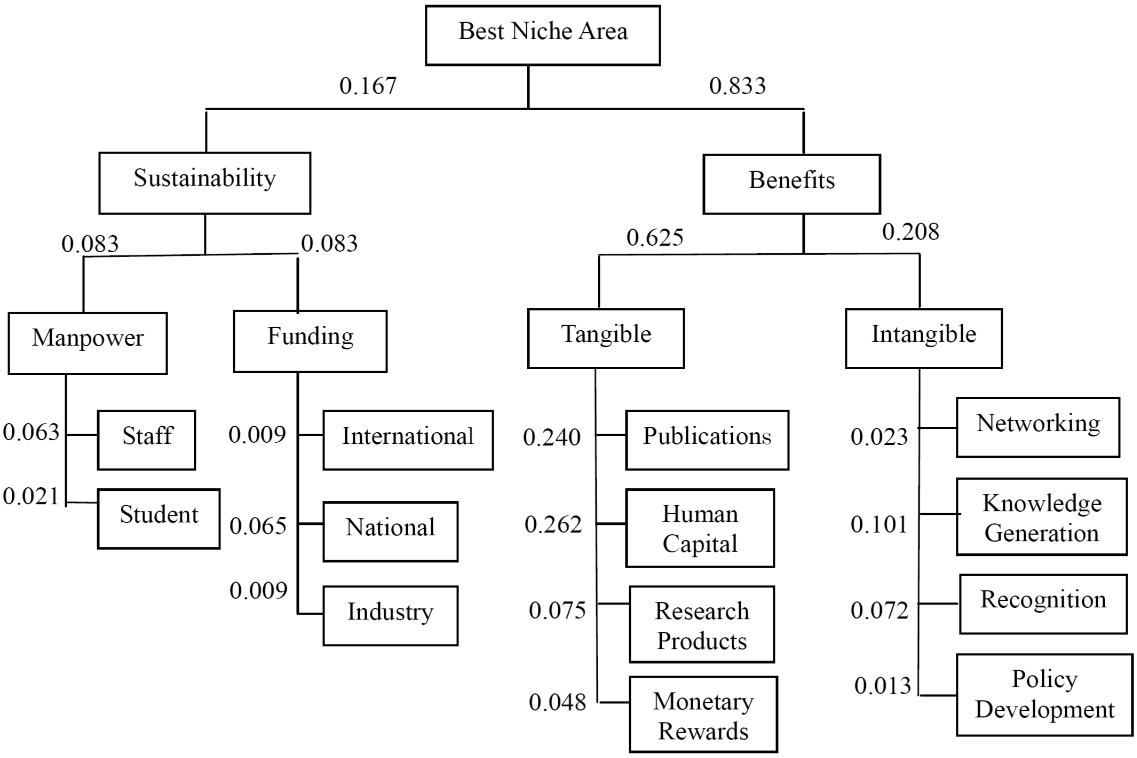

Figure 5. AHP structure

3. **Example.** A recent exercise in a public institution of higher learning saw an influx of funding for research. The thinking is to support funding an area that has generated critical mass and interest while finding feasible and new potential research areas in order to invest in future needs. In the past, decisions have been made in centrally, leaving some project proponents to feel an untoward bias in the process. Some projects that are perceived to be good were under funded at best; with some worse cases receiving an outright rejection. This leads to complaints that: 1) the evaluation committee place more importance in factors that cannot be realized in my area of research, and 2) we do not know how the committee evaluated us.

