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**Research Article**

# Evaluating the campus climate factors using an interval type-2 fuzzy ANP

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## ABSTRACT

University campuses, characterized by their urban amenities, socio-cultural atmosphere, and diverse user population, play a significant role as public places in small cities. The physical layout of campus locations influences our views toward schooling. The concept of an inclusive campus climate refers to how people and groups perceive and interact with the environment within the campus community. The campus atmosphere encompasses the variety of people, their unique experiences, and the interpersonal contact among them.
The membership functions of type-1 (T1) fuzzy sets (FSs) are represented in two dimensions, whereas the membership functions of type-2 (T2) FSs are represented in three dimensions. The introduction of this new third dimension allows for the direct modeling of uncertainties by providing more degrees of freedom. In addition, the membership value of T2 FSs is more adept at managing ambiguities. In this paper, an interval type-2 fuzzy analytic network process (IT2 FANP) is used to evaluate the weight of criteria decided by experts in the evaluation of campus climate factors with trapezoidal fuzzy numbers. The aim of this paper is to evaluate the campus climate factors using an IT2 FANP methodology. For this problem, the three main criteria and nine subcriteria were defined by experts. Therefore, the ranking of main criteria is "Physical Environment" > "Conceptual Environment" > "Administrative Environment", and the ranking of subcriteria is found as "Social Environment" > "Exterior" > "Interior" > "Cultural Environment" > "Psychological Environment" > "Inclusive Goal and Perception" > "Economic Factors" > "Accreditation" > "Legislation on Inclusive Design" by IT2 FANP methodology.

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## INTRODUCTION

In its simplest sense, public space refers to an area in our social life where something like the public can be created [1]. As a common use area, it is a tool to obtain values of public spaces, communication between individuals, meeting the needs, development of the impression and social awareness of the space. The public spaces inside the city, where

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members of society engage in intense social interactions, have a significant impact on urban growth. Cultural, economic, and technological factors that are constantly changing and evolving have an impact on how we understand, need, and use public space. Urban growth necessitates the careful design of public places based on their purpose and significance. Due to their amenities and social atmosphere, campuses serve as vital public areas, resembling little cities. The layout of campus spaces has a significant impact on our attitudes towards education and should be tailored to meet the demands of all campus users.

The word “climate” on a university campus refers to the way people and groups perceive and interact with the school environment. This word encompasses the whole framework of the organization’s inclusive dynamics and the perceived inclusion or exclusion of different stakeholders. Discussions around climate change inherently involve many groups’ objective and subjective experiences, encompassing social identities delineated by race, ethnicity, gender, sexuality, disability, and a wide spectrum of other factors [2].

Diversity and climate are significant concerns on college and university campuses [3]. Over the past two decades, professors with gender, ethnic, disability, and religious disparities have proliferated [4-8].

The campus atmosphere fosters a heterogeneous population composed of individuals from many backgrounds. Conversely, the term “environment” pertains to the encounters and dynamics among individuals and organizations within a campus setting. Put simply, the campus atmosphere is a crucial element of a complete strategy for promoting diversity. In order to establish a learning community, the major objective of the academy should be to cultivate an atmosphere that fosters variety and embraces individual differences.

According to Kenney et al. [9], the following criteria must be met for a comprehensive campus plan, prioritizing the general plan on individual buildings and spaces. Compactness (density) boosts campus life and engagement. They are creating a landscape language that expresses campus, individualism, and regional context. Campus architecture and integrated technologies may fix environmental challenges visually. A beneficial physical connection has been established with the campus environment and provides meaning and beauty to places on campus.

The university facilitates the convergence of people from many socio-cultural backgrounds. Simultaneously, the university facilitates the personal and intellectual growth of individuals while also serving as a space for sociability. Universities generate dynamism through their social, cultural, economic, and geographical impacts.

Academic community opinions and expectations are reflected in campus climate, which is the interaction between people, processes, and institutional culture [3], [8]. Welcomed teachers provide many perspectives, experiences, attitudes, and styles to universities that improve teaching and research. Understanding diversity and connecting with varied college students may be concerns. Different views of campus representative groups are expected, but embracing, accepting, and understanding differences and realizing the need for diversity engagement and exposure increases the likelihood of creating a welcoming atmosphere.

Studying the campus climate and culture is essential for the campus-based conceptual assessment. The adoption of a data-driven approach to culture aims to cultivate a more holistic campus environment. Effective campus climate research results in the establishment of an equitable environment for the university community, including faculty, staff, women, minorities, lesbian, gay, bisexual, and transgender (LGBT) community members, and others.

With their economic, social, cultural, and spatial effects, universities have started to give cities a new identity and vitality. Today, various sectoral development outputs of this process have begun to be obtained. Universities have an important mission by playing a role in reducing multiple problems such as inequality of opportunity in education and regional disparities. Thus, the investment made for the establishment of the university and the payments made by the university in the city after the university started to work have an effect that is more than the first payment. According to this model, the multiplier effect, the university’s expenditures, and the costs made by students and university staff stimulate the demand for other products and services by facilitating the economic activity in the enterprises that provide this demand [10].

Universities make essential contributions in both quantity and quality to social development and development. Among these contributions are creating equal opportunities in the society, building human resources at an international level, raising leaders, developing entrepreneurial spirit, supporting technological development, influencing the disposition trend, creating positive effects in income distribution, and ensuring national unity [11].

Campus design is crucial to making a good first impression on potential students [12-14]. Open areas, parking, living rooms, and library and student club designs stand out in the campus plan. Universities are influential institutions that drive the development and direction of the towns and areas where they are situated. Consequently, all users possess equitable entitlements and regulations, serving as a model for universal accessibility, both in terms of physical and geographical aspects. These institutions must ensure the accessibility of all individuals, including students, workers, or visitors, who need to utilize their facilities or campus in any capacity. Universities must prioritize accessibility in terms of education, employment, and living rights for handicapped people, who are now an important part of society [15].

The framework prepared for the campus environment includes a conceptual climate, administrative environment, and physical environment. While planning university campuses, it is necessary to think together to provide for psychosocial and cultural regulations, the approach to the administrative environment, physical arrangements in the open areas of the campus, and the buildings within the campus.

