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Research Paper

Identification and prioritization of decline factors in Karaj distressed areas by applying the fuzzy analytic hierarchy process (FAHP)

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Abstract

The problems of distressed urban areas are getting worse year after year. Due to limited resources and Amenities of municipal organizations for solving every problem concerning urban distressed textures, it is essential to determine the priorities of each area based on identified factors and criteria. In distressed areas, there are different circumstances and distinctive citizens with their needs and special expectations, so in this article we face many criteria with fuzziness. This study aimed to apply the fuzzy analytic hierarchy process (FAHP) to prioritize the most important issues for each urban distressed area in Karaj. For this purpose a hierarchical model with 4 main factors (social, physical, environmental and economic) and 17 sub factors were suggested. Four zones of the city (central Karaj, Hesarak, Mehrshahr and Fardis) were analyzed. The findings of the paper suggest that social factors with a weights of about 30% are the most significant problems cause in these areas and physical factors with 27% weight we're in second place. Among the areas, Fardis and Hesarak areas were most affected by social factors and Central Karaj and Mehrshar had the most priority for physical factors.

Keywords: *Fuzzy AHP, Distressed urban areas, Prioritizing, Karaj.*

1. INTRODUCTION

The persistence of distressed areas weakens cities by impeding economic growth and increasing social injustice [1] and it presents pressing challenges to governments at all levels [2] that evokes passionate responses from neighborhood residents and city officials alike [3]. But the scale of the problem and the complexity of causes are two factors which have complicated the design and implementation of policies [4] In this situation, it is reasonable to find the major problems (with priority) in each area to achieve higher satisfaction with the current shortage of resource and funding. In order to specify the top problems, a systematic and sophisticated method is required.

AHP method has been extensively applied by academics in this field [5, 6, 7, 37, 38, 39]. But pure AHP model is subject to criticism and has some shortcomings [8]. Fuzziness and vagueness are common characteristics in many decision-making problems [32] that AHP cannot tolerate. Considering that the fuzzy logic (first introduced by professor Zadeh in 1965) is suitable for decision making in uncertain and ambiguous situations, using this method can reduce ambiguities and increase the effectiveness of decisions made [31]. In order to eliminate shortcomings, Chang (1999) combined fuzzy logic with conventional AHP, called as fuzzy AHP [40]. Therefore; this study chose to apply fuzzy AHP (FAHP) in dealing with this challenge.

The purpose of this article was to apply the Fuzzy AHP model in evaluation of distressed fabric of Karaj for identifying major problems based on urban decline factors. Firstly, the urban decline factors were expected by consideration of literature. Secondly, the hierarchical evaluation model was designed and some questionnaires was distributed among academic experts. Thirdly, the filled questionnaires were gathered and by using of fuzzy AHP model, the final weights and accordingly the ranking of problems were calculated.

2. LITERATURE REVIEW

A large amount of research has been conducted in an attempt to identify factors and causes of Disteressed Urban Areas (here referred to as DUAs). The demographic profiles of DUAs often show similar problems including high levels of poverty, low educational achievement, and low rates of laborforce participation, high numbers of single-parent families and a greater incidence of health

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problems than experienced in other parts of the urban areas. Moreover, these areas often have inadequate access to shops and other services and households often lack adequate means of transport. Participation in democratic processes and community involvement tends to be low, resulting in increasing isolation from the broader society. The incidence of crime and vandalism is often high, leading to feelings of insecurity and enhancement of the sense of isolation[4] to such an extent that cannot reasonably be expected to be reversed or alleviated by private enterprise or governmental action, or both, without rehabilitation or redevelopment [12]. In Table 1, A number of important studies dealing with the issue is summarized with a special focus on distressed urban areas.

2.1. Theoretical Framework

2.1.1 Definitions and Concepts

Distress

Distress means the inefficiency due to the passage of time and consequently the oldness and burnout. when the urban life in some parts of the city is facing recession due to any reason, its urban fabric starts to become distressed [41].

Distressed Urban Areas (DUAs)

The term 'distressed urban areas' refers to areas where interlinked social, economic, and environmental decline occurs at a significant scale [7] that harm the city by reducing job opportunities, the quality of local public services, and other neighborhood amenities [10]. It also impairs retards the provision and substantially impair the sound growth of the municipality, retard the provision of housing accommodations, or constitutes an economic or social liability, and is a menace to the public health, safety, morals or welfare [11]. Therefore these areas can be traced to no single cause; rather they represent a combination of environmental, economic, and social circumstances that take spatial form in different parts of inner cities and suburbs.