TABLE 2. Niche area performance ratings as assessed by 10 decision makers

Criteria	**Niche Area (N)**	**Decision Makers**									
Manpower		**D1**	**D2**	**D3**	**D4**	**D5**	**D6**	**D7**	**D8**	**D9**	**D10**
Staffs (C1)	N1	VG	G	MG	VG	MG	G	G	MG	G	G
	N2	MG	G	G	G	MG	MG	MG	MG	G	MG
	N3	MP	MG	MP	MG	MG	MP	MP	G	MG	MG
Students (C2)	N1	VG	VG	VG	VG	VG	VG	G	G	G	G
	N2	MG	MG	MP	MG	P	P	P	P	MP	MP
	N3	MG	MG	MP	MG	MG	MP	G	MG	MG	MP
Funding											
International (C3)	N1	G	G	VG	G	G	G	G	MG	G	G
	N2	VP	P	P	P	VP	P	MP	P	P	P
	N3	MP	P	MP	MP	P	MP	MP	VP	VP	VP
National (C4)	N1	VG	G	G	VG	VG	G	G	G	VG	G
	N2	MP	MP	MG	MG	MG	MG	MG	MG	MP	MP
	N3	P	MP	MP	P	P	MP	MP	MG	MP	P
Industry (C5)	N1	G	G	MG	MG	MG	MG	MG	G	G	G
	N2	MP	P	P	P	P	MP	MP	P	P	P
	N3	P	P	MG	MG	MP	MP	MP	MP	MG	MP
Tangible											
Publications (C6)	N1	VG	VG	VG	VG	VG	VG	VG	VG	G	VG
	N2	G	G	G	G	VG	VG	VG	VG	VG	VG
	N3	MG	MG	G	MG	MG	MP	MP	MG	MG	G
Human Capital (C7)	N1	MP	MP	MP	MP	MG	MG	MG	MG	MG	MG
	N2	VG	VG	VG	VG	VG	MP	MP	MP	MP	VG
	N3	VP	P	P	P	P	VP	MG	MG	MP	MP
Research Products (C8)	N1	VP	VP	VP	P	P	P	P	P	P	P
	N2	MP	MP	P	P	P	MP	MG	MG	MP	MP
	N3	VP	VP	VP	P	P	VP	MP	MP	MP	MP
Monetary Rewards (C9)	N1	G	G	MG	G	G	MG	G	MG	G	G
	N2	MG	MP	MG	MP	MG	MG	MG	MG	MG	MP
	N3	MP	MG	MP	MP	MP	MP	MG	MP	MG	MP
Intangible											
Networking (C10)	N1	P	G	P	MP	G	G	G	MP	G	G
	N2	VG	VG	G	G	G	VG	G	VG	G	G
	N3	MP	MP	P	P	P	VG	MP	P	MP	P
Knowledge Generation (C11)	N1	VG	VG	G	G	VG	VG	G	G	MG	G
	N2	VG	G	G	VG	G	G	G	MG	G	G
	N3	G	VG	G	G	VG	G	G	G	G	MG
Recognition (C12)	N1	VG	G	G	MG	G	G	G	VG	MG	VG
	N2	MP	MG	G	G	G	MG	MG	G	G	MG
	N3	MG	MG	MP	MG	MG	G	MG	MG	MP	MG
Policy Development (C13)	N1	G	G	MP	MP	MP	MG	MG	MG	P	MG
	N2	G	VG	VG	VG	G	G	G	VG	G	VG
	N3	MG	VG	VG	VG	VG	VG	VG	VG	VG	VG

Note: VP= Very Poor, P= Poor, MG=Medium Good, G=Good, VG=Very Good

To resolve such misconceptions and to promote transparency, the decision making process summarized below is implemented for funding support among the niche areas in a certain faculty in a university.

Table 3. Fuzzy decision matrix

	Criteria												
	C1	**C2**	**C3**	**C4**	**C5**	**C6**	**C7**	**C8**	**C9**	**C10**	**C11**	**C12**	**C13**
Niche 1	(7.1, 8.6, 9.7)	(8.5, 9.6, 10)	(7.3, 8.9, 9.9)	(8.1, 9.4, 10)	(6.3, 8, 9.5)	(8.9, 9.9, 10)	(3.8, 5.4, 7.4)	(0.3, 0.7, 2.4)	(6.7, 8.4, 9.7)	(4.7, 6.2, 7.6)	(7.9, 9.2, 9.9)	(7.3, 8.9, 9.8)	(4.1, 5.6, 7.4)
Niche 2	(6.2, 7.8, 9.4)	(2.2, 3.4, 5.4)	(0.4, 1, 2.8)	(3.8, 5.4, 7.4)	(0.6, 1.6, 3.6)	(8.3, 9.6, 10)	(5.9, 7.2, 8)	(1.9, 3.2, 5.2)	(4.2, 5.8, 7.8)	(8.1, 9.4, 10)	(7.5, 9, 9.9)	(6, 7.6, 9.1)	(8.1, 9.5, 10)
Niche 3	(4, 5.6, 7.5)	(4.4, 6, 7.9)	(0.6, 1.7, 3.4)	(1.3, 2.6, 4.6)	(2.4, 3.8, 5.8)	(4.9, 6.6, 8.4)	(1.6, 2.4, 4.2)	(0.8, 1.4, 3)	(2.6, 4.2, 6.2)	(1.6, 2.7, 4.5)	(7.6, 9, 9.9)	(4.8, 6.4, 8.3)	(8.7, 9.7, 9.9)

Table 4. Normalized fuzzy decision matrix with AHP weights

	Criteria												
	C1	**C2**	**C3**	**C4**	**C5**	**C6**	**C7**	**C8**	**C9**	**C10**	**C11**	**C12**	**C13**
Niche 1	(.71, .86, .97)	(.85, .96, 1)	(.73, .89, .99)	(.81, .94, .1)	(.63, .8, .95)	(.89, .99, 1)	(.38, .54, .74)	(.03, .07, .24)	(.67, .84, .97)	(.47, .62, .76)	(.79, .92, .99)	(.73, .89, .98)	(.41, .56, .74)
Niche 2	(.62, .78, .94)	(.22, .34, .54)	(.04, .01, .28)	(.38, .54, .74)	(.06, .16, .36)	(.83, .96, 1)	(.59, .72, .8)	(.19, 2, .52)	(.42, .58, .78)	(.81, .94, 1)	(.75, .9, .99)	(.6, .76, .91)	(.81, .95, 1)
Niche 3	(.4, .56, .75)	(.44, .6, .79)	(.06, .17, .34)	(.13, .26, .46)	(.24, .38, .58)	(.49, .66, .84)	(.16, .24, .42)	(.08, .14, .3)	(.26, .42, .62)	(.16, .27, .45)	(.76, .9, .99)	(.48, .64, .83)	(.87, .97, .99)
AHP Weights	.063	.021	.009	.065	.009	.24	.262	.075	.048	.023	.101	.072	.013

