Prioritization of Factors Impacting Lecturer Research Productivity Using an Improved Fuzzy Analytic Hierarchy Process Approach

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Abstract: Improving the scientific research productivity of lecturers is an important strategy contributing to improving the reputation of universities, attracting external funding sources, and improving the credibility of both domestic and international students. This study was carried out with the aim of determining the priority of the university’s governance factors that affect lecturers’ scientific research productivity. Six university governance factors were considered, including (i) research objectives and strategies, (ii) decentralization, (iii) leadership, (iv) support for research activities, (v) policy towards lecturers, and (vi) resources for research activities. In this study, an improved analytic hierarchy process method using generalized triangular fuzzy numbers and a centroid index was proposed. The research data were collected via in-depth interviews with experts and administrators at Vietnam National University, Hanoi (VNU). The results indicate that “resources for research activities” constitute the most important factor affecting the research productivity of lecturers at VNU, followed by research objectives and strategies and leadership.

Keywords: lecturer research productivity; AHP; generalized fuzzy numbers; Vietnam National University

1. Introduction

In recent years, administrators and universities all over the world have been increasingly interested in improving lecturers’ research productivity, which is a key criterion for university rankings and one of the most important factors to consider when evaluating a university’s research performance [1,2]. Many scholars have conducted research on individual and organizational factors that influence university lecturers’ research productivity and research outcomes [3–5]. According to Nafukho et al. [3], the research productivity of lecturers at top Kenyan universities varies with gender, subject major, number of years of experience, terminal degree, number of students enrolled, proportion of students pursuing a doctoral degree, and research funding. These authors also point out that at top Kenyan universities, lecturers’ experience is not a determining factor in their research productivity. Abramo et al. [4] investigated how individual and organizational factors interact to influence lecturer collaboration and research productivity in Italy. According to their findings,
academic rank has an impact on cooperation but not on lecturers’ research productivity. The authors further show that research productivity has a positive impact on national and international collaboration, but only domestic collaboration has a positive impact on research productivity. Tafreshi et al. [5] investigated the factors that influence lecturers’ research productivity at Islamic Azad University. Their results show that individual factors such as job satisfaction, learning and teaching processes, and the desire to specialize have an impact on lecturers’ scientific research productivity, but organizational factors such as organizational support, organizational culture, organizational objectives, motivational factors, student characteristics, and industrial relationships have no direct impact.

In addition, there have been a number of studies addressing factors related to university governance that affect lecturers’ research productivity. Typical factors include research objectives and strategies [2,6,7], the autonomy and decentralization of academic institutions and lecturers [1,8,9], leadership [6,10,11], support for scientific research activities [4,12], policy regimes affecting lecturers [13,14], and resources [15,16]. Jung [1] indicated that the research productivity of Hong Kong academics was influenced by personal characteristics, workload, differences in research styles, and institutional characteristics. Hedjazi and Jaleh [2] found that network of communication with colleagues, resources of facilities, corporate management, and clear research objectives were significant predictors for agricultural faculty members’ research product all over Tehran Province. Abramo et al. [4] applied different cross-lagged panel models to analyze the relationship between research productivity, collaboration, and their determinants. Their results showed that only collaboration at the intramural and domestic level has a positive effect on research productivity. Jahan et al. [6] indicated that research training and skill, financial support, technical and logistic support, mentorship, and teamwork were the main factors affecting quality academic research at Oman Medical College. Bland [7] found that faculty productivity was influenced more by individual and institutional characteristics; group productivity was more affected by institutional and leadership characteristics. Ryu [9] showed that leadership was the most important factor affecting basic research performance. Knowledge sharing, autonomy, collaboration, and creativity in sequence were also statistically valuable factors that impact the performance of basic research in South Korea. Kok and McDonal [10] revealed a thematic framework of eight broad themes that contribute to excellence in academic departments. These were in the areas of change management, research and teaching, communication, strategy, and shared values, leadership, departmental culture, rewards, and staffing. Salman [13] found that teaching responsibilities and conferences play a significant role in determining research productivity in universities. Hoffmann et al. [14] indicated that the research productivity of academic librarians was significantly impacted by individual attributes, peers and community, and institutional structures and supports. Yang [15] mentioned that university professors in Taiwan generally considered governmental research funding to be the most important indicator, followed by students’ academic ability and digital library resources. However, there seems to have been no research examining the overall impact of university governance factors on lecturers’ scientific research productivity. The research methods frequently applied in previous studies include regression analysis [1,3,17], analysis of variance [10,18], structural equation modeling [4,5,19], descriptive statistics and qualitative analysis [11,20], and analytic hierarchy process methods [15].

Currently, the extent analysis method for fuzzy AHP, as proposed by Chang [21], has become one of the most widely used tools for multiple criteria decision-making (MCDM). Fuzzy AHP methodology is used to demonstrate a hierarchical structure and to examine the weights of the decision elements reviewed and evaluated by experts in a vague environment. The literature has proposed numerous fuzzy AHP approaches for solving various types of problems, including renewable energy resources selection [22,23], urban green evaluation [24], operational efficiencies of airports [25], digital transformation strategy analysis [26], land suitability assessment [27], diagnosis of heart diseases [28], supplier selection [29,30], and teaching performance evaluation [31]. Despite its merits, there are some shortcomings associated with Chang’s [21] approach. Wang et al. [32] indicated that
Chang’s [21] approach may assign an irrational zero weight to some useful decision criteria and sub-criteria. In addition, Chang’s [21] approach may make a wrong decision and select the worst decision alternative as the best one. Furthermore, the application of the approach is limited in normalized triangular fuzzy numbers. To overcome all the aforementioned shortcomings with Chang’s [21] approach, this paper proposes an improved fuzzy AHP approach for generalized triangular fuzzy numbers. In the proposed approach, a centroid index is used to determine the priority of the weight vectors. The proposed approach is further applied to define the prioritization of factors impacting lecturer research productivity at Vietnam National University, Hanoi, Vietnam (VNU).

