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A Simulation-based Analytic Hierarchy Process (AHP) Method for Fund Allocation Assessment

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***Abstract*— The effectiveness of government financing is a challenge in various industries, including higher education universities. The funding source and the resources' size are the key determinants of quality education. The problems arise in multi-criteria decision-making, where many subjective opinions are needed from the experts. It is, therefore necessary to prioritize the limited budget available for important criteria. On the other hand, multi-criteria evaluation leads to technically rigorous and enlightened university budget decisions. This paper proposes the exploitation of the Analytic Hierarchy Process (AHP) in budget allocation at one of the public universities in Malaysia. This study's participants were eight top management experts in managing expenditure at the faculty level. The findings showed that the most significant factors in deciding budget allocations are Teaching and Learning (0.30) and Maintenance (0.26). Furthermore, the most dominant sub-criteria were laboratory and equipment devices (S4) and training and conferences (S10), with a weighted mean of 0.682 and 0.664, respectively. The weights were aggregated by the geometric mean and median, as well as the simulated mean and median, which showed deviating results and rank reversals. The geometric mean weights differed significantly. In contrast, the aggregation using measures of the median was similar to the geometric median, with only a few rankings criteria differing. This highlights that the median score is significant in weight calculation.**

***Keywords*— Fund allocation; analytic hierarchy process; limited resources; optimal budget.**

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I. INTRODUCTION

Financial decision-making is imperative in planning a resourceful finance budget. It should fulfill the company's strategic planning while ensuring the expenses meet the objectives of the existing resources. The current financial crisis and decreased funding by the government have impacted decreasing funding received, especially for government-funded universities. In due time, resource competition among university faculties needs to be resolved. Therefore, a well-planned budget allocation will be crucial since it effectively by distributing resources to the most desired place.

This study concerns the factors affecting the budget allocation problem in the Faculty of Science and Defence Technology (FSTP), at the University of National Defence Malaysia (UPNM) by suggesting an AHP approach. The FSTP consists of three main departments: the Department of Computer Science, the Department of Science and Maritime Technology, and the Department of Defence Science.

FSTP has more than 700 students, over 60 academic staff, and around 24 administrative staff to foster its functions. Moreover, resources to FSTP from the university's financial department will be allocated to several activities such as material and supplies, research and development, teaching and learning, maintenance, and staff claims. FSTP can still coordinate staff requirements and run its ongoing activities with limited resources. However, the UPNM administrator has indicated due to the lower funding and tighter budget, departments and faculties will compete for resources in the long term. As a result, FSTP, or any other department in higher learning education, cannot afford the current demanding system. Over-budgeting will result from an impromptu spending plan and poor expenditure planning. Therefore, such an issue needs to be resolved by a systematic budget allocation and will be crucial since effective use of the resources at hand can result in significant financial savings.

The Multi-Criteria Decision Making (MCDM) methodology has become increasingly popular and widely used in various fields and applications [1]. Moreover, management science ideas and methods have been used for a while in academic and administrative fields. Most academics and researchers use the MCDM methodological framework to handle challenging issues, particularly in university administration involving decision problems, to simultaneously cope with several conflicting goals. MCDM was first made available in the early 1970s.

In Sinuany-Stern [2] identified the allocation of resources, budgeting, scheduling, planning, getting resources, and performance measurement or evaluation are the main areas in which management science techniques are applied in academic administration. Furthermore, Mustafa and Goh [3] reported that more than 60 university administrations had proposed using MCDM techniques in higher education. Within the MCDM, the Analytic Hierarchy Process (AHP) approach has attracted considerable attention throughout the industry, such as in construction [4], operations management [5], and medical and healthcare [6] due to its simplicity and great flexibility.

Recent surveys by Ho and Ma [7] studied the literature on the integrated AHP methods and implementation published from 2007 until 2016, a comprehensive review based on Ho [8]. Refer to Dos Santos [9] and Khan et al. [10] for the latest studies; despite the many advantages, some difficulties have been the focus of large-scale research, including the pairwise comparison procedure and the restrictions of consistency in AHP. Aiming for more realistic and promising decisions, AHP has been merged with other methods such as mathematical programming, quality function deployment (QFD), meta-heuristics, SWOT analysis, and data envelopment analysis (DEA) [8].