Table 1 Literature review on Urban Distressed Area and its characteristics

Author	Description
M.Conway, J.Konvitz(2000)	Meeting the Challenge of Distressed Urban Areas
G.Hellman,F.Wassenberg(2004)	The renewal of what was tomorrow's idealistic city. Amsterdam's Bijlmermeer high- rise
E.Glaeser, J.Gyourko(2005)	Urban decline and durable housing
LDUA Team (2006)	Understanding Large Urban Distressed Areas
Kazmierczak, Curwell, Turner(2007)	Assessment methods and tools for regeneration of large urban distressed areas
Stuart S.Rosenthal(2008)	Old Homes, Externalities, and Poor Neighborhoods: A Model of Urban Decline and Renewal
T.Ware and Associate(2007)	An Analysis of existing condition Relating to blight
J. L.Vigdor(2010)	Is urban decay bad? Is urban revitalization bad too?

2.2. Factors and Sub Factors of Distressed Urban Areas

The initial step for assessment of DUAs is to consider the areas, based on a set of factors and criteria. These criteria show the most inclusive issues and we can prioritize them by their prevalence and so they play an important role for urban planning [13]. Most of the criteria for analysis of the Distressed urban areas have been applied by North America and West Europe countries and other countries have localized them [14].

In the UK, various criteria and factors have been considered for assessment of DUAs, such as deprivation and decline, suburbia, decreased value of structure and facilities, abandoned housing[15]. McCarty (2007) accentuates on social factors and note 'social poverty' and 'demand' [16]. Perkins et al (1992) suggests that unplanned street and inaccessibility increase violence and crime in quarters [17]. Vigdor (2010) analyses the decline in DUAs with four factors: Abandoned housing, Bars on windows (sense of security), Streets in disrepair, Trash in street. Some researchers avoid specifying a physical border for DUAs and discuss these areas where the physical decline of housing accelerates the social problems and subsidence of the area population [18]. And others believe the geographical border of DUAs is equal to inner city which surrounds the Central Business District (CBD), and chose land value, nonresidential activities and need for redevelopment for assessment of areas [19]. Yeatesed and Garner (1980) describe the characteristics of DUAs with aged building, change in social structure and transforming land use [20].

In United States, Philadelphia city planning commission listed the DUAs conditions in these factors: incomplete street (with no pavement or below the standards), numerous void or undeveloped land, existence of trash lands, undesirable land uses, and vacant lands which have bad effect on adjacent development and have no tax revenue, numerous empty lands and blocks (5% of whole redevelopment area), inefficient land uses, low property value (less than one third of the mean value of city property), high tax violations and unsuitable streets network [21]. Other criteria also can be found in Oregon urban planning constitution, vacant housing (10% of whole area), economic and social incompatible land uses, existence of trash and studding in the area [22]. In Cramer Hill redevelopment plan assessment of area was carried out with these criteria: high number of industrial land use, number of dilapidated spaces, vacant field and buildings with bad condition, areas without infrastructure and public services, environmental pollution [23]. California Health and Safety Code Section characterized these areas by the existence of the following: unhealthy Buildings for persons to live or work, Depreciated property values, abnormally high business vacancies, high crime rate that threatens the public

safety, obsolete design or construction of blocks and streets, existence of subdivided lots that are in multiple ownership and whose physical development has been impaired by their irregular shapes and inadequate sizes [12].

2.3. Factor and Sub-Factor Selection

Considering the above literature and review of existing data in Karaj, factors which effectively present the conditions and problems of DUAs were selected. Some that were parallel in meaning and application, were omitted and finally the rest were classified into four main factors, each categorized the relevant sub factors. The selected list was given to academic experts and with some revision and supervision the final table of factors is shown in Table 2.

