Chapter-3

EVALUATING CAMPUS COMPONENTS ACCORDING TO THE INCLUSIVE DESIGN PRINCIPLES USING CFPR AND FANP METHODOLOGIES

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Abstract

Campus setting is a place for people to learn, meet, explore, think, or relax. Inclusive design is an important step for the accreditation system with the current legislation. The inclusive design has become important not only in terms of access to the campus or access to the building but also in matters such as the way lessons are taught and the curriculum. Eight performance indicators based on inclusive design principles are "Class climate", "Interaction", "Physical environment and products", "Teaching methods", "Information resources and technology", "Feedback", "Evaluation" and "Residential". The prioritization or weighting of these principles can be addressed as a Multi Criteria Decision Making (MCDM) problem. For this reason, in this paper, Consistent Fuzzy Preference Relations (CFPR) and Fuzzy Analytic Network Process (FANP) are used for the evaluation of these principles and the results of both methodologies are compared.

Keywords: Campus climate; inclusive design; decision making; CFPR; Fuzzy ANP; MCDM.

1. Introduction

The public spaces of the city should be shaped according to need, as they have an important place in urban development. Because campuses function as small cities thanks to their facilities and social environment, they emerge as important public spaces. Campus areas affect our attitudes towards education and should be tailored to the needs and designed to cover all campus users.

Every individual who lives in the city and has the opportunity to participate in daily life in public spaces has the right to benefit equally from the opportunities and opportunities provided by the city where he lives. The concept of Inclusive Design has emerged to enable people to reach the existing opportunities as equally as possible[1] and in its shortest definition it is defined as the process of designing products and environments that many people can use in many possible situations.[2]

An inclusive environment is unimpeded to ensure equal opportunities and participation for all. Design is more than shape and function, it is about being able to change people's attitude perceptions and how they interact with the environment. One obstacle that prevents them from taking their full place in society is based on the interaction between the individual and the built environment. People of different abilities, sizes and ages should be able to participate fully independently in society.

MCDM is a modeling and methodological tool for dealing with complex engineering problems. Decision makers face many problems with incomplete and vague information in MCDM problems since the characteristics of these problems often require this kind of information.[3] The CFPR and FANP are useful methodologies to solve MCDM problems.

There are many studies about CFPR method in the literature. Ozdemir et al.[4] determined personnel selection criteria and to prioritized these criteria by CFPR. Alias et al.[5] proposed a modified approach of consistent fuzzy preference relation with geometric Bonferroni mean operator for assessing the quality of life. Park et al.[6] utilized CFPR methodology, which handles both qualitative and quantitative factors in order to select optimal routes for small and medium ports (SMPs). Huynh and Phi[7] applied CFPR to select a strategy that attracts Foreign Direct Investment (FDI) in developing supporting industries for Vietnam.

There are many studies about FANP method in the literature. Hemmati et al.[8] proposed the FANP model and applied it to a sulfuric acid production facility for selecting the maintenance policy of an acid manufacturing company. Danai et al.[9] developed an FANP method for selecting the best supplier in the supply chain. Alilou et al.[10] proposed a novel framework to assess watershed health using the FANP approach considering geo-environmental and topo-hydrological criteria. Galankashi et al.[11] developed specific criteria and an FANP method to prioritize and select portfolios on the Tehran Stock Exchange (TSE).

The rest of this paper is organized as follows: a brief description about inclusive campus climate is given in the 2nd section. CFPR methodology and the FANP methodology are explained in the 3rd and 4th sections, respectively. An application of CFPR and FANP methodologies in evaluating of campus components according to the inclusive design principles is given in 5th section. Also, computational results are given in this section. Finally, comparison of the results and future research directions are discussed in 6th section, which concludes the paper.

2. Inclusive Campus Climate

The university brings together individuals from different socio-cultural backgrounds. At the same time, the university contributes to the personal and intellectual development of individuals and functions as a socialization area. Universities create vitality with their social, cultural, economic, and spatial effects.