Some articles studied decision problems at higher education institutions [11]–[13]. There has been less focus on budgeting for resources and allocation, particularly at the faculty level. However, since public funding for higher education is gradually declining, resource distribution is essential to preserving or enhancing university performance. Among the related work is modeling the allocation of resources for the university library. One of the studies by Mohd Dahalan [14] proposed AHP, linear, and integer programming methods to assign government-funded university library spending plans for academic units. A study by Uzoka and Ijatuyi [15] also proposed an AHP scheme for a Nigerian university library procurement decision-support system. In the same direction, Bakar et al. [16] used a combination of two approaches (AHP and optimization) which exhibits many positive signs for the improvement of the model. The model was later improved by Hye et al. [17], who proposed the Compromised- Analytic Hierarchy Process (C-AHP) method, mainly used to calculate the weight of the determining criteria. Due to this newly proposed framework, university libraries may have a strategic decision for cost allocation and expenditure following the needs of the stakeholders in the libraries and specific requirements enforced by the university administration. In addition, Khairuddin and Yulmaini [18] obtained priority criteria in the university effectiveness development approach based on RAISE++ (relevance, academic atmosphere, internal management, sustainability, efficiency and productivity, leadership, access, and equity).

Recent studies have shown the hybrid method of AHP in decision-making regarding resource allocation. The method that has raised attention among researchers is the development of mathematical programming (MP) models for budgeting. One of the works by Alho and Salo [19] investigated the model allocation of resources with irregular discrepancies. They also suggested that hierarchical allocation systems might offer means to lessen the variability of the allocations made using formulas. Maijamaa and Gabriel [20] constructed a mathematical model for optimizing the manpower recruitment and promotional system. More advancement in the method can be seen in the works contributed by Abd El-Mageed [21], who created a system for allocating funds for various university organizational units based on a fuzzy multi-level quadratic optimization model. Meanwhile, focusing on the research and publication agenda Maijama'a and Bakar [22] showed how to utilize university resources using an integer programming model. In another work, Ho et al. [23] developed a university resource allocation model by integrating the AHP and GP.

Most of the research in ranking and choosing concentrated on computing the single best scheme from several alternatives. Choosing the most favorite criterion can be useful in the modern global simulation optimization procedure that only needs a smaller number of candidate solutions in each algorithm iteration. However, simulation research is widely applied in engineering, specifically in supplier selection and design. A study by Farshchian et al. [24] suggested a simulation model that aids companies in optimizing budget-allocation scenarios and adds to the body of knowledge in portfolio management. The model is evaluated using historical data from a portfolio of its projects, and scenarios are examined to determine the most effective budget allocation scenario. The outcome produced a model recognizing feasible solutions and optimally managing projects under restricted budgets. Xiao et al. [25] determined that a series of experimental measurements show that the suggested simulation budget allocation method can perform better than any other selection rule. Unfortunately, none of the studies developed using the randomized dataset to enhance the budgeting process's efficiency at higher learning institutions.

Based on the literature review, it is inferred that several researchers have attempted AHP for several applications. However, simulation-based AHP in resource allocation in a faculty setting is found to be scant. Therefore, our motivation is to develop a baseline budget allocation using simulation-based AHP that can be customized to faculties' conditions for making the most of faculties' budget allocation while accomplishing well-organized and maintainable finances. Therefore, the objectives of the study are:

- To identify the main criteria and sub-criteria of the faculty budget allocation.
- To use the AHP approach and compute priority weights for the main and sub-criteria.
- To aggregate the different weights of each criterion using simulation.