Multi-Criteria Decision Making (MCDM) involves prioritizing options depending on various criteria [16]. The act of solving the architectural design process includes decision-making stages of different nature. In this process, evaluation based on decision-making is made in two main stages, product-based and process-based. In the field of architecture, where intuition is intense, these decision-making stages contain incomplete and imprecise information. Therefore, the evaluations made in the architectural design process are expressed as complicated decision-making processes. In this respect, within the scope of the study, the solution to the problem in campus design was handled in the context of decision-making, and a decision-making method was applied in the design process.

In this paper, the evaluation of the campus climate factors was considered an MCDM case. MCDM approaches examine numerous factors to choose the optimum solution [17]. By prioritizing the campus climate factors, the authors asked three industry experts (architect, interior architect, and civil engineer) of the same importance about the problem of evaluating the campus climate factors. This paper uses an interval type-2 fuzzy analytic network process (IT2 FANP) methodology to assess the campus climate factors with trapezoidal fuzzy numbers. No other paper has used this strategy to evaluate campus climate factors. We sought a flexible and intentional approach to explore fuzzy MCDM problems. The MCDM approach is used in the model to assist decision-makers in assessing options by minimizing ambiguity and complexity.

Many studies handle MCDM problems using the fuzzy analytical network process (FANP). Ayag and Ozdemir [18] proposed a smart approach to the selection of enterprise resource planning (ERP) software through a FANP. Kang et al. [19] developed an FANP supplier selection model and implemented it to simplify the decision process. Dargi et al. [20] proposed an FANP technique for supplier selection, which determines the most critical factors in the Iranian automotive industry. Govindan et al. [21] developed an FANP model for barrier evaluation in the reproduction of automotive parts. In their study, Hemmati et al. [22] created and utilized the FANP model to determine the optimal maintenance strategy for an acid manufacturing company. Danai et al. [23] introduced a FANP technique for selecting the optimal supplier in the supply chain. Alilou et al. [24] created a new framework to evaluate the health of a watershed by utilizing the FANP method, which takes into account both geo-environmental and topo-hydrological parameters. Galankashi et al. [25] introduced a set of precise criteria and a FANP technique to assess and choose portfolios on the tehran stock exchange (TSE).

Zadeh introduced type-2 fuzzy sets (T2 FSs) [26]. The concept of T2 FSs is an extension of a T1 fuzzy set. The T2 fuzzy set approach represents uncertainty and provides flexibility compared to T1 FSs. In addition, a T2 fuzzy set ensures that uncertainty is adequately modeled [27]. T2 FSs allow modeling and minimizing delays in rule-based fuzzy logic systems. T1 FSs, whose membership functions are completely crisp, cannot directly model uncertainties [28].

T1 FSs have two-dimensional membership functions, whereas T2 FSs have three-dimensional membership functions. IT2 FS is an instance of the more general T2 FS. Interval type-2 fuzzy sets (IT2 FSs) are the most frequently implemented T2 FSs due to their computational efficiency and simplicity in comparison to general T2 FSs. The literature records the contributions of Kahraman et al. [29], Karnik et al. [30], Mendel et al. [31], Boran and Akay [32], and Sola et al. [33] to the development of IT2 FSs.

In the literature, there is limited research on the FANP approach using IT2 FSs. Senturk et al. [27] modified Buckley's methodology with IT2 FSs to create a FANP method using IT2 FSs. Wu and Liu [34] presented a FANP technique using IT2 FSs to assess enterprise technology innovation ability (ETIA). Senturk et al. [35] suggested an IT2 FANP technique for third-party logistics (3PL) firm selection problems based on benefit, opportunity, cost, and risk (BOCR). Erginel et al. [36] created a FANP technique for rating completed six sigma projects using IT2 FSs.

The originality of the paper comes from the first-time usage of this approach based on IT2 FANP methodology in evaluating campus climate factors. No campus environment factor research has used this strategy, as shown in the literature. This article aims to evaluate campus climate factors using an IT2 FANP methodology. Experts have defined three main criteria and nine subcriteria for this problem. The ranking of main criteria and subcriteria was obtained by this method. The rest of this paper is organized as follows. A brief description of the campus climate is given in Section 2. The problem is defined in Section 3. Section 4 describes trapezoidal IT2 FSs and IT2 FANP methodology. In Section 5, IT2 FANP method was applied in evaluating campus climate factors. Section 5 also includes computational findings. Finally, in Section 6, which closes the work, future research directions are outlined.

## PROBLEM DEFINITION AND METHODOLOGY

Evaluating the campus climate factors [37] was chosen for this study, and IT2 FANP methodology was used. We asked three experts (namely architect, interior architect, and civil engineer) with the same essential value about the problem of evaluating the campus climate. Three primary criteria and nine subcriteria were identified and weighted.

In this study, the IT2 FANP methodology prioritizes the campus climate factors. The aim of using IT2 FANP methodology in this study is; Type-2 fuzzy sets enable us to effectively model and mitigate the impact of uncertainty in rule-based fuzzy logic systems. IT2 FSs are commonly employed as Type-2 fuzzy sets due to their simplicity and

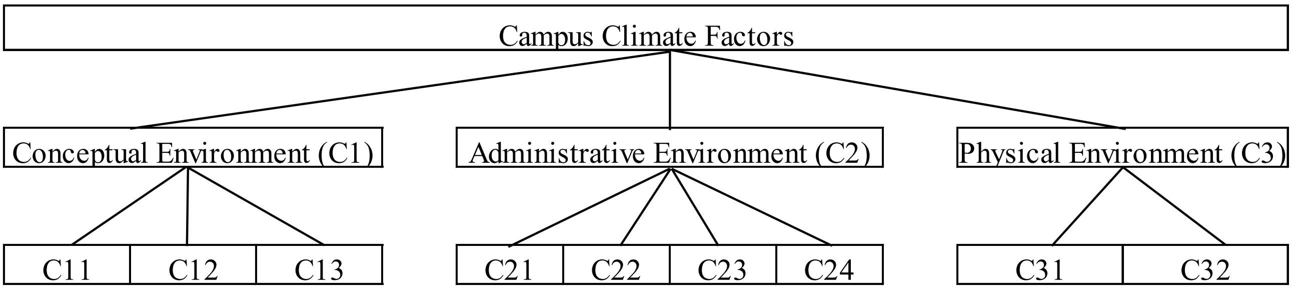


**Figure 1.** The problem's hierarchy.

lower computing requirements compared to broader Type-2 fuzzy sets. Consequently, we employed IT2 FSs.