The climate on a university campus is a term used to discuss how individuals and groups experience the environment in the campus community. This is a general term that summarizes the inclusion dynamics of the organization and the extent to which the inclusion or exclusion of various stakeholders is felt. As climate-related conversations are naturally concerned with the real and perceived realities of different groups, this notion always embraces social identities defined in terms of race, ethnicity, gender, sexuality, disability, and an unlimited spectrum.[12]

The physical environment can be a source of some opportunities, and the physical environment of the campus has a great psychological impact. Having socialization areas on campus directs individuals to spend more time on campus. Social opportunities offered by the campus; Structures such as show areas and sports halls turn the campus into a living space and have a positive psychological impact. The fact that all these opportunities can be used by everyone and that they are designed with the principles of inclusion creates a positive effect.

On the other hand, it is stated that university students are faced with various problems and needs that are getting more and more complex today.[13, 14, 15] Such problems may be related to developmental needs or situations, as well as various relationship problems, academic concerns, stress, depression, suicidal thoughts, personality disorders, and exposure to sexual assault.[16] Therefore, it is of great importance to determine the changing academic, social, personal, and professional needs of students at regular intervals and to plan the services offered by student support units in the light of these requirements.[17] In addition, the understanding that faculty members, academic advisors, university administrators, and specialists working in student support units, in short, all academic and administrative staff working at the university should have sufficient knowledge and experience about the changing needs of students should be adopted.[18]

Inclusive design principles can also be applied to specific teaching materials, facilities, and strategies (such as lectures, classroom discussions, group work, web-based teaching, laboratories, fieldwork, and demonstrations). The inclusive curriculum offers students a variety of tools to present, express, and participate in a variety of abilities, disabilities, ethnicity, language skills, and learning styles. Below are examples of teaching using the principles of inclusion. It is organized into eight categories of performance indicators, each with one goal expression.[19]

Eight performance indicators that should be included in campus components according to inclusive design principles are evaluated as follows.[19]

Class climate; Adopting practices that reflect high values in terms of both diversity and inclusion; To seek the views of students to discuss their curriculum, disability-based, and other special learning needs.

Interaction; To encourage regular and effective interactions between students and lecturers and to make communication methods accessible to all participants; to make students do group work.

Physical environment and products; Ensure that facilities, activities, materials, and equipment are physically accessible and usable by all students and that all possible student characteristics are addressed with security considerations; Developing safety procedures for all students, including the blind, deaf, or wheelchair users.

Teaching methods; To use accessible teaching methods accessible to all learners; enable students to choose from multiple options for learning whenever possible, lectures, collaborative learning options, real-time activities, internet-based communication, educational software, fieldwork, etc. Thinking about such matters.

Information resources and technology; Ensure that course materials, notes, and other information resources are interesting, flexible and accessible to all students; Choose printed materials and prepare an early curriculum to allow students to read the materials and start working on assignments before the lesson begins, organizing alternative formats such as books in audio format.

Feedback; Provide specific feedback; allowing students to present some of the major projects for feedback before the final project is over.

Evaluation; Regularly assessing the student's progress using multiple accessible methods and tools and adjusting the instructions accordingly; to evaluate group performance and individual success.

Residential; Planning for students who do not meet their needs with educational design; Knowing campus protocols for receiving materials in alternative formats, rescheduling classroom spaces, and arranging other handicapped accommodations.

3. Consistent Fuzzy Preference Relations Methodology

Consistent fuzzy preference relations (CFPR) proposed by[20] simplifies the pairwise comparison. The methodology only requires $n-1$ judgments for a preference matrix with n elements. Moreover, CFPR provides better consistency, because it reduces judgment times. CFPR determines the relative importance of main criteria and subcriteria by computational procedure discussed in.[21, 22]

The steps of CFPR can be listed as follows:[23, 24]

Step 1: Risk identification. Main criteria and subcriteria are determined.

Step 2: Degree of preference. Linguistic terms and corresponding numbers are presented in Table 1 and they are used to obtain pairwise comparisons.

Table 1. Linguistic scale.

Definition	Relative Importance
Equally important	1
Moderately more important	3
Strongly more important	5
Very strongly more important	7
Absolutely more important	9
Intermediate values	2, 4, 6, 8

Step 3: Comparison. Construct pairwise comparison matrices amongst the criteria (C_i, $i = 1, \dots, n$). Pairwise comparisons for a set of $n-1$ preference values are provided by the decision makers.