The rest of the paper is organized as follows. Section 2 presents the concepts and definitions of generalized fuzzy numbers. Section 3 briefly reviews Chang’s extent analysis method for fuzzy AHP. Section 4 presents the shortcomings of Chang’s method and the proposed and improved generalized fuzzy AHP method. An application of the proposed method is given in Section 5 to demonstrate its suitability. Finally, conclusions are drawn in Section 6.

2. Fuzzy Number

In this section, some basic concepts of generalized fuzzy numbers are reviewed as follows [33].

Definition 1. A generalized fuzzy number $\tilde{T}$ is described as any fuzzy subset of the real line $\mathbb{R}$ with a membership function $f_T$ that can generally be defined as:

1. $f_T \in [0, w]$, $0 \leq w \leq 1$;
2. $f_T(x) = 0$, for all $x \in (-\infty, a_1]$;
3. $f_T$ is strictly increasing on $[a_1, a_2]$;
4. $f_T(x) = w$, for all $x \in [a_2, a_3]$;
5. $f_T$ is strictly decreasing on $[a_3, a_4]$;
6. $f_T(x) = 0$, for all $x \in (a_4, \infty)$,

where $a_1, a_2, a_3$ and $a_4$ are real numbers.

Definition 2. The fuzzy number $\tilde{T} = (a_1, a_2, a_3, a_4; w)$ is a trapezoidal fuzzy number if its membership function is given by:

$$f_T(x) = \begin{cases} f_T^L(x), & a_1 \leq x \leq a_2, \\ w, & a_2 \leq x \leq a_3, \\ f_T^R(x), & a_3 \leq x \leq a_4, \\ 0, & \text{otherwise}, \end{cases}$$

where $f_T^L(x)$ and $f_T^R(x)$ are the left and right membership functions of $\tilde{T}$, respectively. If $a_1 < a_2 = a_3 < a_4$ then $\tilde{T}$ becomes a generalized triangular fuzzy number and can be denoted by $\tilde{T} = (a_1, a_2, a_4; w)$. If $w = 1$, then $\tilde{T}$ is a normal fuzzy number.

3. Chang’s Extent Analysis Method on Fuzzy AHP

Chang [21] proposed an extent analysis method for fuzzy AHP to obtain a crisp priority vector from a triangular fuzzy comparison matrix. Chang’s [21] approach is briefly discussed as follows:

Let $T = \{t_1, t_2, \ldots, t_n\}$ be an object set and $G = \{g_1, g_2, \ldots, g_m\}$ be a goal set. According to Chang’s [21] approach, each object is taken, and an extent analysis for each goal $(g_i)$ is performed. Therefore, $m$ extent analysis values for each object can be obtained as $M_{g_i}^1, M_{g_i}^2, \ldots, M_{g_i}^m$, $i = 1, 2, \ldots, n$, where $M_{g_i}^j$ $(j = 1, 2, \ldots, n)$ are triangular fuzzy numbers (TFNs).
Assuming that $M_{S_i}^j = (l_{ij}, m_{ij}, u_{ij})$ are the values of the extent analysis of the $i$th object for $m$ goals, the value of the fuzzy synthetic extent $S_i$ is defined as:

$$S_i = \sum_{j=1}^{n} M_{S_i}^j \otimes \left[ \sum_{i=1}^{n} \sum_{j=1}^{n} M_{S_i}^j \right]^{-1} = \left( \sum_{j=1}^{n} l_{ij}, \sum_{j=1}^{n} m_{ij}, \sum_{j=1}^{n} u_{ij} \right), \ i, j = 1, 2, \ldots, n. \tag{2}$$

Letting $S_1 = (l_1, m_1, u_1)$ and $S_2 = (l_2, m_2, u_2)$ be two TFNs, the degree of possibility of $S_1 \geq S_2$ is defined as follows:

$$V(S_1 \geq S_2) = \sup_{x_1 \geq x_2} \left[ \min(\mu_{S_1}(x_1), \mu_{S_2}(x_2)) \right] \tag{3}$$

The membership degree of possibility can be expressed as in Equation (4)

$$V(S_1 \geq S_2) = \text{hgt}(S_1 \cap S_2) = \begin{cases} 1 & \text{if } m_1 \geq m_2 \\ 0 & \text{if } l_1 \geq u_2 \\ \frac{l_1 - u_2}{m_2 - u_2 - (m_1 - l_1)} & \text{otherwise} \end{cases} \tag{4}$$

where $d$ is the ordinate of the highest intersection point of two membership functions $\mu_{S_1}(x_1)$ and $\mu_{S_2}(x_2)$, as shown in Figure 1.