In the numerical example, the architect, the interior architect, and the civil engineer needed to prioritize the campus climate factors. Experts defined the main criteria, and experts determined subcriteria [37], as seen in Figure 1. There are three main criteria and nine subcriteria. In this paper, the main criteria were Conceptual Environment, Administrative Environment, and Physical Environment. The arrows in Figure 1 represent the hierarchy of the problem.

Conceptual Environment criteria (C1) include subcriteria about conceptual issues: "Cultural Environment (C11)", "Social Environment (C12)", and "Psychological Environment (C13)".

Administrative Environment criteria (C2) include subcriteria about administration: "Inclusive Goal and Perception (C21)", "Economic Factors (C22)", "Legislation on Inclusive Design (C23)", and "Accreditation (C24)".

Physical Environment criteria (C3) include the following subcriteria: "Exterior (C31)", and "Interior (C32)".

### Arithmetic Operations among Trapezoidal Interval Type-2 Fuzzy Sets

Some basic operational laws associated with trapezoidal interval IT2 FSs are briefly investigated in this section [16].

**Definition 1.1.** To characterize type-1 fuzzy systems, the upper and lower membership functions of IT2 FSs are utilized. Figure 2 illustrates a trapezoidal IT2 FS in the following manner:

$\tilde{\tilde{A}}_i = (\tilde{A}_i^U; \tilde{A}_i^L) = \Big(\big(a_{i1}^U, a_{i2}^U, a_{i3}^U, a_{i4}^U; H_1(\tilde{A}_i^U), H_2(\tilde{A}_i^U)\big),$ $\big(a_{i1}^L, a_{i2}^L, a_{i3}^L, a_{i4}^L; H_1(\tilde{A}_i^L), H_2(\tilde{A}_i^L)\big)\Big)$ where $\tilde{A}_i^U$ and $\tilde{A}_i^L$ are type-1 fuzzy systems, $a_{i1}^U, a_{i2}^U, a_{i3}^U, a_{i4}^U$, $a_{i1}^L, a_{i2}^L, a_{i3}^L$ and $a_{i4}^L$ are the references points of the IT2 fuzzy set $\tilde{\tilde{A}}_i$, $H_j(\tilde{A}_i^U)$ represents the membership value of the element $a_{j(j+1)}^U$ in the upper trapezoidal membership function $\tilde{A}_i^U$, $1 \le j \le 2$, and $H_j(\tilde{A}_i^L)$ represents the membership value of the element $a_{j(j+1)}^L$ in the lower trapezoidal membership function $\tilde{A}_i^L$, $1 \le j \le 2$, where $H_1(\tilde{A}_i^U) \in [0,1]$, $H_2(\tilde{A}_i^U) \in [0,1]$, $H_1(\tilde{A}_i^L) \in [0,1]$, $H_2(\tilde{A}_i^L) \in [0,1]$ and $1 \le i \le n$ [17].

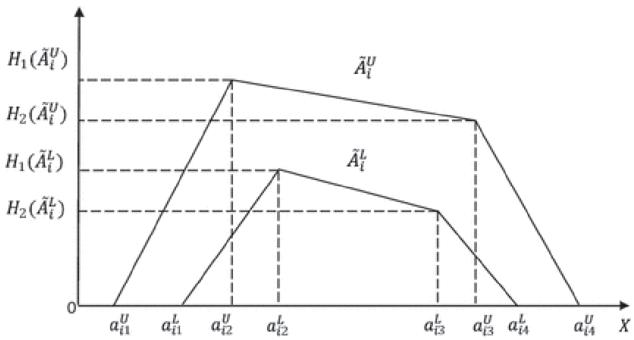


**Figure 2.** The membership functions of the IT2 fuzzy set $\tilde{\tilde{A}}$.

**Definition 1.2.** The addition of two trapezoidal IT2 FSs

$\tilde{\tilde{A}}_1 = \Big(\big(a_{11}^U, a_{12}^U, a_{13}^U, a_{14}^U; H_1(\tilde{A}_1^U), H_2(\tilde{A}_1^U)\big), \big(a_{11}^L, a_{12}^L, a_{13}^L, a_{14}^L; H_1(\tilde{A}_1^L), H_2(\tilde{A}_1^L)\big)\Big)$ and
$\tilde{\tilde{A}}_2 = \Big(\big(a_{21}^U, a_{22}^U, a_{23}^U, a_{24}^U; H_1(\tilde{A}_2^U), H_2(\tilde{A}_2^U)\big), \big(a_{21}^L, a_{22}^L, a_{23}^L, a_{24}^L; H_1(\tilde{A}_2^L), H_2(\tilde{A}_2^L)\big)\Big)$ is defined as:

$$\tilde{\tilde{A}}_1 \oplus \tilde{\tilde{A}}_2 = \Big(\Big(a_{11}^U + a_{21}^U, a_{12}^U + a_{22}^U, a_{13}^U + a_{23}^U, a_{14}^U + a_{24}^U; min\big(H_1(\tilde{A}_1^U); H_1(\tilde{A}_2^U)\big), min\big(H_2(\tilde{A}_1^U); H_2(\tilde{A}_2^U)\big)\Big), \Big(a_{11}^L + a_{21}^L, a_{12}^L + a_{22}^L, a_{13}^L + a_{23}^L, a_{14}^L + a_{24}^L; min\big(H_1(\tilde{A}_1^L); H_1(\tilde{A}_2^L)\big), min\big(H_2(\tilde{A}_1^L); H_2(\tilde{A}_2^L)\big)\Big)\Big)$$