Step 4: Transformation. Transform the preference value $a_{ij} \in \left[\frac{1}{9}, 9\right]$ into $p_{ij} \in [0,1]$ through (1).

$$p_{ij} = \frac{1}{2} \times (1 + log_9\, a_{ij}) \quad (1)$$

Then, calculate the remaining p_{ij}^k by using (2), (3) and (4).

$$p_{ij} + p_{ji} = 1 \quad (2)$$

$$p_{ji} = \frac{j - i + 1}{2} - p_{i(i+1)} - p_{i+1(i+2)} - \cdots - p_{j-1(j)} \quad (3)$$

$$p_{ij} + p_{jk} + p_{ki} = \frac{3}{2} \quad (4)$$

This preference matrix can contain values included in the interval $[-a,\ 1 + a]$ rather than in the interval$[0,\ 1]$. In this situation, to preserve reciprocity, a transformation function is used. The transformation is found by (5).

$$f(p_{ij}) = \frac{p_{ij} + a}{1 + 2a} \quad (5)$$

Here a indicates the absolute value of the minimum in this preference matrix. Likewise, the fuzzy preference relation matrices for all decision makers are calculated.

Step 5: Aggregation. Aggregate the fuzzy preference relation matrices to find the importance weights of the selection criteria. Let p_{ij}^k denote the transformed fuzzy preference value of the k -th decision maker for criteria i and criteria$j$. The average value method (6) is used to integrate the judgments of m decision makers. The total number of decision makers is denoted as m.

$$p_{ij} = \frac{1}{m}(p_{ij}^1 + p_{ij}^2 + \cdots + p_{ij}^m), \quad k = 1,2,\dots,m \quad (6)$$

Step 6: Normalization. Normalize the aggregated fuzzy preference relation matrices. h_{ij} is used to indicate the normalized fuzzy preference value of each criteria in (7) and the normalized fuzzy preference relation matrix is found.

$$h_{ij} = \frac{p_{ij}}{\sum_{i=1}^{n} p_{ij}} \quad i,j = 1,2,\dots,n \quad (7)$$

Step 7: Prioritization. Calculate the importance weight of each criteria (8).

$$w = \frac{1}{n}\sum_{j=1}^{n} h_{ij} \tag{8}$$

4. FANP Methodology

Analytical Network Process (ANP) was introduced by Saaty[25] and is a generalization of the Analytical Hierarchy Process (AHP).[25] Saaty[25] suggested using AHP to solve the problem of independence over alternatives or criteria and ANP to solve the problem of dependence between alternatives or criteria.[26] ANP is used to evaluate the priorities of the elements in the network and the alternatives of the goal. ANP allows modeling complex and dynamic environments affected by changing external factors.[27] Buckley's fuzzy AHP algorithm[28, 29, 30] based fuzzy ANP is used for weighting the Design principles in this paper.

The steps of FANP can be listed as follows:[31,32]

Step 1: Determine alternatives, criteria and subcriteria to be used in the model.

Step 2: Create a network of alternatives, criteria, subcriteria, inner and outer dependencies among the model.

Step 3: Build pairwise matrices of the components with fuzzy numbers by the experts.

Step 4: Construct the fuzzy comparison matrix by using fuzzy numbers:

Step 5: Calculate fuzzy eigen value to find whether the constructed matrix is consistent or not:

To verify the consistency of the comparison matrix, Saaty[25] proposed a consistency index (C.I.) and consistency ratio (C.R.). The consistency index of a matrix is given by

$$C.I. = (\lambda max - n)/(n-1)$$

$$C.R = C.I/R.I$$

where, R.I is Random Consistency Index. The consistency index should be less than or equal to 0.10.

Step 6: Form initial supermatrix of the network of ANP is composed by listing all nodes horizontally and vertically.
Step 7: Obtain weighted supermatrix by multiplying the unweighted supermatrix with the corresponding cluster priorities
Step 8: Calculate limited supermatrix by limiting the weighted supermatrix by raising it to sufficiently large power so that it converges into a stable supermatrix (i.e, all columns being identical).
To solve the problem using FANP, fuzzy numbers are used as shown in Table 2.

Table 2. Relationship between fuzzy numbers and degrees of linguistic importance.