![Figure 1. The comparison of two fuzzy numbers.](image-url)

The degree of possibility for a convex fuzzy number to be greater than $k$ convex fuzzy numbers $S_i (i = 1, 2, \ldots, k)$ can be defined as:

$$V(S \geq S_1, S_2, \ldots, S_k) = \min V(S \geq S_i), i = 1, 2, \ldots, k. \tag{5}$$

The weight vector is given by:

$$W' = (d'(A_1), d'(A_2), \ldots, d'(A_n))^T \tag{6}$$

where $A_i (i = 1, 2, \ldots, n)$ are $n$ elements,

$$d'(A_i) = \min V(S_i \geq S_k), k = 1, 2, \ldots, n; k \neq i \tag{7}$$

Via normalization, the weight vectors can be obtained as:

$$W = (d(A_1), d(A_2), \ldots, d(A_n))^T \tag{8}$$

where $W$ is a non-fuzzy number.
4. Shortcomings of Chang’s Approach and the Proposed Improved Generalized Fuzzy AHP Method

Wang et al. [32] indicated that using Chang’s [21] approach may assign an irrational zero weight to some useful decision criteria and alternatives, leading to them not being considered in decision analysis. This problem is shown in Example 1.

Example 1. Assume that a university wishes to evaluate its lecturers’ performance. Three decision makers, D1, D2, and D3, are responsible for the evaluation of three candidates, A1, A2, and A3. Five criteria are chosen for evaluating the lecturers: publication (C1), classroom teaching (C2), student advising (C3), personality factors (C4), and fluency in a foreign language (C5). Table 1 shows the fuzzy comparison matrix of the five criteria based on three decision makers. Accordingly, the priority vector of the five criteria is estimated by Chang’s approach as \( W = (1, 0, 0, 0.008, 0) \), which means that the criteria C2, C3, and C5 are given a zero weight and are not considered in decision analysis.

Table 1. Fuzzy comparison matrix of five criteria and its priority vector using Chang’s approach.

| Criteria | C1         | C2         | C3         | C4         | C5         | Chang’s [21] Approach |
|----------|------------|------------|------------|------------|------------|-----------------------|
|          | Value Of Fuzzy Synthetic Extent | Priority Vector |
| C1       | (1.00, 1.00, 1.00) | (4.00, 5.00, 6.00) | (5.00, 6.00, 7.00) | (2.00, 3.00, 4.00) | (4.00, 5.00, 6.00) | (0.34, 0.52, 0.78)   |
| C2       | (0.17, 0.20, 0.25) | (1.00, 1.00, 1.00) | (1.00, 1.00, 1.00) | (0.33, 0.50, 1.00) | (1.00, 1.00, 1.00) | (0.07, 0.10, 0.14)   |
| C3       | (0.14, 0.17, 0.20) | (1.00, 1.00, 1.00) | (1.00, 1.00, 1.00) | (0.33, 0.50, 1.00) | (1.00, 1.00, 1.00) | (0.07, 0.10, 0.14)   |
| C4       | (0.25, 0.33, 0.50) | (1.00, 2.00, 3.00) | (1.00, 2.00, 3.00) | (1.00, 1.00, 1.00) | (1.00, 2.00, 3.00) | (0.09, 0.19, 0.34)   |
| C5       | (0.17, 0.20, 0.25) | (1.00, 1.00, 1.00) | (1.00, 1.00, 1.00) | (0.33, 0.50, 1.00) | (1.00, 1.00, 1.00) | (0.07, 0.10, 0.14)   |

In addition, Liu et al. [34] found that Chang’s [21] approach is inappropriate for normal fuzzy numbers. How-ever, in the real world, it is impossible to restrict the membership function to the normal form in some cases. In order to overcome the shortcomings of Chang’s [21] approach, this paper proposes a revised fuzzy AHP based on the centroid index ranking approach as follows.

The first step defines the generalized triangular fuzzy comparison matrix. The matrix is expressed by:

\[
\tilde{T} = (\tilde{x}_{ij})_{n \times m} = \begin{bmatrix}
    (1, 1, 1; w_{11}) & (a_{12}, b_{12}, c_{12}; w_{12}) & \cdots & (a_{1n}, b_{1n}, c_{1n}; w_{1n}) \\
    (a_{21}, b_{21}, c_{21}; w_{21}) & (1, 1, 1; w_{22}) & \cdots & (a_{2n}, b_{2n}, c_{2n}; w_{2n}) \\
    \vdots & \vdots & \ddots & \vdots \\
    (a_{n1}, b_{n1}, c_{n1}; w_{n1}) & (a_{n2}, b_{n2}, c_{n2}; w_{n2}) & \cdots & (1, 1, 1; w_{nn})
\end{bmatrix}
\]

where \( \tilde{x}_{ij} = (a_{ij}, b_{ij}, c_{ij}; w_{ij}) \), \( \tilde{x}_{ij}^{-1} = (1/c_{ij}, 1/b_{ij}, 1/a_{ij}; w_{ij}) \) for \( i, j = 1, \ldots, n \) and \( i \neq j \).
In addition, Liu et al. [34] found that Chang’s [21] approach fails to correctly determine the relative importance of fuzzy numbers. Furthermore, Chang’s [21] approach only can apply to normal fuzzy numbers. Therefore, it is impossible to restrict the membership function to the normal form in some cases. In order to overcome the shortcomings of Chang’s [21] approach, this paper proposes a revised fuzzy AHP based on the centroid index ranking approach as follows.