**Definition 1.3.** The subtraction of two trapezoidal IT2 FSs

$\tilde{\tilde{A}}_1 = \Big(\big(a_{11}^U, a_{12}^U, a_{13}^U, a_{14}^U; H_1(\tilde{A}_1^U), H_2(\tilde{A}_1^U)\big), \big(a_{11}^L, a_{12}^L, a_{13}^L, a_{14}^L; H_1(\tilde{A}_1^L), H_2(\tilde{A}_1^L)\big)\Big)$ and
$\tilde{\tilde{A}}_2 = \Big(\big(a_{21}^U, a_{22}^U, a_{23}^U, a_{24}^U; H_1(\tilde{A}_2^U), H_2(\tilde{A}_2^U)\big), \big(a_{21}^L, a_{22}^L, a_{23}^L, a_{24}^L; H_1(\tilde{A}_2^L), H_2(\tilde{A}_2^L)\big)\Big)$ is defined as:

$$\tilde{\tilde{A}}_1 \ominus \tilde{\tilde{A}}_2 = \Big(\Big(a_{11}^U - a_{24}^U, a_{12}^U - a_{23}^U, a_{13}^U - a_{22}^U, a_{14}^U - a_{21}^U; min\big(H_1(\tilde{A}_1^U); H_1(\tilde{A}_2^U)\big), min\big(H_2(\tilde{A}_1^U); H_2(\tilde{A}_2^U)\big)\Big), \Big(a_{11}^L - a_{24}^L, a_{12}^L - a_{23}^L, a_{13}^L - a_{22}^L, a_{14}^L - a_{21}^L; min\big(H_1(\tilde{A}_1^L); H_1(\tilde{A}_2^L)\big), min\big(H_2(\tilde{A}_1^L); H_2(\tilde{A}_2^L)\big)\Big)\Big)$$

**Definition 1.4.** The multiplication of two trapezoidal IT2 FSs

$\tilde{\tilde{A}}_1 = \Big(\big(a_{11}^U, a_{12}^U, a_{13}^U, a_{14}^U; H_1(\tilde{A}_1^U), H_2(\tilde{A}_1^U)\big), \big(a_{11}^L, a_{12}^L, a_{13}^L, a_{14}^L; H_1(\tilde{A}_1^L), H_2(\tilde{A}_1^L)\big)\Big)$ and
$\tilde{\tilde{A}}_2 = \Big(\big(a_{21}^U, a_{22}^U, a_{23}^U, a_{24}^U; H_1(\tilde{A}_2^U), H_2(\tilde{A}_2^U)\big), \big(a_{21}^L, a_{22}^L, a_{23}^L, a_{24}^L; H_1(\tilde{A}_2^L), H_2(\tilde{A}_2^L)\big)\Big)$ is defined as:

$$\tilde{\tilde{A}}_1 \otimes \tilde{\tilde{A}}_2 \cong \Big(\Big(a_{11}^U \times a_{21}^U, a_{12}^U \times a_{22}^U, a_{13}^U \times a_{23}^U, a_{14}^U \times a_{24}^U; min\big(H_1(\tilde{A}_1^U); H_1(\tilde{A}_2^U)\big), min\big(H_2(\tilde{A}_1^U); H_2(\tilde{A}_2^U)\big)\Big), \Big(a_{11}^L \times a_{21}^L, a_{12}^L \times a_{22}^L, a_{13}^L \times a_{23}^L, a_{14}^L \times a_{24}^L; min\big(H_1(\tilde{A}_1^L); H_1(\tilde{A}_2^L)\big), min\big(H_2(\tilde{A}_1^L); H_2(\tilde{A}_2^L)\big)\Big)\Big)$$

**Definition 1.5.** Mathematical procedures between trapezoidal IT2 FS

$$\tilde{\tilde{A}}_1 = \left(\left(a_{11}^U, a_{12}^U, a_{13}^U, a_{14}^U; H_1\left(\tilde{A}_1^U\right), H_2\left(\tilde{A}_1^U\right)\right), \left(a_{11}^L, a_{12}^L, a_{13}^L, a_{14}^L; H_1\left(\tilde{A}_1^L\right), H_2\left(\tilde{A}_1^L\right)\right)\right)$$

and the crisp value $k$ are defined as:

$$k\tilde{\tilde{A}}_1 = \left(\left(k \times a_{11}^U, k \times a_{12}^U, k \times a_{13}^U, k \times a_{14}^U; H_1\left(\tilde{A}_1^U\right), H_2\left(\tilde{A}_1^U\right)\right), \left(k \times a_{11}^L, k \times a_{12}^L, k \times a_{13}^L, k \times a_{14}^L; H_1\left(\tilde{A}_1^L\right), H_2\left(\tilde{A}_1^L\right)\right)\right)$$

$$\frac{\tilde{\tilde{A}}_1}{k} = \left(\left(\frac{1}{k} \times a_{11}^U, \frac{1}{k} \times a_{12}^U, \frac{1}{k} \times a_{13}^U, \frac{1}{k} \times a_{14}^U; H_1\left(\tilde{A}_1^U\right), H_2\left(\tilde{A}_1^U\right)\right), \left(\frac{1}{k} \times a_{11}^L, \frac{1}{k} \times a_{12}^L, \frac{1}{k} \times a_{13}^L, \frac{1}{k} \times a_{14}^L; H_1\left(\tilde{A}_1^L\right), H_2\left(\tilde{A}_1^L\right)\right)\right)$$

where $k > 0$.

**Defuzzification Method for Type-2 Fuzzy Sets**

Defuzzification of trapezoidal Type-2 fuzzy sets (DTraT) method is defined as follows [38]:

$$DTraT = \frac{\frac{(u_U - l_U) + (\beta_U . m_{1U} - l_U) + (\alpha_U . m_{2U} - l_U)}{4} + l_U + \left[\frac{(u_L - l_L) + (\beta_L . m_{1L} - l_L) + (\alpha_L . m_{2L} - l_L)}{4} + l_L\right]}{2} \quad (1)$$

α and β represent the highest degrees of membership for the lower membership function of the Type-2 fuzzy set. $u_U$ is the upper membership function's maximum value, while $l_U$ is its minimum value. $m_{1U}$ and $m_{2U}$ are the second and third parameters of the upper membership function. $u_L$ represents the upper membership function's maximum value, while $l_L$ represents its minimum value. $m_{1L}$ and $m_{2L}$ are the second and third parameters of the lower membership function, respectively.