Low/high Levels		Fuzzy Numbers
Label	**Linguistic Terms**	
E	Just equal	(1,1,1)
SL	Slightly Low	(1,1,3)
M	Middle	(1,3,5)
SH	Slightly High	(3,5,7)
H	High	(5,7,9)
VH	Very High	(7,9,9)
EH	Extra High	(9,9,9)

5. Application: Evaluating the Campus Components

In this paper, performance indicators based on inclusive design principles are studied and prioritizing the criteria using Multi Criteria Decision Making (MCDM) techniques, Consistent Fuzzy Preference Relations (CFPR) and Fuzzy Analytic Network Process (FANP) is aimed. In order to prioritize, eight performance indicators based on inclusive design principles referred as criteria were identified and evaluated by 3 experts from academia and industry. These criteria are Class Climate (C1), Interaction (C2), Physical Environment and Products (C3), Teaching Methods (C4), Information Resources and Technology (C5), Feedback (C6), Evaluation (C7), and Residential (C8).

All experts were asked to determine the importance of criteria based on Table 1 (for the CFPR methodology) and Table 2 (for the FANP methodology).

Firstly for the CFPR methodology, the pairwise comparison matrices for the criteria were provided by decision maker 1 are shown in Table 3.

Table 3. Fuzzy preference pairwise comparison matrix of decision maker 1 for the criteria.

	C1	C2	C3	C4	C5	C6	C7	C8
C1	1	3						
C2		1	0.33					
C3			1	1.00				
C4				1	1			
C5					1	1		
C6						1	1	
C7							1	1
C8								1

Then, the remaining p_{ij}^{k} for the criteria are calculated by using Eq. (1), (2), (3) and (4) (Table 4).

Table 4. Transformed fuzzy preference values of decision maker 1 for the criteria.

	C1	C2	C3	C4	C5	C6	C7	C8
C1	0.5	0.75	0.5	0.5	0.5	0.5	0.5	0.5
C2	0.25	0.5	0.25	0.25	0.25	0.25	0.25	0.25
C3	0.5	0.75	0.5	0.5	0.5	0.5	0.5	0.5
C4	0.5	0.75	0.5	0.5	0.5	0.5	0.5	0.5
C5	0.5	0.75	0.5	0.5	0.5	0.5	0.5	0.5
C6	0.5	0.75	0.5	0.5	0.5	0.5	0.5	0.5
C7	0.5	0.75	0.5	0.5	0.5	0.5	0.5	0.5
C8	0.5	0.75	0.5	0.5	0.5	0.5	0.5	0.5

Preference values transformed by transformation function for the criteria are obtained by Eq. (5) (Table 5).

Table 5. Preference values transformed by transformation function for the criteria.

	C1	C2	C3	C4	C5	C6	C7	C8
C1	0.50	0.67	0.50	0.50	0.50	0.50	0.50	0.50
C2	0.33	0.50	0.33	0.33	0.33	0.33	0.33	0.33
C3	0.50	0.67	0.50	0.50	0.50	0.50	0.50	0.50
C4	0.50	0.67	0.50	0.50	0.50	0.50	0.50	0.50
C5	0.50	0.67	0.50	0.50	0.50	0.50	0.50	0.50
C6	0.50	0.67	0.50	0.50	0.50	0.50	0.50	0.50
C7	0.50	0.67	0.50	0.50	0.50	0.50	0.50	0.50
C8	0.50	0.67	0.50	0.50	0.50	0.50	0.50	0.50

Likewise, the fuzzy preference relation matrices of the other 2 decision makers for all criteria are calculated by using above computational procedure.

To integrate the judgments of 3 decision makers Eq. (6) is used and the normalized fuzzy preference relation matrices for the criteria are calculated by using Eq. (7). Finally, the importance weight of the criteria determined by three decision makers using Eq. (8) can be seen from Table 6.

Table 6. Importance weights of the criteria.

	Importance weight	Ranking
C1	0.156454488	1
C2	0.120506502	3
C3	0.156454488	1
C4	0.134885696	2
C5	0.113316905	4
C6	0.091748113	5
C7	0.091748113	5
C8	0.134885696	2

Secondly, to solve the problem using FANP, we used triangular fuzzy numbers as shown in Table 2 and compared our results with those of experts. Different experts' assessments are aggregated using arithmetic mean method. Evaluations of the criteria by 3 experts can be seen on Table 7.