II. MATERIALS AND METHOD

The AHP approach is selected for this study to assist decision-makers at a higher education institution decide the amount that should be distributed to each area. This includes allocating material and supplies, teaching and learning, research and development, faculty maintenance, and staff claims. Three AHP standards are used to organize: the weighting of requirements, the weighting of priorities, and the weighting of criteria level. The study was conducted on 8 participants (decision makers) who provided data for this study. The decision-makers (DM) comprise the faculty director, head of departments, senior administrative staff, and lecturers with over ten years of service. A survey method using a set of questionnaires was employed to gather data. Table I lists the main criteria and sub-criteria in this study. The main criteria chosen are extracted based on the component identified in the Expenditure Book provided by the government of Malaysia, where budget allocation simply known as VOT is stated and modified to the context of our study. Some criteria align with Ho et al. [11] and Ignatius [28]. Meanwhile, the chosen sub-criteria resulted from an interview with a faculty-level committee. Experts or decision makers are requested to set up a pairwise comparison matrix at each hierarchy. Table II shows Saaty's scale interpretation entries in a pairwise comparison matrix [26]. Table IV shows an example of the questionnaire setting used.

Essentially, the AHP modeling process is based on four phases, namely, indicating the problem, constructing the hierarchy of decisions, building a matrix of pairwise comparison, employing the priorities gained from the assessments to consider the priorities in the succeeding level, and continuing this process by improving the weigh and count until the final preferential order of the criteria is reached [27]. The AHP framework was created using these principles to aid in the calculations. Thus, we suggested the following action.

1) Step 1: Outline the objective or decision goal.

2) Step 2: Identify criteria and sub-criteria for faculty budget allocation. A hierarchy consists of the objective, criteria, sub-criteria, and alternatives at the succeeding levels.

3) Step 3: Construct a hierarchy framework for analysis.

4) Step 4: Data is obtained from investors or decision-makers. They will weigh two criteria at once. The decision-making process utilizes a scale from 1 to 9, as described on the Saaty scale [2] in Table II. Meanwhile, for fuzzy AHP, the fuzzy scale [28,29] is displayed in Table III, which measures the expert's judgment to transform crisp data into traditional AHP.

5) Step 5: The pairwise comparisons produced are converted into a pairwise comparison matrix, where the entries describe one factor's relative importance or strength concerning another.

6) Step 6: The relative weights of criteria and sub-criteria are calculated.

7) Step 7: Perform the consistency test. The consistency index, CI is computed to describe the reliability of judges during evaluation. CI is computed using equation (1) as follows:

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

where λ_{max} is the maximum eigenvalue and n is the number of criteria. The consistency ratio, CR is computed using equation (2) as follows:

$$CR = \frac{CI}{RI} \quad (2)$$

Here, RI is the random index and Table V shows the average random consistency index where n is the size of the matrix. The judgment is considered as consistent if the value of $CR < 0.10$. Otherwise, it is inconsistent [29]. The decision maker should re-evaluate if inconsistencies happen.

TABLE I
CRITERIA AND SUB-CRITERIA

Criteria	**Sub-criteria**
Material and Supply (MS)	Office supplies (S1) Spare parts (S2) Equipment Installation (S3)
Research and Development (RD)	Training/ Conferences (S4) Research Material Supply (S5) Hospitality/ Honorarium (S6)
Teaching and Learning (TL)	TL equipment (S7) Innovation (S8) Industrial Training (S9)
Maintenance (MT)	Lab machine and Devices (S10) Teaching Devices (S11) Printing and Photocopy (S12)
Staff Claims (ST)	Travel allowance (S13) Overtime (S14) Part-time Staff (S15)

TABLE II
AHP SCALE [26]

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

TABLE III
A NINE-POINT SCALE FUZZY NUMBERS [28], [29]

Code	Linguistic Variables	L	M	U
1	Equally important	1	1	1
2	Intermediate value between 1 and 3	1	2	3
3	Slightly important	2	3	4
4	Intermediate value between 3 and 5	3	4	5
5	Important	4	5	6
6	Intermediate value between 5 and 7	5	6	7
7	Strongly important	6	7	8
8	Intermediate value between 7 and 9	7	8	9
9	Extremely important	9	9	9

TABLE IV
AHP QUESTIONNAIRE DISTRIBUTED TO RESPONDENT

Criteria A	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Criteria B

TABLE V
VALUES OF THE RANDOM INDEX (RI)

n	1	2	3	4	5	6	7	8	9	10
RI	0	0	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.51

8) Step 8: Develop an overall score for each criterion and sub-criteria. The consistency of the AHP technique is ideal for subsequent analysis of the research in this context. First, we consider calculating individual rather than group responses due to the requirement of inconsistent computation. Then we calculate the consistency for each participant for the main and any other criterion of the participants. Finally, we combine all the inputs from different participants or decision-makers (DM) to compute all participants' total weighted geometric mean to get reliable and more accurate results and a better overall consistency ratio.