**Interval Type-2 Fuzzy ANP Methodology**

The Analytic Network Process (ANP) is an advantageous approach for resolving MCDM difficulties. The ANP can provide us with the optimal choice based on several parameters from a range of options [39]. Saaty created the ANP, which is an extension of the Analytical Hierarchy Process (AHP) [40]. Saaty proposed employing the AHP to address the issue of independence among alternatives or criteria and utilizing the ANP to tackle the problem of dependency between alternatives or criteria [41]. Senturk et al. [27] introduced the FANP with IT2 FSs approach by adapting Buckley's technique with IT2 FSs.

In this section, IT2 FANP methodology is studied. The steps of the IT2 FANP methodology are described as follows [27]:

**Step 1.** Identify and ascertain the problem's nature and objective based on the problem itself. Determine the primary criterion and subcriteria for establishing the model.

**Step 2.** Create the fuzzy pairwise comparison matrices for all the criteria based on the information provided in Table 1 as follows:

$$\tilde{\tilde{A}} = \begin{bmatrix} 1 & \tilde{\tilde{a}}_{12} & \cdots & \tilde{\tilde{a}}_{1n} \\ \tilde{\tilde{a}}_{21} & 1 & \cdots & \tilde{\tilde{a}}_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ \tilde{\tilde{a}}_{n1} & \tilde{\tilde{a}}_{n2} & \cdots & 1 \end{bmatrix} = \begin{bmatrix} 1 & \tilde{\tilde{a}}_{12} & \cdots & \tilde{\tilde{a}}_{1n} \\ 1/\tilde{\tilde{a}}_{12} & 1 & \cdots & \tilde{\tilde{a}}_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ 1/\tilde{\tilde{a}}_{1n} & 1/\tilde{\tilde{a}}_{2n} & \cdots & 1 \end{bmatrix} \quad (2)$$

where

$$\frac{1}{\tilde{\tilde{a}}} = \left(\left(\frac{1}{a_{14}^U}, \frac{1}{a_{13}^U}, \frac{1}{a_{12}^U}, \frac{1}{a_{11}^U}; H_1(a_{12}^U), H_2(a_{13}^U)\right), \left(\frac{1}{a_{24}^L}, \frac{1}{a_{23}^L}, \frac{1}{a_{22}^L}, \frac{1}{a_{21}^L}; H_1(a_{22}^L), H_2(a_{23}^L)\right)\right)$$

Table 1 [38] shows the linguistic variables and the trapezoidal IT2 fuzzy scales that go with them. The trapezoidal IT2 fuzzy scale corresponding to the linguistic variable is in this table.

The conventional FANP method typically verifies the consistency of each pairwise comparison matrix by utilizing defuzzified matrices.

**Step 3.** Compute the geometric mean for each row, and then calculate the fuzzy weights using normalization. The geometric mean of each row $\tilde{\tilde{r}}_i$ is obtained using the following formula:

$$\tilde{\tilde{r}}_i = [\tilde{\tilde{a}}_{i1} \otimes \cdots \otimes \tilde{\tilde{a}}_{in}]^{1/n}, \forall i \quad (3)$$

where

**Table 1**. Linguistic words with their respective trapezoidal interval type-2 (IT2) fuzzy scales

| Linguistic Terms | Trapezoidal interval type-2 fuzzy scales |
|---|---|
| Absolutely Strong (AS) | (7,8,9,9;1,1) (7.2,8.2,8.8,9;0.8,0.8) |
| Very Strong (VS) | (5,6,8,9;1,1) (5.2,6.2,7.8,8.8;0.8,0.8) |
| Fairly Strong (FS) | (3,4,6,7;1,1) (3.2,4.2,5.8,6.8;0.8,0.8) |
| Slightly Strong (SS) | (1,2,4,5;1,1) (1.2,2.2,3.8,4.8;0.8,0.8) |
| Exactly Equal (E) | (1,1,1,1;1,1) (1,1,1,1;1,1) |
| If factor i is given one of the linguistic variables when compared to factor j, then j has the reciprocal value when compared to factor i. | Reciprocals of above |

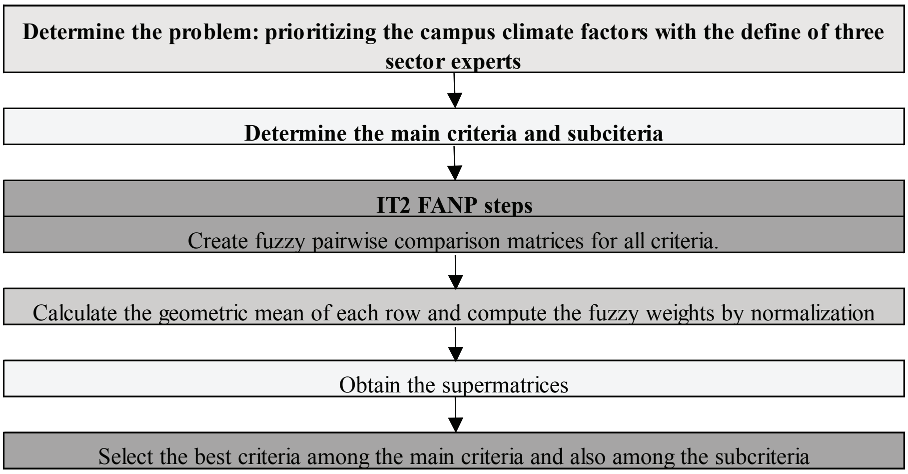


**Figure 3.** The flow diagram of the application of IT2 FANP methodology.

$$\sqrt[n]{\tilde{\tilde{a}}_{ij}}=\left(\left(\sqrt[n]{a_{ij1}^{U}},\sqrt[n]{a_{ij2}^{U}},\sqrt[n]{a_{ij3}^{U}},\sqrt[n]{a_{ij4}^{U}};\ H_1^U(a_{ij}),H_2^U(a_{ij})\right),\left(\sqrt[n]{a_{ij1}^{L}},\sqrt[n]{a_{ij2}^{L}},\sqrt[n]{a_{ij3}^{L}},\sqrt[n]{a_{ij4}^{L}};\ H_1^L(a_{ij}),H_2^L(a_{ij})\right)\right).$$

