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Research Article

An Interval Type-2 Fuzzy Analytic Network Process For Prioritizing of Store Plan Alternatives Produced With Ruled Based Design

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Decision making.

Abstract

The widespread use of computer technologies in engineering and architecture provides essential contributions to engineers and architects in solving design problems. The computational design approach, which emerged depending on computer science and design theories and software and hardware technologies, is reflected in today's engineering and architectural works. In this study, store plan alternatives were prioritized by the Interval Type-2 Fuzzy Analytic Network (IT2 FANP) methodology, and the best alternative of store plans was selected. In addition, the results obtained for the four methods were compared. Type-2 Fuzzy Set can reduce the effects of vagueness and uncertainties. These sets make it probable to model uncertainties directly. There are very few studies on the IT2 FANP method for architectural design area in the literature. Our aim is to contribute to the literature by increasing the studies in this field.

1. Introduction

Spaces are shaped according to the determined principles and gain meaning according to human needs. Depending on these requirements, spaces with different functions were needed for various actions.

In addition to receiving the necessary needs in the history of mankind, shopping can be described as a relaxation, arousal and social act. Therefore, the designs of the stores which have shopping venues have gained great importance.

According to Novak's definition, the store design is the architectural character or style of that store, which tells customers what the store is about [1]. The design of the stores is very diverse in terms of variety, scale and geographical location. Large and very high stores can have negative effects on some customers, such as shyness or intimidation. In order to eliminate this shyness of customers, some floors of multi-storey stores are built underground [2]. Store design should be designed in such a way as to have a positive impact on customers, as well as to make retailing activities more economical.

Interior and facade design has an important place in the design of the store, which is a shopping area. While designing the interior of the store, firstly, the product sold and the quality of the product are determined [3].

Store plan alternatives were prioritized by Fuzzy Analytical Hierarchy Process (FAHP), Fuzzy Analytic Network Process (FANP) and Generalized Choquet Integral methods in the previous studies [4], [5]. In this paper, we applied an IT2 FANP technique to choose the best alternative of store plan.

Multiple-Criteria Decision-Making (MCDM) methodologies are very important for decision-making problems. Many decision-making problems are solved by

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MCDM methodologies. There are many studies in the literature using MCDM methodologies [6];[14].

The FANP methodology is used to solve MCDM problems. Many researchers have studied FANP. Mohanty et al. [15] used a FANP in selecting research and development projects. Guneri et al. [16] used a FANP approach for shipyard location selection. Kang et al. [17] proposed a FANP model to evaluate various aspects of suppliers. Dargi et al. [18] developed a framework for supplier selection. Rezaeiniya et al. [19] used FANP methodology for greenhouse locating.

Interval Type-2 Fuzzy Set (IT2 FS) is an especial version of generalized Type-2 Fuzzy Set (T2 FS). Karnik, Mendel and Liang [20], Mendel, John and Liu [21], Chen and Lee [22], Sola et al. [23] and Boran and Akay [24] have contributed to developing IT2 FSs.

The FANP methodology with Interval Type-2 Fuzzy Sets (IT2 FSs) is used to solve MCDM problems. Senturk et al. [25] aimed to propose a new FANP method using IT2 FSs. Wu and Liu [26] developed a FANP methodology with IT2 FSs to evaluate the Enterprise Technology Innovation Ability (ETIA). Senturk et al. [27] found a new IT2 FANP methodology to model a Third-party Logistics (3PL) company selection problem by integrating ANP and IT2 FSs.

In the second section, an IT2 FANP method for prioritizing store plan alternatives is made. Finally, the "Conclusion" section concludes the article discusses the comparison of outcomes and future research directions. This document provides required guidelines for the authors to prepare their English papers by an identical standard format acceptable to this journal. The fulfillment of these instructions is mandatory for all contributors.

2. An IT2 FANP Application: Prioritization of Plan Alternatives

In this study, IT2 FANP methodology was used with the same data as previous studies [4], [5]. The outcomes are compared with the previous studies. In this section, we apply the IT2 FANP technique, which was found for choosing the best store plan alternative [25]. Decision criteria and alternatives for the problem were determined by the decision-makers in Figure 1. 8 sub-criteria were categorized under 3 main criteria and shown in Table 1.

Table 1. Criteria of problem

Main Criteria		Sub-criteria	
C1	Store Presentation Area Features	C11	Facade/Showcase
		C12	Interior Layout
		C13	Entrance
C2	Store Retail Area Features	C21	Retail Area Position
		C22	Security
		C23	Circulation
C3	Store-Customer Relationship	C31	Customer Pleasure
		C32	Items That Meet The Customer First

The plan alternatives are A1, A2, and A3, as seen in Figure 1. These are given in Figures 2, 3, 4. All characters used in the Figures are explained in Table 2 [28].