The first step defines the generalized triangular fuzzy comparison matrix. The matrix is expressed by:

\[ S_i = (g_i, h_i, k_i; \min(w_{ij})) = \sum_{j=1}^{n} M_{ij}^{-1} \otimes \sum_{j=1}^{n} M_{ij}^{-1} \]

where

\[ M_{ij}^{-1} = \left( \sum_{j=1}^{n} a_{ij}, \sum_{j=1}^{n} b_{ij}, \sum_{j=1}^{n} c_{ij}; \min(w_{ij}) \right), \quad i, j = 1, 2, \ldots, n \]

The third step is to calculate the centroid indices of the fuzzy synthetic extent, \( S_i \) by using Dat et al.’s [35] approach.

Suppose \( S_1, S_2, \ldots, S_n \) are the values of the fuzzy synthetic extents. The centroid point of all fuzzy numbers \( C_i = (\overline{x}_{S_i}, \overline{y}_{S_i}), i = 1, 2, \ldots, n \) can be calculated by:

\[ \overline{x}_{S_i} = (g_i + h_i + k_i) / 3 \]

\[ \overline{y}_{S_i} = \min(w_{ij}) / 3 \]
The distance between the centroid point \( C_i = (\overline{x}_{S_i}, \overline{y}_{S_i}), i = 1, 2, \ldots, n \) and the minimum point \( G = (x_{\text{min}}, y_{\text{min}}) \), is determined by Equation (12) and Figure 3:

\[
D(S_i, G) = \sqrt{(\overline{x}_{S_i} - x_{\text{min}})^2 + (\overline{y}_{S_i} - \overline{w}_{\text{min}})^2}
\]

(12)

where \( x_{\text{min}} = \min(g_i), y_{\text{min}} = \min(w_i) \)

![Figure 3](image)

**Figure 3.** The distance between the centroid point \( C_i = (\overline{x}_{S_i}, \overline{y}_{S_i}) \) and the minimum point \( G = (x_{\text{min}}, y_{\text{min}}) \).

The fourth step defines the weight vector \( W = (w_1, \ldots, w_n)^T \) of the fuzzy comparison matrix as:

\[
w_i = \frac{D(S_i, C_i)}{\sum_{i=1}^{n} D(S_i, C_i)} = \frac{\sqrt{(\overline{x}_{S_i} - x_{\text{min}})^2 + (\overline{y}_{S_i} - \overline{w}_y)^2}}{\sum_{i=1}^{n} \sqrt{(\overline{x}_{S_i} - x_{\text{min}})^2 + (\overline{y}_{S_i} - \overline{w}_y)^2}}, i = 1, \ldots, n
\]

(13)

**Example 2.** This re-considers the data in Example 1. Using Equations (9)–(11), the new fuzzy synthetic extents and the centroid point of five criteria are obtained, respectively (as shown in Table 2). The minimum point of the five criteria is \((x_{\text{min}}, y_{\text{min}}) = (0.07, 1.0)\). By using Equation (12), the distances between the centroid point and minimize point of five criteria are calculated. Finally, the priority vector of five criteria is obtained using Equation (13). Evidently, the priority vector obtained by the proposed fuzzy AHP approach is more reasonable than the outcome obtained using Chang’s [21] approach.

**Example 3.** This considers two fuzzy numbers in Figure 2a, i.e., \( \tilde{A} = (3, 4, 7) \) and \( \tilde{B} = (1, 4, 5) \). Using Equation (9), the fuzzy synthetic extent values of fuzzy numbers \( \tilde{A} \) and \( \tilde{B} \) are 0.375, 0.500, and 0.875 and 0.125, 0.500, and 0.625, respectively. Then, the centroid points of fuzzy numbers \( \tilde{A} \) and \( \tilde{B} \) are obtained by using Equations (10) and (11), i.e., \( C_{\tilde{A}} = (0.583, 0.333) \) and \( C_{\tilde{B}} = (0.417, 0.333) \). By using Equation (12), the relative importance measures of \( \tilde{A} \) and \( \tilde{B} \) are 0.611 and 0.389, respectively, and thus \( \tilde{A} \succ \tilde{B} \). Note that the priority \( \tilde{A} \sim \tilde{B} \) obtained using Chang’s approach is seen as unreasonable and not consistent with human intuition. Clearly, the revised approach can overcome the shortcomings of the inconsistency of Chang’s [21] approach.

**Example 4.** This considers two fuzzy numbers in Figure 2b, i.e., \( \tilde{A} = (6, 6.2, 11.6) \) and \( \tilde{B} = (1, 6.4, 6.6) \). Using Equation (9), the fuzzy synthetic extent values of fuzzy numbers \( \tilde{A} \) and \( \tilde{B} \) are 0.476, 0.492, and 0.921 and 0.079, 0.508, and 0.524, respectively. Then, the centroid points of fuzzy numbers \( \tilde{A} \) and \( \tilde{B} \) are obtained by using Equations (10) and (11), i.e., \( C_{\tilde{A}} = (0.63, 0.333) \) and \( C_{\tilde{B}} = (0.37, 0.333) \). By using Equation (12), the relative importance of \( \tilde{A} \) and \( \tilde{B} \) is 0.654 and 0.346, respectively, and thus \( \tilde{A} \succ \tilde{B} \). Note that the priority \( \tilde{B} \succ \tilde{A} \) obtained using Chang’s [21] approach.
is not consistent with human intuition. Again, this example shows that the proposed approach can overcome the shortcomings of Chang’s [21] approach.