The weight $\tilde{\tilde{w}}_i$ of the ith criteria is determined using the following calculation:

$$\tilde{\tilde{w}}_i=\tilde{\tilde{r}}_i\otimes[\tilde{\tilde{r}}_1\oplus\cdots\oplus\tilde{\tilde{r}}_i\oplus\cdots\oplus\tilde{\tilde{r}}_n]^{-1} \quad (4)$$

where

$$\frac{\tilde{\tilde{a}}_{ij}}{\tilde{\tilde{b}}_{ij}}=\begin{pmatrix}\frac{a_1^U}{b_4^U},\frac{a_2^U}{b_3^U},\frac{a_3^U}{b_2^U},\frac{a_4^U}{b_1^U},min\left(H_1^U(a),H_1^U(b)\right),min\left(H_2^U(a),H_2^U(b)\right),\\ \frac{a_1^L}{b_4^L},\frac{a_2^L}{b_3^L},\frac{a_3^L}{b_2^L},\frac{a_4^L}{b_1^L},min\left(H_1^L(a),H_1^L(b)\right),min\left(H_2^L(a),H_2^L(b)\right)\end{pmatrix}.$$

The fuzzy weights are determined in the following manner:

$$\tilde{\tilde{U}}_i=\sum_{i=1}^{n}\tilde{\tilde{w}}_j\tilde{\tilde{r}}_{ij} \quad (5)$$

where $\tilde{\tilde{U}}_i$ is the fuzzy utility of criteria.

**Step 4.** Produce supermatrices. For deffuzzified matrices, the DTraT methods are utilized; see Equation (1). Weights are applied to an unweighted supermatrix that incorporates both inner and exterior dependences as well as feedback. Following unweighted supermatrix normalization, the weighted supermatrix is computed. Multiplying the weighted supermatrix by $2^{k+1}$ yields the limit supermatrix, where k is an extremely large quantity.

**Step 5.** Select the best criteria among main criteria and among subcriteria. A criterion which has the maximum weight is selected as being the best criteria.

**An IT2 Fanp Application: Evaluating The Campus Climate Factors**

This paper uses the IT2 FANP methodology to prioritize the campus climate factors. The configuration of the application case is illustrated in Figure 3. The steps of the IT2 FANP application are given in this figure.

To address the issue utilizing the IT2 FANP technique, we utilize Interval Type 2 fuzzy scales to compare with experts, as seen in Table 1. Additionally, fuzzy pairwise comparison matrices for both the major criterion and subcriteria can be found in Table 2 and Table 3, respectively. E1, E2, and E3 represent the evaluations conducted by Expert-1, Expert-2, and Expert-3, respectively, in these tables. The methodology was applied and these tables were obtained. There are 3 main criteria and 9 subcriteria in these tables.

Table 4 and Table 5 present the geometric mean of the main criteria and the subcriteria, respectively. The trapezoidal IT2 fuzzy scale was used in these tables.

The fuzzy weights for the main criteria and subcriteria are calculated as seen in Tables 6 and 7, respectively. The trapezoidal IT2 fuzzy scale was used in these tables for main criteria and subcriteria.

**Table 2.** Fuzzy pairwise comparison matrix among main criteria

| | C1 | | | C2 | | | C3 | | |
|---|---|---|---|---|---|---|---|---|---|
| | E1 | E2 | E3 | E1 | E2 | E3 | E1 | E2 | E3 |
| C1 | E | E | E | E | FS | 1/SS | E | SS | 1/SS |
| C2 | E | 1/FS | SS | E | E | E | E | 1/SS | E |
| C3 | E | 1/SS | SS | E | SS | E | E | E | E |

**Table 3.** Fuzzy pairwise comparison matrix among subcriteria

| | **C11** | | | **C12** | | | **C13** | | | **C21** | | | **C22** | | | **C23** | | | **C24** | | | **C31** | | | **C32** | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **E1** | **E2** | **E3** | **E1** | **E2** | **E3** | **E1** | **E2** | **E3** | **E1** | **E2** | **E3** | **E1** | **E2** | **E3** | **E1** | **E2** | **E3** | **E1** | **E2** | **E3** | **E1** | **E2** | **E3** | **E1** | **E2** | **E3** |
| **C11** | E | E | E | 1/SS | 1/SS | 1/SS | SS | 1/SS | E | E | FS | E | SS | SS | 1/SS | SS | SS | SS | SS | FS | 1/SS | SS | E | 1/SS | E | SS | 1/SS |
| **C12** | SS | SS | SS | E | E | E | SS | E | SS | SS | VS | SS | FS | FS | SS | FS | FS | FS | SS | VS | SS | SS | SS | E | SS | FS | E |
| **C13** | 1/SS | SS | E | 1/SS | E | 1/SS | E | E | E | 1/SS | VS | E | SS | SS | 1/SS | SS | SS | SS | E | VS | 1/SS | E | E | 1/SS | 1/SS | SS | 1/SS |
| **C21** | E | 1/FS | E | 1/SS | 1/VS | 1/SS | SS | 1/VS | E | E | E | E | SS | SS | 1/SS | SS | SS | SS | SS | FS | 1/SS | SS | E | 1/SS | E | SS | 1/SS |
| **C22** | 1/SS | 1/SS | SS | 1/FS | 1/FS | 1/SS | 1/SS | 1/FS | SS | 1/SS | FS | SS | E | E | E | E | E | SS | 1/SS | SS | E | 1/SS | 1/SS | 1/SS | 1/SS | E | 1/SS |
| **C23** | 1/SS | 1/SS | 1/SS | 1/FS | 1/FS | 1/FS | 1/SS | 1/FS | 1/SS | 1/SS | FS | 1/SS | E | E | 1/SS | E | E | E | 1/SS | SS | 1/SS | 1/SS | 1/SS | 1/FS | 1/SS | E | 1/FS |
| **C24** | 1/SS | 1/FS | SS | 1/SS | 1/VS | 1/SS | E | 1/VS | SS | 1/SS | SS | SS | SS | 1/SS | E | SS | 1/SS | SS | E | E | E | E | 1/FS | 1/SS | 1/SS | 1/SS | 1/SS |
| **C31** | 1/SS | E | SS | 1/SS | 1/SS | E | E | 1/SS | SS | 1/SS | FS | SS | SS | SS | SS | SS | SS | FS | E | FS | SS | E | E | E | 1/SS | SS | E |
| **C32** | E | 1/SS | SS | 1/SS | 1/FS | E | SS | 1/FS | SS | E | FS | SS | SS | E | SS | SS | E | FS | SS | SS | SS | SS | 1/SS | E | E | E | E |