Table 7. Average values used in Fuzzy ANP

	C1			C2			C3			C4		
C1	1.00	1.00	1.00	1.00	1.00	1.00	0.20	0.33	1.00	0.33	1.00	1.00
C2	1.00	1.00	1.00	1.00	1.00	1.00	0.20	0.33	1.00	0.33	1.00	1.00
C3	1.00	3.00	5.00	1.00	3.00	5.00	1.00	1.00	1.00	1.00	1.00	3.00
C4	1.00	1.00	3.00	1.00	1.00	3.00	0.33	1.00	1.00	1.00	1.00	1.00
C5	1.00	1.00	1.00	1.00	1.00	1.00	0.20	0.33	1.00	0.33	1.00	1.00
C6	0.33	1.00	1.00	0.33	1.00	1.00	0.14	0.20	0.33	0.20	0.33	1.00
C7	0.33	1.00	1.00	0.33	1.00	1.00	0.14	0.20	0.33	0.20	0.33	1.00
C8	1.00	1.00	3.00	1.00	1.00	3.00	0.33	1.00	1.00	1.00	1.00	1.00
	C5			C6			C7			C8		
C1	1.00	1.00	1.00	1.00	1.00	3.00	1.00	1.00	3.00	0.33	1.00	1.00
C2	1.00	1.00	1.00	1.00	1.00	3.00	1.00	1.00	3.00	0.33	1.00	1.00
C3	1.00	3.00	5.00	3.00	5.00	7.00	3.00	5.00	7.00	1.00	1.00	3.00
C4	1.00	1.00	3.00	1.00	3.00	5.00	1.00	3.00	5.00	1.00	1.00	1.00
C5	1.00	1.00	1.00	1.00	1.00	3.00	1.00	1.00	3.00	0.33	1.00	1.00
C6	0.33	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.20	0.33	1.00
C7	0.33	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.20	0.33	1.00
C8	1.00	1.00	3.00	1.00	3.00	5.00	1.00	3.00	5.00	1.00	1.00	1.00

The fuzzy weight matrix of the criteria is given in Tables 8. The evaluation and the methodology described above produced the results shown in Table 9.

Table 8. Fuzzy weight matrix of the criteria

	l	m	u
C1	0.04	0.10	0.23
C2	0.04	0.10	0.23
C3	0.09	0.26	0.70
C4	0.06	0.15	0.40
C5	0.04	0.10	0.23
C6	0.02	0.07	0.16
C7	0.02	0.07	0.16
C8	0.06	0.15	0.40

Table 9. Weights of the criteria

	Weight	Ranking
C1	0.125968	3
C2	0.125968	3
C3	0.349346	1
C4	0.204678	2
C5	0.125968	3
C6	0.083594	4
C7	0.083594	4
C8	0.204678	2

6. Conclusion

The concept of Inclusive Design has emerged to ensure that individuals can benefit from all opportunities equally. Inclusive Campus Climate is a term used to discuss how individuals and groups experience the environment in the campus community. Campus climate includes the diversity of individuals, the experience of individuals, and communication between individuals. The campus climate should be places where all individuals with or without disabilities can receive education together.

Although the characteristics of the campus physical environment theoretically include all possibilities, the layout, location, and arrangement of spaces and facilities can make some behaviors more likely than others. Campuses create an overall perception of their work, education, accommodation, recreation, and sports units, green areas, and circulation areas.

In this paper, multi criteria-decision making techniques, CFPR and FANP methods are used for the evaluation of campus components according to the inclusive design principles. As a result of evaluation process, these two MCDM methods have determined the most important design component as “Physical environment and products” (C3). And the least important design components in both methodologies are “Feedback” (C6), and “Evaluation” (C7). The ranking of the other indicators vary due to the differences in two methodologies. It is recommended that this ranking be taken into account when designing inclusive university campuses.

For future researches, the problem could be solved by other MCDM techniques. Also, the trapezoidal fuzzy sets instead of triangular fuzzy sets could be used for decision making and intelligent software to calculate solutions automatically could be developed.

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