9) Step 9: Simulation-based criterion AHP evaluation. The different weights (different opinions from experts) of each criterion and sub-criteria are aggregated using simulation. A faculty budget criterion is generated and includes five aspects: MS, RD, TL, MT and SC. Perform a simulation study that considers criterion uncertainties and produces a cumulative dataset distribution. Furthermore, identify the maximum weighted score E_{max} and minimum weighted score E_{min} for each criterion (namely, the upper and lower boundaries of the DM estimates). The measure of mean and median of the randomized weighted is taken. A high mean and median suggest a high evaluation result for the criteria, equating to a high level of DM preferences and vice versa. This way, the expert inputs' uncertainty can be decreased.

III. Results and Discussion

All the invited experts accepted the invitation favorably and decided to participate in the interview. The key criteria used in this study are (1) Material and Supplies, (2) Research and Development, (3) Teaching and Learning, (4) Maintenance, and (5) Staff Claims. The sub-criteria for each criterion is summarized in Fig. 1.

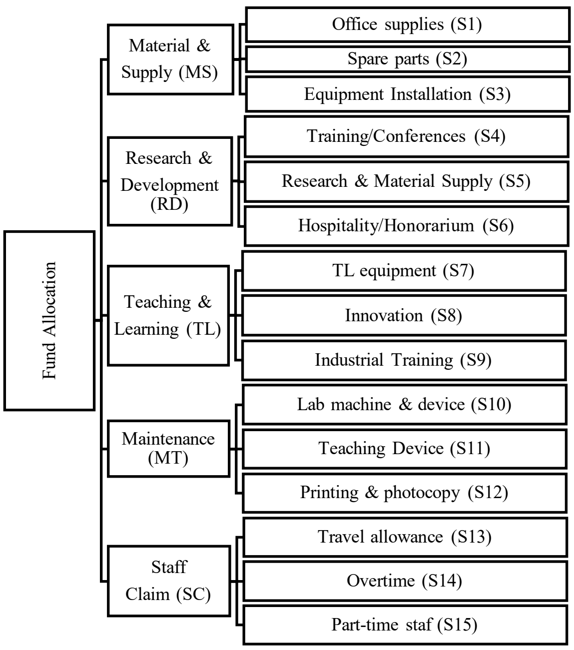

Fig. 1 AHP hierarchical framework

The hierarchical structure is created by incorporating all the main criteria and sub-criteria (S) into the research problem. The independence of each of the fifteen criteria is assumed, and the preference of criteria is paired wisely compared by all the DMs to compute criteria weights rendering to the AHP framework. For illustrative purposes, we use one of the respondent's inputs on the pairwise comparison, as shown in Table VI. Consistencies based on human opinions/judgment are difficult to establish, which is entirely natural. From the initial study, we found three participants with high inconsistencies level; the fourth, seventh and eighth participants with consistency $CR_4 = 1.13$, $CR_7 = 0.94$ and $CR_8 = 1.03$, respectively. Among the sub-criteria comparison, one respondent showed inconsistency in their preferences with $CR = 1.19$ on the evaluation of material and supply. Nonetheless, after close engagement with guidance, we tend to improve the inconsistency level with the respondent's agreement.

TABLE VI
PAIRWISE COMPARISON MATRIX FOR MAIN CRITERIA

	MS	RD	TL	MT	SC
MS	1	$\frac{1}{7}$	$\frac{1}{9}$	$\frac{1}{9}$	$\frac{1}{3}$
RD	7	1	$\frac{1}{5}$	$\frac{1}{2}$	3
TL	9	5	1	7	9
MT	9	2	$\frac{1}{7}$	1	4
SC	3	$\frac{1}{3}$	$\frac{1}{9}$	$\frac{1}{4}$	1

$(CI = 0.11; CR = 0.10)$

Table VII presents the result for classic AHP. As demonstrated, DM showed preferences for teaching & learning, and maintenance is more important than the criterion on material and supply.