**Table 4.** The geometric mean for the main criteria ($\tilde{\tilde{r}}_i$).

| | **U** | | | | | | **L** | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| C1 | 0.79 | 0.93 | 1.22 | 1.48 | 1.00 | 1.00 | 0.82 | 0.95 | 1.18 | 1.41 | 0.80 | 0.80 |
| C2 | 0.67 | 0.76 | 0.93 | 1.06 | 1.00 | 1.00 | 0.69 | 0.77 | 0.91 | 1.03 | 0.80 | 0.80 |
| C3 | 0.84 | 1.00 | 1.26 | 1.43 | 1.00 | 1.00 | 0.87 | 1.03 | 1.23 | 1.39 | 0.80 | 0.80 |
| Total | 2.30 | 2.68 | 3.41 | 3.97 | 1.00 | 1.00 | 2.39 | 2.75 | 3.32 | 3.83 | 0.80 | 0.80 |
| Reciprocal | 0.25 | 0.29 | 0.37 | 0.43 | 1.00 | 1.00 | 0.26 | 0.30 | 0.36 | 0.42 | 0.80 | 0.80 |

**Table 5.** The geometric mean for the subcriteria ($\tilde{\tilde{r}}_i$).

| | **U** | | | | | | **L** | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| C11 | 0.67 | 0.93 | 1.48 | 1.98 | 1.00 | 1.00 | 0.73 | 0.97 | 1.41 | 1.84 | 0.80 | 0.80 |
| C12 | 1.44 | 2.17 | 3.39 | 3.94 | 1.00 | 1.00 | 1.60 | 2.30 | 3.27 | 3.83 | 0.80 | 0.80 |
| C13 | 0.66 | 0.86 | 1.33 | 1.79 | 1.00 | 1.00 | 0.70 | 0.90 | 1.27 | 1.66 | 0.80 | 0.80 |
| C21 | 0.58 | 0.78 | 1.21 | 1.57 | 1.00 | 1.00 | 0.62 | 0.82 | 1.16 | 1.47 | 0.80 | 0.80 |
| C22 | 0.40 | 0.51 | 0.84 | 1.24 | 1.00 | 1.00 | 0.42 | 0.53 | 0.79 | 1.12 | 0.80 | 0.80 |
| C23 | 0.29 | 0.34 | 0.55 | 0.87 | 1.00 | 1.00 | 0.30 | 0.35 | 0.52 | 0.77 | 0.80 | 0.80 |
| C24 | 0.38 | 0.49 | 0.79 | 1.12 | 1.00 | 1.00 | 0.40 | 0.51 | 0.75 | 1.03 | 0.80 | 0.80 |
| C31 | 0.81 | 1.11 | 1.68 | 2.10 | 1.00 | 1.00 | 0.87 | 1.16 | 1.61 | 1.99 | 0.80 | 0.80 |
| C32 | 0.72 | 1.01 | 1.57 | 1.99 | 1.00 | 1.00 | 0.78 | 1.06 | 1.51 | 1.88 | 0.80 | 0.80 |
| Total | 5.93 | 8.20 | 12.83 | 16.58 | 1.00 | 1.00 | 6.42 | 8.62 | 12.28 | 15.61 | 0.80 | 0.80 |
| Reciprocal | 0.06 | 0.08 | 0.12 | 0.17 | 1.00 | 1.00 | 0.06 | 0.08 | 0.12 | 0.16 | 0.80 | 0.80 |

**Table 6.** The fuzzy weight for the main criteria ($\tilde{\tilde{p}}_i$).

| | **U** | | | | | | **L** | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| C1 | 0.20 | 0.27 | 0.45 | 0.65 | 1.00 | 1.00 | 0.21 | 0.29 | 0.43 | 0.59 | 0.80 | 0.80 |
| C2 | 0.17 | 0.22 | 0.34 | 0.46 | 1.00 | 1.00 | 0.18 | 0.23 | 0.33 | 0.43 | 0.80 | 0.80 |
| C3 | 0.21 | 0.29 | 0.47 | 0.62 | 1.00 | 1.00 | 0.23 | 0.31 | 0.45 | 0.58 | 0.80 | 0.80 |

**Table 7.** The fuzzy weight for the subcriteria ($\tilde{\tilde{p}}_i$).

| | U | | | | | | L | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| C11 | 0.04 | 0.10 | 0.18 | 0.33 | 1.00 | 1.00 | 0.05 | 0.08 | 0.16 | 0.29 | 0.80 | 0.80 |
| C12 | 0.09 | 0.20 | 0.41 | 0.66 | 1.00 | 1.00 | 0.10 | 0.19 | 0.38 | 0.60 | 0.80 | 0.80 |
| C13 | 0.04 | 0.10 | 0.16 | 0.30 | 1.00 | 1.00 | 0.04 | 0.07 | 0.15 | 0.26 | 0.80 | 0.80 |
| C21 | 0.03 | 0.10 | 0.15 | 0.26 | 1.00 | 1.00 | 0.04 | 0.07 | 0.13 | 0.23 | 0.80 | 0.80 |
| C22 | 0.02 | 0.00 | 0.10 | 0.21 | 1.00 | 1.00 | 0.03 | 0.04 | 0.09 | 0.17 | 0.80 | 0.80 |
| C23 | 0.02 | 0.00 | 0.07 | 0.15 | 1.00 | 1.00 | 0.02 | 0.03 | 0.06 | 0.12 | 0.80 | 0.80 |
| C24 | 0.02 | 0.00 | 0.10 | 0.19 | 1.00 | 1.00 | 0.03 | 0.04 | 0.09 | 0.16 | 0.80 | 0.80 |
| C31 | 0.05 | 0.10 | 0.20 | 0.35 | 1.00 | 1.00 | 0.06 | 0.09 | 0.19 | 0.31 | 0.80 | 0.80 |
| C32 | 0.04 | 0.10 | 0.19 | 0.34 | 1.00 | 1.00 | 0.05 | 0.09 | 0.17 | 0.29 | 0.80 | 0.80 |