Table 2. Fuzzy comparison matrix of five criteria and its priority vector using the proposed approach.

| Criteria | C1 | C2 | C3 | C4 | C5 |
|----------|----|----|----|----|----|
| Value of fuzzy synthetic extent | (0.41, 0.52, 0.62) | (0.08, 0.10, 0.14) | (0.07, 0.10, 0.13) | (0.10, 0.19, 0.28) | (0.08, 0.10, 0.14) |
| Centroid point | (0.52, 0.33) | (0.10, 0.33) | (0.10, 0.33) | (0.19, 0.33) | (0.10, 0.33) |
| The distance between the centroid point and minimized point | 0.441 | 0.027 | 0.026 | 0.118 | 0.027 |
| Priority vector | 0.689 | 0.043 | 0.041 | 0.184 | 0.043 |

5. Application of the Proposed Fuzzy AHP Approach

In this section, the improved fuzzy AHP approach is applied to define the priority of the university’s governance factors that affect lecturers’ scientific research productivity at Vietnam National University, Hanoi, Vietnam (VNU). VNU is one of two leading multidisciplinary and multi-sectoral national universities in Vietnam. VNU is entrusted with the task of producing highly qualified human resources for the industrialization and modernization of the country. VNU holds a special position in Vietnam’s higher education system, operating according to a special regulation promulgated by the Prime Minister. Currently, this university has 35 members (including 8 affiliated universities, 4 affiliated schools, 7 research institutes, 2 training and research centers, and 13 support/service units), 33 research groups, 216 laboratories, and 4.326 staff members. As of the end of 2020, VNU had 488 training programs (including 185 undergraduate programs, 187 master’s programs, and 116 doctoral programs), with 40.038 undergraduate students, 7500 graduate students, and 819 international students.

In this study, data were collected by conducting semi-structured interviews with the director of VNU’s Organization-Personnel Department, University of economics and Business -VNU’s Office of Human resources and department head, University of economics and Business-VNU’s faculty head. A committee of three decision makers (D₁, D₂, and D₃) conducted the evaluation of the university’s governance factors.

The entire the evaluation of university’s governance factors was characterized by the following steps:

Step 1: Defining the university’s governance factors.
Step 2: Determining fuzzy judgment matrices of factors and sub-factors.
Step 3: Aggregating decisions from decision makers based on geometric means.
Step 4: Calculating fuzzy synthetic extent values of factors and sub-factors.
Step 5: Determining the weight vector of factors and sub-factors impacting lecturer research productivity.

Steps 1 and 2 were performed by the committee (three decision makers, i.e., D₁, D₂, and D₃) without any intervention from the authors. Steps 3–5 were calculated using the improved fuzzy AHP approach on a spreadsheet.

5.1. Defining the University’s Governance Factors

Following a survey of the literature and discussions with the committee, six factors and twenty-two sub-factors affecting lecturers’ scientific research productivity were chosen. Table 3 shows the factors and sub-factors used in this study.
Table 3. Factors affecting lecturers’ scientific research productivity.

| No. | Factors                                      | Sub-Factors and Description                                                        | References |
|-----|----------------------------------------------|--------------------------------------------------------------------------------------|------------|
|     | Research objectives and strategies (RO&S)    | Development orientation towards research university (RO&S1) [2,5,6]                  |            |
| 1   |                                              | Establishing a set of plans and strategies to boost research activities (RO&S2) [9,11,36] |            |
|     |                                              | Specific and widely communicated objectives (RO&S3) [7]                               |            |
|     |                                              | Research strategies and objectives are built up in multiple dimensions (from top to bottom, from bottom to top, there is coordination between units and peer groups) (RO&S4) [1,7,17] |            |
| 2   | Decentralization (DC)                        | Governance decisions are made on the basis of extensive stakeholder engagement, with emphasis on feedback systems and collaboration (DC1) [7,8] |            |
|     |                                              | Governance activities promote academic independence, equality, communication, and connection among members (DC2) [1,17] |            |
|     |                                              | The autonomy of institutions and lecturers (DC3) [9]                                 |            |
|     |                                              | Degree of lecturers’ participation in the decision-making process about scientific research activities in their faculty/university (DC4) [17] |            |
| 3   | Leadership (LD)                             | Professional competence and research experience (LD1) [9]                            |            |
|     |                                              | Ability to connect research groups, attract funding, and create an environment that ensures research activities and innovation (LD2) [20] |            |
|     |                                              | Having a high reputation and clear communication skills (LD3) [6,10]                 |            |
|     |                                              | Leaders’ support for scientific research work and ability to create a departmental research atmosphere (LD4) [15] |            |
| 4   | Support for research activities (SR)         | Specific policies to support scientific research activities (SR1) [19]              |            |
|     |                                              | Administrative support of employees, coordinators in departments, and lecturers’ efforts in promoting research (SR2) [6,11,12,17] |            |
|     |                                              | Support for the transfer and commercialization of research products (SR3) [16,37]   |            |
| 5   | Policy towards lecturers (PL)               | Policy on salaries, bonuses, and incentives (P1) [6,11,38,39]                       |            |
|     |                                              | Research training activities for lecturers (P2) [8]                                  |            |
|     |                                              | Recruiting and signing labor contracts commensurate with lecturers’ scientific research capacities (P3) [11,40] |            |
| 6   | Resources for research activities (R)        | Facilities and equipment for research activities (R1) [9,18]                         |            |
|     |                                              | Budget and research funds for research (R2) [3,14]                                  |            |
|     |                                              | Human resources for research activities (R3) [16]                                   |            |
|     |                                              | Appropriate resource allocation mechanisms (R4) [11]                                 |            |

5.2. Determining Fuzzy Judgment Matrices of Factors and Sub-Factors

In this study, the committee was requested to separately proceed to their own fuzzy judgment matrices for the evaluation of the university’s governance factors. This study adopts an intensity scale for fuzzy numbers to transform the linguistic values into TFNs, as shown in Table 4.