TABLE VII
GLOBAL WEIGHT OF CRITERIA AND SUB-CRITERIA AHP WEIGHTING RESULTS

Criteria	**Weights**	**Rank**	**Sub-Criteria**	**Weight Sub-Criteria**	**Rank**
		3	S1	0.604	5
MS	0.17		S2	0.302	6
			S3	0.093	15
		4	S4	0.664	2*
RD	0.15		S5	0.237	7
			S6	0.099	14
		1	S7	0.638	3*
TL	0.30		S8	0.233	8
			S9	0.129	13
		2	S10	0.682	1*
MT	0.26		S11	0.138	12
			S12	0.181	10
		5	S13	0.635	4
SC	0.12		S14	0.173	11
			S15	0.191	9

*Top 3 highest ranking

Table VIII shows the eight decision-makers' mean aggregated weights and their corresponding ranks for two alternative AHP methods: simulation-based AHP and fuzzy AHP. The decision maker estimated that teaching and learning (TL) is preferred as compared to the other components in the faculty budget. The evaluations are followed by maintenance (MT) criteria with a mean weight of 0.26, whereby the other criteria of importance are material & supplies (0.17), research & development (0.15), with staff claim (0.12) deemed as the lowest preference. Meanwhile, for Fuzzy AHP, TL is the priority, followed by MT, MS, and RD, respectively. It is observed that the top three rankings for the criterion are consistent for three methods: classic AHP, simulation-based AHP, and Fuzzy AHP.

After aggregating the DM's relative preference on the main criteria, the sub-criteria from each criterion extracted from DM were aggregated. Finally, all sub-criteria are multiplied by the overall weight of the single-choice criteria to arrive at the final results. The results are summarized in

Table IX displays the local weights, global weights, and the associated rank for three AHP methods. Among all the fifteen sub-criterion evaluations in classic AHP, the laboratory machines and equipment (S10) scored the highest (0.682). The weights for other dimensions are training/ conference, S4 (0.664), teaching and learning equipment, S7 (0.638), travel allowances, S13 (0.635), office supplies, S1 (0.604). Moreover, the less important dimension is equipment installation, S3 (0.093).

The analysis of the evaluation was further carried out by estimating the simulated mean value from the randomized dataset. The evaluations consider the uncertainties in the DM preferences by looking at the two main statistic values i.e., measuring the mean and median of the scores. The variations in the DM's preference is displayed in Fig. 3. Table IX shows the comparison between the mean weighted and its corresponding median (column 2 and 4), and the mean simulated and its median (column 6 and 8) at 95% confidence interval as well as weights for Fuzzy AHP (column 10). For column 3 and column 5, the ranking is based on weighted mean for evaluators, respectively. These two evaluations have similarities in ranking for sub-criteria 1, 12, and 13. Compared to the Fuzzy-AHP, the proposed simulation-based AHP method ranks items S2, S3, and S7 similarly. The top three priorities were identical (S4, S7, and S10), although they differed only in ranking order.

The simulation-based AHP results on the sub-criteria ranking are in columns 7 and 9 for the DMs at the 95% confidence intervals, respectively. Based on the median score, most DMs showed similar preference for sub-criterion 3, 4, 5, 9, 12, and 13 for both geometric weighted and simulated aggregations (columns 5 and 9). However, criterion weights aggregated by geometric mean are unpredictable, showing deviating results and rank reversal (columns 3 and 7). The median value is more significant when the two statistics values are compared. This is indicated by the error bar in Fig 2a being narrower in width than in Fig. 2b. This signifies that the DM preferences are more reliable using the median score. This also highlights the importance of including weights representing the evaluators in calculating the final weights of the criteria. This occurs because, considering the variation in DM judgment, the final overall ranking of the criteria is affected, even though the numerical example is only made of five criteria and eight decision-makers. When various aggregations were employed to rate each particular criterion, all criteria rankings were relatively changed.