Table 5. Fuzzy weighted normalized decision matrix

	Criteria												
Niche	**C1**	**C2**	**C3**	**C4**	**C5**	**C6**	**C7**	**C8**	**C9**	**C10**	**C11**	**C12**	**C13**
1	(.04, .05, .06)	(.02, .02, .02)	(.01, .01, .01)	(.05, .06, .07)	(.01, .01, .01)	(.21, .24, .24)	(.1, .14, .19)	(0, .01, .02)	(.03, .04, .05)	(.01, .01, .02)	(.08, .09, .1)	(.05, .06, .07)	(.01, .01, .01)
2	(.04, .05, .06)	(0, .01, .01)	(0, 0, 0)	(.02, .04, .05)	(0, 0, 0)	(.2, .23, .24)	(.15, .19, .21)	(.01, .02, .04)	(.02, .03, .04)	(.02, .02, .02)	(.08, .09, .10)	(.04, .05, .07)	(.01, .01, .01)
3	(.03, .04, .05)	(.01, .01, .02)	(0, 0, 0)	(.01, .02, .03)	(0, 0, .01)	(.12, .16, .20)	(.04, .06, .11)	(.01, .01, .02)	(.01, .02, .03)	(0, .01, .01)	(.08, .09, .10)	(.03, .05, .06)	(.01, .01, .01)

Table 6. Final 3 computational steps

	d_i^*	d_i^-	RC_i	$RC_{scaled\,i}$	Rank
Niche 1	12.2551	0.7563	0.058126	0.38	1
Niche 2	12.2669	0.7432	0.057125	0.37	2
Niche 3	12.5093	0.5103	0.039195	0.25	3

Step 1: A set of proposals that are a homogenous subset of the context or subject of evaluation is compiled.

Step 2: A meeting with the project proponents is organized, to get them to agree on the structure (Figure 5) and the evaluation criteria. This step can be interpreted as a collective decision making effort, where agreement is sought upfront through AHP.

Step 3: A separate committee comprising experts is formed to evaluate the proposals. This committee places linguistic ratings (e.g., fair, medium good, etc.) on the alternatives (proposals), bearing in mind that the criteria for 'fair', 'good', etc. (Table 2) have been decided by this committee collectively through the Delphi process. The weights of the assessment that are derived from AHP are not communicated to the evaluators

Step 4: An arbitrating panel integrates the weights from the AHP with fuzzy TOPSIS.

Step 4a: Aggregate all values of the linguistic ratings across the K DMs (Equation (4), see Table 3).

Step 4b: Normalize the values of the criteria (Equation (5), see Table 4).

Step 4c: Create the weighted fuzzy normalized matrix (Equation (7), see Table 5).

Step 4d: Compute the distance measures d_i^* and d_i^- (Equation (10), see Table 6).

Step 4e: Compute the relative closeness coefficients of RC_i (Equation (12), see Table 6).

Step 4f: Rescale RC_i by Equation (13) (see Table 6).

4. **Conclusions.** From a pragmatic standpoint, the approach suggested in this paper allows for the project proponents to agree on the evaluation criteria. Similarly, verbal linguistic ratings can be easily attached to alternatives (project proposals) once the DMs (or assessors) agree on their meaning. For instance, the term 'poor' for the *Publications* criterion is considered as having 'no publications for that year'. From a computational standpoint, the AHP-fuzzy TOPSIS technique is ideal and saves decision makers time, especially when the number of alternatives and DMs are many. In addition, the values of the scaled relative coefficients can be used to rank (see Table 6) and allocate funds (similar to the interpretation of percentages) for the alternatives.

In a separate group ranking study, Shih et al. [30] suggest that future studies test other forms of weighting combinations, normalization methods, scaling techniques and distance measures, and group synthesis. Here, we provide an extension to the TOPSIS group ranking problem. First, we elicit the weighing process through AHP and expert deliberations in an actual context. By invoking the fuzzy set theory, we illustrate an AHP-fuzzy TOPSIS hybrid modeling, where the input data type are subjective and in the form of fuzzy linguistic ratings. Subsequently, interactions between external evaluators through the Delphi process allow subjective ratings on alternative proposals to have accurate and consistent quantitative interpretation. Thus, research projects (alternatives) can be compared on the same platform, reaching a meaningful ranking and consensus. Finally, the AHP-fuzzy TOPSIS method can be easily programmed using a spreadsheet to automate the decision making process. Future research may seek to explore the proposed hybrid model under the D-S theory of evidence [31].

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