5.3. Aggregating Decisions from Decision Makers Based on Geometric Means

By using the collected data from questionnaires, the averaged fuzzy comprehensive pair-wise comparisons for the two levels of a hierarchical system are calculated, as shown in Tables 5–11.
Table 4. Intensity scale for generalized fuzzy AHP pair-wise comparison.

| Order | Linguistic Values | Triangular Fuzzy Numbers | Reciprocal Triangular Fuzzy Scale |
|-------|-------------------|--------------------------|----------------------------------|
| 1     | Equal importance (EI) | (1, 1, 1; 1.0) | (1, 1, 1; 1.0) |
| 2     | Between EI and WI | (1, 2, 3; 0.7) | (1/3, 1/2, 1; 0.7) |
| 3     | Weak importance of one over another (WI) | (2, 3, 4; 0.7) | (1/4, 1/3, 1/2; 0.7) |
| 4     | Between WI and SI | (3, 4, 5; 0.8) | (1/4, 1/4, 1/3; 0.8) |
| 5     | Strong importance (SI) | (4, 5, 6; 0.8) | (1/6, 1/5, 1/4; 0.8) |
| 6     | Between SI and VSI | (5, 6, 7; 0.9) | (1/7, 1/6, 1/5; 0.9) |
| 7     | Very strong importance (VSI) | (6, 7, 8; 0.9) | (1/8, 1/7, 1/6; 0.9) |
| 8     | Between VSI and AI | (7, 8, 9; 1.0) | (1/9, 1/8, 1/7; 1.0) |
| 9     | Absolute importance (AI) | (8, 9, 9; 1.0) | (1/9, 1/9, 1/8; 1.0) |

Table 5. Averaged fuzzy comparison matrix of six factors assessed by the committee.

| Factors | RO&S | DC | LD | SR | PL | R |
|---------|------|----|----|----|----|---|
| RO&S   | (1.00, 1.00, 1.00; 1.00) | (1.11, 1.83, 2.67; 0.70) | (1.33, 2.33, 3.33; 0.70) | (1.67, 2.67, 3.67; 0.70) | (0.50, 0.56, 0.67; 0.70) | (0.21, 0.26, 0.36; 0.70) |
| DC     | (0.53, 0.94, 1.50; 0.70) | (1.00, 1.00, 1.00; 1.00) | (0.23, 0.31, 0.44; 0.70) | (0.28, 0.39, 0.67; 0.70) | (0.23, 0.31, 0.44; 0.70) | (0.14, 0.16, 0.19; 0.90) |
| LD     | (0.31, 0.44, 0.83; 0.70) | (2.33, 3.33, 4.33; 0.70) | (1.00, 1.00, 1.00; 1.00) | (0.33, 0.50, 1.00; 0.70) | (2.00, 3.00, 4.00; 0.70) | (0.16, 0.19, 0.25; 0.80) |
| SR     | (0.28, 0.39, 0.67; 0.70) | (1.67, 2.67, 3.67; 0.70) | (1.00, 2.00, 3.00; 0.70) | (1.00, 1.00, 1.00; 1.00) | (1.00, 1.33, 1.67; 0.70) | (0.53, 0.94, 1.50; 0.70) |
| PL     | (1.67, 2.33, 3.00; 0.70) | (2.33, 3.33, 4.33; 0.70) | (0.26, 0.36, 0.61; 0.70) | (0.78, 0.83, 1.00; 0.70) | (1.00, 1.00, 1.00; 1.00) | (0.22, 0.29, 0.42; 0.70) |
| R      | (3.00, 4.00, 5.00; 0.70) | (5.33, 6.33, 7.33; 0.90) | (4.33, 5.33, 6.33; 0.80) | (1.11, 1.83, 2.67; 1.00) | (2.67, 3.67, 4.67; 0.70) | (1.00, 1.00, 1.00; 1.00) |

Table 6. Averaged fuzzy comparison matrix of four sub-factors with respect to “research objectives and strategies” as assessed by the committee.

| RO&S   | RO&S1 | RO&S2 | RO&S3 | RO&S4 |
|--------|-------|-------|-------|-------|
| RO&S1  | (1.00, 1.00, 1.00; 1.00) | (0.51, 0.58, 0.78; 0.70) | (2.00, 2.67, 3.33; 0.70) | (1.00, 1.67, 2.33; 0.70) |
| RO&S2  | (1.67, 2.33, 3.00; 0.70) | (1.00, 1.00, 1.00; 1.00) | (4.00, 5.00, 6.00; 0.70) | (2.33, 3.33, 4.33; 0.70) |
| RO&S3  | (0.48, 0.53, 0.61; 0.70) | (0.19, 0.24, 0.33; 0.70) | (1.00, 1.00, 1.00; 1.00) | (0.56, 0.67, 1.00; 0.70) |
| RO&S4  | (0.56, 0.67, 1.00; 0.70) | (0.24, 0.33, 0.56; 0.70) | (1.00, 1.67, 2.33; 0.70) | (1.00, 1.00, 1.00; 1.00) |