Table 2. Character explanation

Character	Explanation
a	Cashier and the warehouse
c	Window
r	Interior exhibit
s	Dead-walls (black cells)
t	Shop window-exhibit
o	Changing room for customers

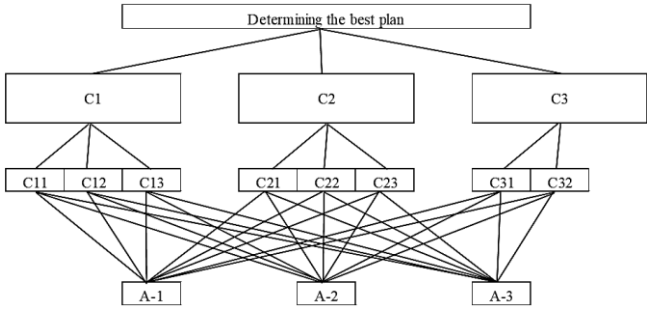

Figure 1. Hierarchy of the selection problem

At the same time as growing the model [28], the present shop typologies have been examined by considering the dominated-based design precept. The main spatial aspects of the shop have been emphasized in the scope of the performance (Figure 2, 3 and 4).

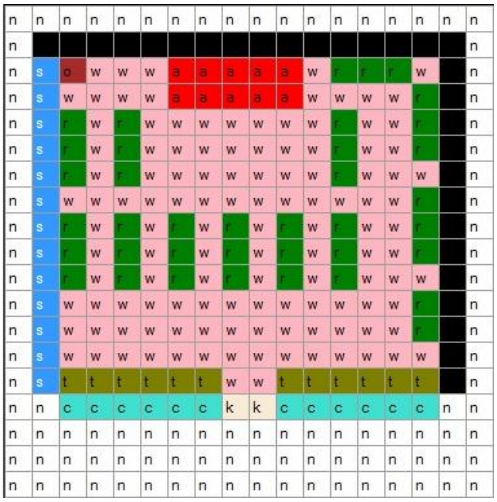

Figure 2. Alternative-1 [28]

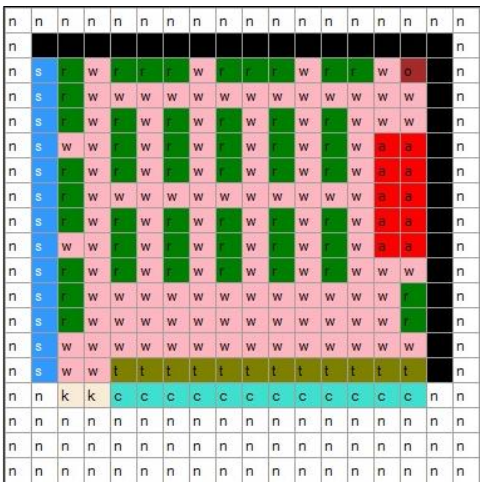

Figure 3. Alternative-2 [28]

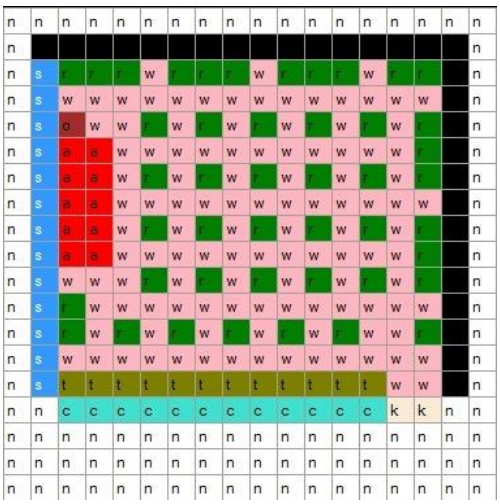

Figure 4. Alternative-2 [28]

IT2 fuzzy scales can be seen in Table 3 [29]. Also, these terms can be used in IT2 FANP.

The geometric mean of criteria (main, sub) is calculated. Then fuzzy weights for criteria (main, sub) are obtained [26]. Alternatives' local weights are found and their fuzzy weights are aggregated in Table 6.

Table 3. IT2 fuzzy scales

Low/ high Levels	Linguistic Terms	Trapezoidal IT2 fuzzy scales
F	Fairly Strong	(3,4,6,7;1,1) (3.2,4.2,5.8,6.8;0.8,0.8)
E	Exactly Equal	(1,1,1,1;1,1) (1,1,1,1;1,1)
A	Absolutely Strong	(7,8,9,9;1,1) (7.2,8.2,8.8,9;0.8,0.8)
S	Slightly Strong	(1,2,4,5;1,1) (1.2,2.2,3.8,4.8;0.8,0.8)
V	Very Strong	(5,6,8,9;1,1) (5.2,6.2,7.8,8.8;0.8,0.8)

Comparisons are made to solve the problem using IT2 FANP methodology by decision-makers. The fuzzy pairwise comparison matrix (Fpcm) between main and sub-criteria are shown in Table 4 and Table 5. Dma, Dmb, and Dmc denote the comparisons of decision-maker-A, decision-maker-B, and decision-maker-C in these tables.