Table 2 Factors and Sub factors for assessment of Distressed urban areas

	Main Factor	Sub Factor	Explanation/criteria	references
1	Physical Factors	**road Access**	Appropriate link (without any preventive element) to secondary and main street, Suitable width for emergency access adequate means of transport	Vigdor, 2010; Philadelphia City Planning Commission, 2006; California Health and safety code section , 2005; perkins et al, 1992
2		**building Vulnerability**	Appropriate condition against natural hazards Estate of building code violations	Rosenthal, 2008; ley, 1991; lawless ,2006; Cramer Hill Redevelopment, 2004; kiefer, 1980
3		**Building lots sizes**	Appropriate size for higher welfare and public services access irregular lots design cases	California Health and safety code section,2005; Glaeser, 2005;Turot et al, 2004
4		**Building age**	sign of deterioration by long term neglect Physical decline in buildings Age of building	Rosenthal, 2008 ; kyuha, 2007 ; constantinus et al, 2005;kiefer, 1980
5	Social Factors	**Population density**	population in relation to area infrastructure Adequate population growth rate	Bahi et al, 2008; Richardson & bae, 2000; Bonnes, 1991
6		**unsafety**	Rate of incidence of crime, vandalism, and feel of insecurity. Estate sense of place and social capital	Jones et al, 2010; perkins et al, 1992; kelling &coles, 1988; Taylor et al, 1985
7		**Abandon housing**	Vacant houses because of local neighbors Immigration	Vigdor, 2010;Oregon constitution,2009;Philadelphia Planning Commission,2006;barad, 2006; Taylor,2001
8			Vacant housing because of urban decay	
9	Economic Factors	**Labor force participation**	Financial power condition of families for address basic needs and participation Ratio of workers in family to its number	Hurd,1997; weil,1997; Edward, 1996; ram,1982
10		**Employment type**	Number of labor force in Seasonal or inconstant job without pension or insurance	lawless, 1996; Browder, 1995 ; Perlman,1986; Bourne, 1982; yeatesed & Garner, 1980
11		**Income Level**	Number of labor force in Low paid Jobs shows financial ability for renewing Amount of money earned each month	Rosenthal, 2008;mccarty, 2007; smith, 2004; balchin et al, 1988
12		**Ownership**	Type of ownership of properties shows their tendency or incentive for partnership	Cummings et al, 2002; dipasquale and glaeser, 1999; sampson and raudebush, 1999
13		**Land price**	Value of lands and properties indicates the social class of habitat and their financial power incentive for rebuilding & added value	Xin lue, 2010; smith, 2004; Siram, 2003; huu phe,2002; tiwari, 1998;Lawless, 1996
14	Environmental Factors	**Renewing rate**	prone for improving the living environments Rate of renewing the building in the area	Smith,2004;Bourne,1982;kiefer,1980
15		**Housing dump and studding**	accumulation of trash in unplanned places and in streets Dirty views and environment lower the quality of area and hope for improvement	Vigdor, 2010; California Health and safety code ,2005; Philadelphia City Planning Commission , 2006
16		**Polluter structures**	Undesirable facilities around the residential area so it contaminate the environment Air and sound pollution in a bothering way that threatens the health of citizens	Oregon constitution, 2009; California Health and safety code section, 2005; Bourne, 1982; yeatesed and Garner,1980
17		**water / sewer utilities**	healthy water and collecting network are the basic needs of neighborhoods	Vigdor, 2010; California Health and safety code,2005

3. METHODOLOGY

3.1. Research Method

Library and field survey methods were used in order to collect the required data. The main tool in this survey was questionnaire. On the other hand, indexes were identified and ranked by using the model of expert participatory planning (Delphi). Obtained results were included in the framework of fuzzy AHP. The main used analytical method is fuzzy AHP.

3.2. FAHP Methodology

Analytic Hierarchical Process (AHP) is a multi-criteria decision making tool proposed by Saaty and is very suitable for complex social issues in which intangible and tangible factors cannot be separated [24]. But it is criticized for its inability to properly consider the inherent uncertainty of pair comparisons [25] that are associated with the mapping of human judgment to a number by natural language [26, 27].

The traditional approach of the method cannot reflect the human mind in a realistic way [28, 29, 30]. Decision makers often prefer to employ oral presentation than a numerical value. Due to the nature of pair wise comparisons, they cannot explicitly express their opinions about priorities [31]. These issues have caused the nature of decision making to be full of complexities and ambiguities in the most minor to most major cases. A good decision-making model needs to tolerate vagueness or ambiguity because Fuzziness and vagueness are common characteristics in many decision-making problems [32] Therefore, considering that the fuzzy logic is for decision making in uncertain and ambiguous situations [40], using this method can reduce ambiguities and increase the effectiveness of decisions made [31].

FAHP method is used in this study. FAHP can be seen as a synthetic extension of the classical AHP method by taking into account the fuzzy set theory that was first introduced by professor Zadeh in 1965 [33]. FAHP is applied to resolve the expanded hierarchical issues [28].