Table 7. Averaged fuzzy comparison matrix of three sub-factors with respect to “decentralization” as assessed by the committee.

| DC     | DC1   | DC2   | DC3   | DC4   |
|--------|-------|-------|-------|-------|
| DC1    | (1.00, 1.00, 1.00; 1.00) | (1.33, 2.33, 3.33; 0.70) | (1.67, 2.67, 3.67; 0.70) | (0.53, 0.61, 0.83; 0.70) |
| DC2    | (0.31, 0.44, 0.83; 0.70) | (1.00, 1.00, 1.00; 1.00) | (1.00, 1.67, 2.33; 0.70) | (0.22, 0.29, 0.42; 0.70) |
| DC3    | (0.28, 0.39, 0.67; 0.70) | (0.56, 0.67, 1.00; 0.70) | (1.00, 1.00, 1.00; 1.00) | (0.19, 0.24, 0.33; 0.70) |
| DC4    | (1.33, 2.00, 2.67; 0.70) | (2.67, 3.67, 4.67; 0.70) | (3.33, 4.33, 5.33; 0.70) | (1.00, 1.00, 1.00; 1.00) |
Table 8. Averaged fuzzy comparison matrix of four sub-factors with respect to “leadership” as assessed by the committee.

| LD   | LD1     | LD2     | LD3     | LD4     |
|------|---------|---------|---------|---------|
| LD1  | (1.00, 1.00, 1.00; 1.00) | (1.33, 2.33, 3.33; 0.70) | (1.67, 2.67, 3.67; 0.70) | (0.51, 0.92, 1.44; 0.70) |
| LD2  | (0.31, 0.44, 0.83; 0.70) | (1.00, 1.00, 1.00; 1.00) | (1.00, 1.33, 1.67; 0.70) | (0.21, 0.29, 0.49; 0.70) |
| LD3  | (0.28, 0.39, 0.67; 0.70) | (0.78, 0.83, 1.00; 0.70) | (1.00, 1.00, 1.00; 1.00) | (0.18, 0.26, 0.45; 0.70) |
| LD4  | (1.44, 2.17, 3.00; 0.70) | (3.67, 4.67, 5.67; 0.70) | (4.33, 5.33, 6.44; 0.70) | (1.00, 1.00, 1.00; 1.00) |

Table 9. Averaged fuzzy comparison matrix of three sub-factors with respect to “support for research activities” as assessed by the committee.

| SR   | SR1     | SR2     | SR3     |
|------|---------|---------|---------|
| SR1  | (1.00, 1.00, 1.00; 1.00) | (0.51, 0.58, 0.78; 0.70) | (1.33, 2.00, 2.67; 0.70) |
| SR2  | (1.67, 2.33, 3.00; 0.70) | (1.00, 1.00, 1.00; 1.00) | (2.67, 3.67, 4.67; 0.70) |
| SR3  | (0.53, 0.61, 0.83; 0.70) | (0.22, 0.28, 0.39; 0.70) | (1.00, 1.00, 1.00; 1.00) |

Table 10. Averaged fuzzy comparison matrix of three sub-factors with respect to “policy towards lecturers” as assessed by the committee.

| PL   | PL1     | PL2     | PL3     |
|------|---------|---------|---------|
| PL1  | (1.00, 1.00, 1.00; 1.00) | (1.33, 2.33, 3.33; 0.70) | (1.00, 1.33, 1.67; 0.70) |
| PL2  | (0.31, 0.44, 0.83; 0.70) | (1.00, 1.00, 1.00; 1.00) | (0.53, 0.61, 0.83; 0.70) |
| PL3  | (0.78, 0.83, 1.00; 0.70) | (1.33, 2.00, 2.67; 0.70) | (1.00, 1.00, 1.00; 1.00) |

Table 11. Averaged fuzzy comparison matrix of four sub-factors with respect to “resources for research activities” as assessed by the committee.

| R    | R1      | R2      | R3      | R4      |
|------|---------|---------|---------|---------|
| R1   | (1.00, 1.00, 1.00; 1.00) | (0.28, 0.39, 0.67; 0.70) | (0.78, 1.17, 1.67; 0.70) | (0.28, 0.39, 0.67; 0.70) |
| R2   | (1.67, 2.67, 3.67; 0.70) | (1.00, 1.00, 1.00; 1.00) | (2.00, 3.00, 4.00; 0.70) | (1.00, 1.00, 1.00; 1.00) |
| R3   | (0.78, 1.17, 1.67; 0.70) | (0.28, 0.40, 0.75; 0.70) | (1.00, 1.00, 1.00; 1.00) | (1.56, 2.00, 2.67; 0.70) |
| R4   | (1.67, 2.67, 3.67; 0.70) | (1.00, 1.00, 1.00; 1.00) | (0.72, 1.40, 2.08; 0.70) | (1.00, 1.00, 1.00; 1.00) |

5.4. Calculating Fuzzy Synthetic Extent Values of Factors and Sub-Factors

Using Equation (9) and Tables 5–11, the fuzzy synthetic extent values of factors and sub-factors are calculated (as shown in Table 12).