TABLE VIII

AGGREGATING THE DECISION MAKER WEIGHT CRITERIA OF INTEGRATED AHP

									Simulation-Based AHP		**Fuzzy AHP**	
Criteria	DM1	DM2	DM3	DM4	DM5	DM6	DM7	DM8	Mean	Rank	Weight	Rank
MS	0.03	0.20	0.04	0.53	0.30	0.03	0.13	0.10	0.17	3	0.197	3
RD	0.14	0.04	0.13	0.03	0.03	0.26	0.51	0.04	0.15	4	0.196	4
TL	0.57	0.15	0.33	0.11	0.12	0.50	0.27	0.35	0.30	1*	0.208	1
MT	0.20	0.56	0.44	0.20	0.49	0.13	0.04	0.05	0.26	2	0.204	2
SC	0.06	0.05	0.06	0.12	0.06	0.09	0.06	0.45	0.12	5	0.196	4

TABLE IX

GLOBAL WEIGHT OF SUB-CRITERIA OF INTEGRATED AHP WEIGHTING RESULTS

	AHP				**Simulation-based AHP**				**Fuzzy AHP**	
Sub-Criteria	**Weighted Mean**	**Rank**	**Median**	**Rank**	**Simulated Mean 95% CI**	**Rank**	**Median 95% CI**	**Rank**	**Weight**	**Rank**
S1	0.604	5	0.043	5	0.101	**3**	0.028	8	0.068	4
S2	0.302	6	0.032	7	0.051	7	0.039	6	0.067	6
S3	0.093	15	0.010	13	0.016	14	0.009	13	0.062	13
S4	0.664	**2***	0.053	**3**	0.101	4	0.079	**3**	0.078	**1**
S5	0.237	7	0.007	15	0.034	11	0.005	15	0.062	14
S6	0.099	14	0.012	12	0.015	15	0.011	11	0.056	15
S7	0.638	**3***	0.166	**1**	0.184	**1**	0.122	**2**	0.078	**2**
S8	0.233	8	0.032	6	0.070	6	0.043	5	0.066	7
S9	0.129	13	0.028	9	0.039	9	0.026	9	0.064	12
S10	0.682	**1***	0.143	**2**	0.175	**2**	0.132	**1**	0.072	**3**
S11	0.138	12	0.031	8	0.037	10	0.033	7	0.066	9
S12	0.181	10	0.025	10	0.048	8	0.025	10	0.066	8
S13	0.635	4	0.046	4	0.072	5	0.044	4	0.068	5
S14	0.173	11	0.009	14	0.020	13	0.009	12	0.064	10
S15	0.191	9	0.019	11	0.023	12	0.008	14	0.064	11