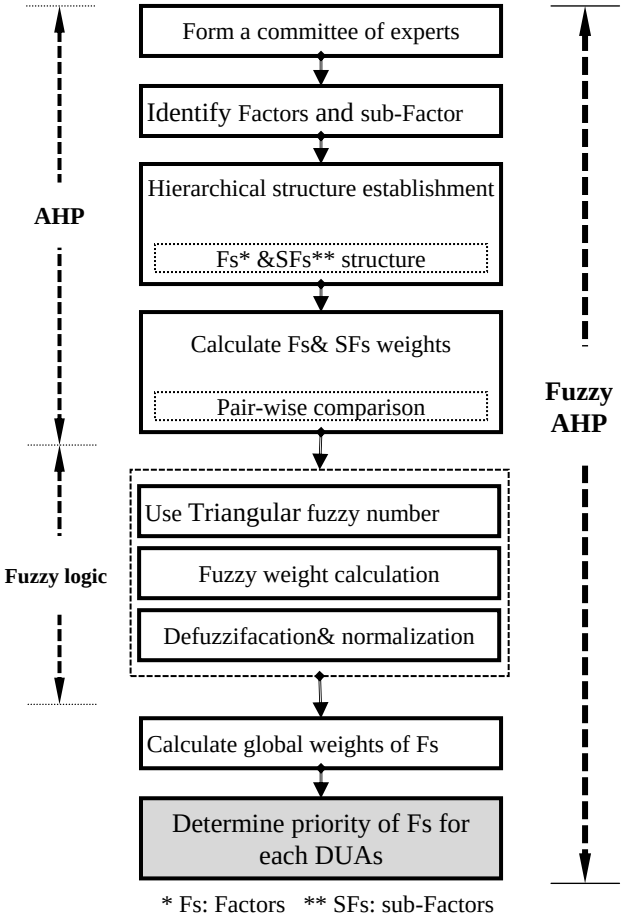

Fig. 1 Framework of the fuzzy AHP

In this study, we utilize Extent Analysis (EA) method for fuzzy AHP, as originally proposed by Chang (1996) [34] [35]. Also, in this study considering the calculated weights of factors, critical problem factors will be determined. In this method, for each pair rows of pair-wise comparisons matrix, the amount of S_k which is a triangular number, is calculated as follows [31]:

$$S_k=\sum_{j=1}^{n} M_{g1}^{j}\left[\sum_{j=1}^{n}\sum_{i=1}^{m} M_{g1}^{j}\right]^{-1} \quad (1)$$

K represents the number of rows and *i* and j, respectively, indicate alternatives and factors. In jomle moshkel dare. Bayad ba farsish motabeghat dade beshe mojadad tarjome beshe. *A* large degree on the M_1 with $M_2$is indicated as $(M_1 \geq M_2)$ which is

K represents the number of rows and i and j, respectively, indicate alternatives and factors. In EA method, after some Sk calculations, their large degrees must be compared with each other and then calculated. A large degree on the M_1 with $M_2$is indicated as $(M_1 \geq M_2)$ which is calculated as follows:

$$V(M_1 \geq M_2) = \sup\left\{Min\left(\mu_{m_1}(x).\mu_{M_2}(y)\right)\right\} \quad (2)$$

$$V(M_1 \geq M_2) = \begin{cases} 1 & M_1 \leq M_2 \\ 0 & U_2 \leq L_1 \\ \dfrac{L_1 - U_2}{(M_2 - U_2) - (M_1 - L_1)} & otherwise \end{cases} \quad (3)$$

We also have: The large degree on the M with M_1, M2, ..., M_k is calculated as follows

$$V\ (M \geq M1, M2\ ,\ldots.,\ Mk) = V[(M \geq M1),(M \geq M2),\ \ldots..,\ (M \geq Mk)] \quad (4)$$

Suppose that d *(Ai)* = min V (Si $\geq$ Sk), k=l, 2, 3, ... ,*n*, $k \neq i$. Then the following weight vector is obtained.

$$A_1(i = 1, 2, \ldots, n) \quad (5)$$

Where A_1 (i = 1, 2, n) are n elements. For normalization, the normalized weight vectors are as follows, where W is a non-fuzzy number:

$$W = [\ d(A_1),\ d(A_2\ ,\ldots..\ ,\ d(\ A_n))^r] \quad (6)$$

Here, we are not going to explain all the intricacies and details of the methodology due to space limitations. Below we give enough of the general approach to enable the reader to follow the paper with ease.

3.3. Application of FAHP

The purpose of this study is to determine the most important problem factors in each distressed area of Karaj based on the results of the previous step. The model to achieve the mentioned targets is composed of the following steps (Fig. 1).

Step 1: Form a committee of experts: an expert team with 10 members (university professors and city authorities) was formed.

Step 2: Identify the factors and sub-factors. After reviewing the literature and interviewing with experts, 17sub-factors were identified, and categorized into 4 main factors (Demonstrated in Fig. 2).