5.5. Determining the Weight Vector of Factors and Sub-Factors Impacting on Lecturer Research Productivity

Using Equations (10)–(13), the weight vectors of the factors and sub-factors affecting lecturer research productivity are shown in Table 13. The result indicates that “resources for research activities” is the most important factor affecting the research productivity of lecturers at VNU. This result is similar to other studies in which it has been found that the quality of human resources, investment in facilities, equipment, and investment funds for research activities have a strong impact on the research productivity of lecturers. VNU is a multi-disciplinary university with a higher percentage of lecturers with doctoral degrees than many other universities in Vietnam. This has been used by VNU in the establishment of interdisciplinary research groups and has resulted in many important achievements through the implementation of national and international research missions. However,
at present, the facilities of many universities under VNU are quite limited, scattered, and not synchronized. The financial resources invested in science and technology activities are not commensurate with the potential or the need to improve the research capacity of the teaching staff to meet international standards.

Table 12. Fuzzy synthetic extent values of factors and sub-factors.

| Factors | Fuzzy Synthetic Extent | Sub-Factors | Fuzzy Synthetic Extent |
|---------|------------------------|-------------|------------------------|
| RO&S    | (0.08, 0.15, 0.24; 0.70) | RO&S1      | (0.17, 0.25, 0.35; 0.70) |
|         |                        | RO&S2      | (0.37, 0.49, 0.74; 0.70) |
|         |                        | RO&S3      | (0.08, 0.10, 0.51; 0.70) |
|         |                        | RO&S4      | (0.10, 0.15, 0.97; 0.70) |
| DC      | (0.03, 0.05, 0.09; 0.70) | DC1        | (0.18, 0.28, 0.41; 0.70) |
|         |                        | DC2        | (0.09, 0.15, 0.31; 0.70) |
|         |                        | DC3        | (0.07, 0.10, 0.26; 0.70) |
|         |                        | DC4        | (0.34, 0.47, 0.99; 0.70) |
| LD      | (0.09, 0.14, 0.23; 0.70) | LD1        | (0.16, 0.27, 0.38; 0.70) |
|         |                        | LD2        | (0.08, 0.12, 0.24; 0.70) |
|         |                        | LD3        | (0.07, 0.10, 0.23; 0.70) |
|         |                        | LD4        | (0.39, 0.51, 0.99; 0.70) |
| SR      | (0.08, 0.14, 0.23; 0.70) | SR1        | (0.21, 0.29, 0.39; 0.70) |
|         |                        | SR2        | (0.44, 0.56, 0.83; 0.70) |
|         |                        | SR3        | (0.12, 0.15, 1.00; 0.70) |
| PL      | (0.09, 0.14, 0.22; 0.70) | PI1        | (0.31, 0.44, 0.55; 0.70) |
|         |                        | PI2        | (0.15, 0.19, 0.46; 0.70) |
|         |                        | PI3        | (0.26, 0.36, 1.00; 0.70) |
| R       | (0.26, 0.38, 0.51; 0.70) | R1         | (0.09, 0.14, 0.23; 0.70) |
|         |                        | R2         | (0.24, 0.36, 0.55; 0.70) |
|         |                        | R3         | (0.14, 0.21, 0.58; 0.70) |
|         |                        | R4         | (0.18, 0.29, 0.99; 0.70) |

Table 13. Weight vector of factors and sub-factors impacting lecturer research productivity.

| Factors | Weight Score | Sub-Factors | Weight Score |
|---------|--------------|-------------|--------------|
| RO&S    | 0.144        | RO&S1       | 0.165        |
|         |              | RO&S2       | 0.399        |
|         |              | RO&S3       | 0.145        |
|         |              | RO&S4       | 0.291        |
| DC      | 0.076        | DC1         | 0.231        |
|         |              | DC2         | 0.132        |
|         |              | DC3         | 0.103        |
|         |              | DC4         | 0.535        |
Table 13. Cont.

| Factors | Weight Score | Sub-Factors | Weight Score |
|---------|--------------|-------------|--------------|
| LD      | 0.143        | LD1         | 0.219        |
|         |              | LD2         | 0.106        |
|         |              | LD3         | 0.096        |
|         |              | LD4         | 0.579        |
| SR      | 0.139        | SR1         | 0.189        |
|         |              | SR2         | 0.499        |
|         |              | SR3         | 0.313        |
| PL      | 0.137        | P1          | 0.353        |
|         |              | P2          | 0.167        |
|         |              | P3          | 0.480        |
| R       | 0.362        | R1          | 0.091        |
|         |              | R2          | 0.292        |
|         |              | R3          | 0.227        |
|         |              | R4          | 0.390        |

6. Conclusions

Increasing lecturers’ research productivity plays an important role in improving teaching quality, as well as universities’ global status and prestige. This study indicated the shortcomings of Chang’s extent analysis method for fuzzy AHP and proposed an innovative revised fuzzy AHP approach. The proposed AHP approach considers both normal triangular fuzzy numbers and non-normal triangular fuzzy numbers. Comparative examples were presented to demonstrate the validity and advantages of the proposed fuzzy AHP approach. This study shows that the results obtained using the proposed fuzzy AHP approach are more consistent with human intuition than Chang’s approach. The proposed fuzzy AHP approach was further applied to determine the priority of the university’s governance factors that affect lecturers’ scientific research productivity. The result indicated that “Resources for research activities” is the most important factor affecting the research productivity of lecturers at VNU, followed by research objectives and strategies and leadership.

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