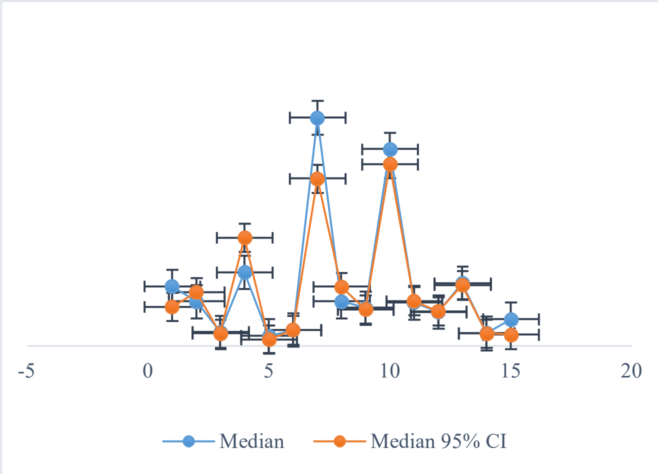

Fig. 2a Weighted Median vs. Median simulated

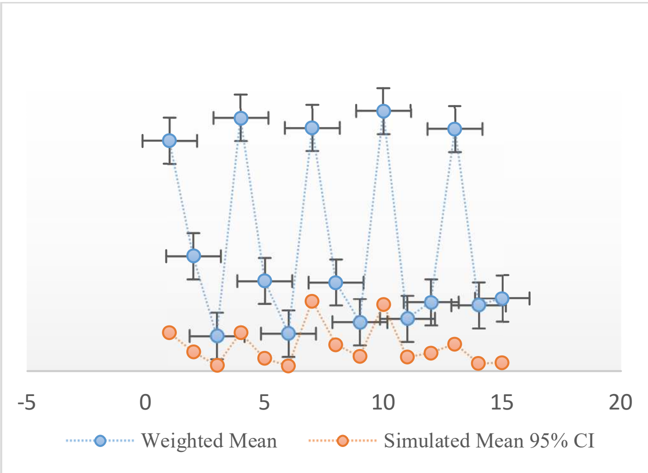

Fig. 2b Weighted mean versus mean simulated

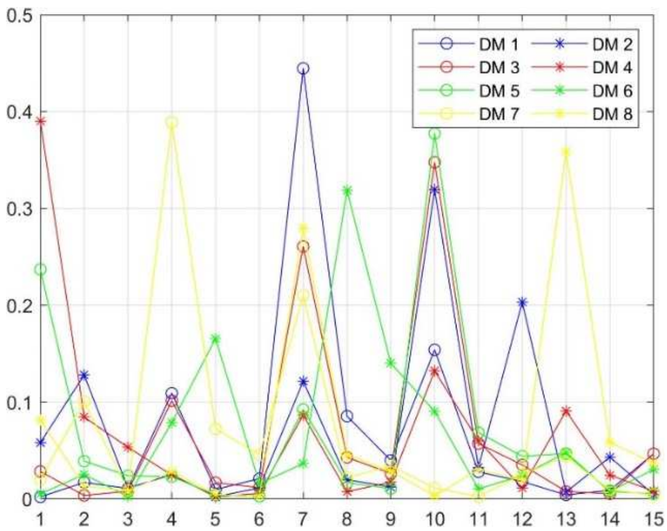

Fig. 3 Variations in DM judgment

IV. Conclusion

A Simulation-based AHP approach was suggested in this paper to assess the most important components of the faculty budget from the perspective of academics and administrative staff. Using the suggested framework, the most important components should be prioritized in the budget. The study demonstrates that the suggested AHP method is applicable as an evaluation tool, and the suggested framework surely makes things easier for the decision maker's while choosing the top importance and exact gears for future budget planning. Furthermore, following a method advocated by [31, 32], our study suggests accompanying a consistency check calculation if a decision-maker has incorrectly entered the pairwise comparison data, rather than if the decision-maker made arbitrary choices. For this purpose, close monitoring and involvement with the decision makers are required for this aim in order to avoid out-of-control scenarios caused by a decision maker's mistakes [30].

Furthermore, it can help decision-makers prioritize the most crucial factors efficiently, especially in the faculty budget policy. Five main criteria for the faculty budget allocation were used in this study: material and supplies, research and development, teaching and learning, maintenance and staff claim. Additionally, the following sub-criteria are considered to be the most important: S10-laboratory machines and equipment, S7 (TL equipment and devices), S4 (training/conferences), S13 (travel allowances), and S1 (office supplies), respectively. The S10 can be explained in the context of faculty maintenance. Based on the selected criteria and the decision-makers judgements, teaching and learning were identified as the most important elements in budget allocation.

In conclusion, the suggested methodology provides an organized and methodical approach to prioritizing faculty allocation assessment. The acquired findings indicate the simulation-based AHP method's efficiency in identifying the ranking order of criteria based on relevance. In addition, the significance of preceding definitions of criteria and sub-criteria that are precise was made evident. By enhancing the conventional AHP approach with modifications in the DM estimations, our proposed framework for the budget allocation policy provides a useful tool for decision-makers in budget planning and monitoring. However, we recognize the limits of the traditional AHP technique. This strategy is frequently criticized for failing to appropriately handle the ambiguity and imprecision associated with transferring decision-maker perceptions to a specific number [33]. Future research might investigate alternative variants of AHP for budget allocation policy in conjunction with the consistency control technique.

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