Table 4. Fpcm among main criteria

	C1			C2			C3		
	Dma	Dmb	Dmc	Dma	Dmb	Dmc	Dma	Dmb	Dmc
C1	E	E	E	E	E	E	E	S	E
C2	E	E	E	E	E	E	E	S	E
C3	E	1/S	E	E	1/S	E	E	E	E

Table 5. Fpcm among sub-criteria

	C11			C12			C13			C21			C22			C23			C31			C32		
	Dma	Dmb	Dmc	Dma	Dmb	Dmc	Dma	Dmb	Dmc	Dma	Dmb	Dmc	Dma	Dmb	Dmc	Dma	Dmb	Dmc	Dma	Dmb	Dmc	Dma	Dmb	Dmc
C11	E	E	E	E	S	1/S	E	S	1/S	E	E	E	E	E	S	E	E	E	E	S	1/S	E	E	V
C12	E	1/S	S	E	E	E	E	E	E	E	1/S	S	E	1/S	F	E	1/S	S	E	E	E	E	1/S	V
C13	E	1/S	S	E	E	E	E	E	E	E	1/S	S	E	1/S	F	E	1/S	S	E	E	E	E	1/S	V
C21	E	E	E	E	S	1/S	E	S	1/S	E	E	E	E	E	S	E	E	E	E	S	1/S	E	E	F
C22	E	E	1/S	E	S	1/F	E	S	1/F	E	E	1/S	E	E	E	E	E	1/S	E	S	1/F	E	E	F
C23	E	E	E	E	S	1/S	E	S	1/S	E	E	E	E	E	S	E	E	E	E	S	1/S	E	E	F
C31	E	1/S	S	E	E	E	E	E	E	E	1/S	S	E	1/S	F	E	1/S	S	E	E	E	E	1/S	V
C32	E	E	1/V	E	S	1/V	E	S	1/V	E	E	1/F	E	E	1/F	E	E	1/F	E	S	1/V	E	E	E

Table 6. Alternatives' fuzzy weights

A1											
0.05	0.11	0.36	0.73	1.00	1.00	0.06	0.12	0.32	0.62	0.80	0.80
A2											
0.03	0.05	0.16	0.35	1.00	1.00	0.03	0.06	0.15	0.29	0.80	0.80
A3											
0.02	0.03	0.10	0.21	1.00	1.00	0.02	0.03	0.09	0.18	0.80	0.80

Then, Type-2 fuzzy numbers are defuzzified using Defuzzification of trapezoidal Type-2 fuzzy sets (DTraT) method, as seen in Table 6.

Table 7. Outcomes of the application using IT2 FANP methodology

	Fuzzy weights	Normalized values
A1	0.284	56.80%
A2	0.135	27.00%
A3	0.081	16.20%

Fuzzy weights are found as 0.284, 0.135, and 0.081 in Table 7. So, the ranking is found as "A1>A2>A3". The comparison of the outcomes with FAHP, FANP and Choquet integral methods is shown in Table 8. When the outcomes are analyzed for all methods, the ranking is found as "A1>A2>A3". Furthermore, it would be said that choosing A1 is the most relevant result.

Table 8. Comparison of the outcomes with FAHP, FANP and Choquet integral

	Weights				Normalized Values			
	IT2 FANP	Choquet integral	FAHP	FANP	IT2 FANP	Choquet integral	FAHP	FANP
A1	0.284	1.1339	2.3766	1.0000	56.80%	45.87%	69.34%	65.23%
A2	0.135	0.8987	0.7892	0.3548	27.00%	36.35%	23.02%	23.14%
A3	0.081	0.4396	0.2618	0.1782	16.20%	17.78%	7.64%	11.62%

10. Conclusions

These days, many different application regions of ruled-based design are encountered. The improvement in laptop generation presents an advantage to designers at tiers, including developing different layout strategies using rule-primarily based facilities.

In this study, Type-2 Fuzzy Analytic Network (IT2 FANP) methodology was compared with FAHP, FANP and Choquet integral methods.

Consequently, using the IT2 fuzzy scales, this methodology has obtained the most appropriate outcome as A1 and ranking as "A1>A2>A3". When the results are analyzed, the alternative's ranking is "A1>A2>A3" for all methods with normalized values and different weights.

Concerning future research, the problem can be evaluated with other MCDM methods, and more hybrid/integrated solutions can be studied for the evaluation processes of store plan alternatives. In addition, intelligent software can be developed to automatically calculate solutions to these problems.

Conflict of Interest Statement

The authors declare that they have no conflicts of interest/competing interests.

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