**Table 8.** The defuzzified weights and the normalized values of the main criteria

| | Weights | Normalized Values |
|---|---|---|
| C1 | 0.3688 | 35.90% |
| C2 | 0.2822 | 27.47% |
| C3 | 0.3764 | 36.63% |

**Table 9.** The defuzzified weights and the normalized values of the subcriteria

| | Weights | Normalized Values |
|---|---|---|
| C11 | 0.1442 | 11.65% |
| C12 | 0.3105 | 25.10% |
| C13 | 0.1312 | 10.60% |
| C21 | 0.1172 | 9.47% |
| C22 | 0.0856 | 6.92% |
| C23 | 0.0585 | 4.73% |
| C24 | 0.0795 | 6.42% |
| C31 | 0.1606 | 12.98% |
| C32 | 0.1502 | 12.14% |

The defuzzification of IT2 fuzzy integers is performed using the DTraT technique, as shown in Table 8 and Table 9. Also, the defuzzified weights and the normalized values are calculated accordingly.

Based on the findings presented in Table 8, the defuzzified overall values of main criteria using an IT2 FANP method are obtained as 0.3688, 0.2822, and 0.3764. This means that the ranking order of main criteria from the best to the worst is C3 (Physical Environment), C1 (Conceptual Environment), and C2 (Administrative Environment).

Also, the ranking order of subcriteria from best to the worst according to the results in Table 9 is C12 (Social Environment), C31 (Exterior), C32 (Interior), C11 (Cultural Environment), C13 (Psychological Environment), C21 (Inclusive Goal and Perception), C22 (Economic Factors), C24 (Accreditation), and C23 (Legislation on Inclusive Design), respectively.

## CONCLUSION

It is an established truth that the social and cultural atmosphere at a university contributes to variances in people's opinions. Many cultures may be seen on campus, where individuals of all beliefs can come together and mingle.

The physical surroundings can present advantageous prospects, and the campus's physical environment has a significant psychological influence. The existence of socializing places at the school encourages individuals to allocate a greater amount of time on campus. The campus provides many social amenities, including facilities such as showrooms and sports halls. These structures contribute to transforming the campus into a vibrant living environment and have a beneficial impact on individuals' psychological well-being. These possibilities are accessible to all individuals and have a beneficial effect, formulated with principles of inclusivity.

The campus's behavioral and psychological atmosphere depends on its culture. Discrimination and diversity are campus psychological factors. The behavioral component affects group interactions and socialization. The physical environment may provide certain possibilities, or campus structuring might alter some behavior, which is important for inclusion. While the campus physical environment theoretically includes all options, the structure, placement, and organization of spaces and amenities might encourage certain behaviors. Campus education-shelter-recreation-sports units, green spaces, and circulation areas provide an overall impression. Circulation is another important factor in campus image and planning. Movement in an environment affects its visual, physical, and psychological perception.

Combining circulation zones and social spaces is beneficial for maintaining social interaction in accessible locations.

In this study, an IT2 FANP methodology is used for evaluating the campus climate factors. As a result of the evaluation process, this method using the interval type 2 fuzzy scales, has determined the most important main criteria for campus climate is "Physical Environment". The ranking of the other main criteria is "Conceptual Environment" > "Administrative Environment".

Also, the ranking of the subcriteria from the most important to the least important are "Social Environment" > "Exterior" > "Interior" > "Cultural Environment" > "Psychological Environment" > "Inclusive Goal and Perception" > "Economic Factors" > "Accreditation" > "Legislation on Inclusive Design".

Trapezoidal Interval Type-2 fuzzy scales are employed in the IT2 FANP steps, which produce superior results for daily use. In regular (type-1) fuzzy sets [42], each element of a set has a degree of membership between 0 and 1. Because fuzzy numbers can handle uncertainty and ambiguity better, type-2 fuzzy sets have this membership value. According to Mendel and John [28], membership functions of type-1 fuzzy sets are two-dimensional, whereas membership functions of type-2 fuzzy sets are three-dimensional, and this extra third dimension gives additional degrees of freedom that allow for direct modeling of uncertainties [29]. This strategy is justified since decision-makers do not need discrete or continuous FSs.

The primary benefit of this article is its enhanced capacity to effectively manage ambiguities. This paper's primary contribution is its pioneering use of the IT2 FANP approach to assess campus environment elements. The primary constraint of the used approach is the expensive and arduous information that is required from decision makers, which involves around 40 pairwise comparisons. Additional constraints of the model arise from the expert's inclinations, encompassing elements of ambiguity and disputes. Moreover, it frequently necessitates the involvement of several experts to reach a decision.

In terms of future studies, the problem might be tackled using various MCDM approaches with interval-type 2 fuzzy scales and additional solutions compared to campus climate factor evaluation processes. Intelligent software that calculates solutions automatically might also be developed.

## AUTHORSHIP CONTRIBUTIONS

Authors equally contributed to this work.

## DATA AVAILABILITY STATEMENT

The authors confirm that the data that supports the findings of this study are available within the article. Raw data that support the finding of this study are available from the corresponding author, upon reasonable request.

## CONFLICT OF INTEREST

The author declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

## ETHICS

There are no ethical issues with the publication of this manuscript.

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