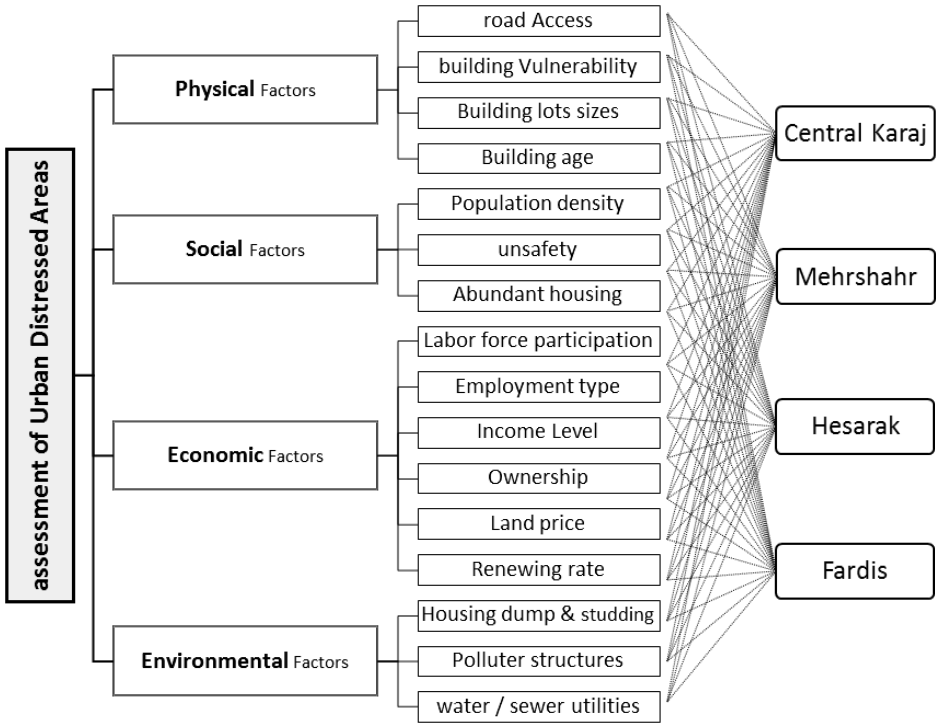

Fig. 2 Hierarchical structure of Factors and sub Factors of study

Step 3: Structure the hierarchy based on the factors and sub-factors identified in Step 2.

Step 4: Determine the local weights of the factors and sub-factors by using pair wise comparison matrices and calculate Fuzzy weights. A question form is used involving pair wise comparisons of Factors or alternatives and filled by the experts on the subject. The traditional AHP pair wise comparison may not be appropriate [36] Hence, the scale is converted into linguistic scale as proposed by [29] (Table 3).

Table 3 linguistic scale and their corresponding triangular fuzzy numbers (Kahraman, 2008)

Linguistic scale*	Triangular fuzzy scale	Triangular fuzzy reciprocal scale
Just equal	(1,1,1)	(1,1,1)
Equal dominance	(1/2,1,3/2)	(2/3,1,2)
Weak Dominance	(1,3/2,2)	(1/2,2/3,1)
Strong dominance	(3/2,2,2.5)	(2/5,1/2,2/3)
Very strong dominance	(2,2.5,3)	(1/3,2/5,1/2)
Absolute dominance	(2.5,3,7/2)	(2/7,1/3,2/5)

*For pairwise verbal comparisons, dominance of element i over j may be interpreted as importance, preference, influence

Step 5: Calculate the global weights for the sub-factors. Global sub-factor. At these steps we changed the linguistic scale of experts' opinion to Triangular fuzzy scale and put the geometric mean of them into final pair-wise Tables (Table 4).

Equation (1) was used to calculate the fuzzy weight of Factors. Defuzzification weights were obtained by equation (3).

The Final weight of Factors was acquired with equation (5) and at last normalized. (Table 5).

Table 4 Pair-wise comparison matrix of main-factors

Item	En. F	Ec. F	Sc. F	Ph. F
En. F	(1,1,1)	(0/2,0/7,1/2)	(0/2,0/5,0/8)	(0/2,0/6,1)
Ec. F	(0/833,1/4286,5)	(1,1,1)	(0/2,0/7,1/2)	(0/5,0/8,1/2)
Sc. F	(1/25,2,5)	(0/833,1/4286,1)	(1,1,1)	(0/7,1/2,1/7)
Ph. F	(1,1/667,5)	(0/9091,1/25,2)	(0/833,1/4286,0/5882)	(1,1,1)

Note: Ph. F= Physical Factors, Sc. F= Social Factors, Ec. F= Economical Factors, En. F= Environmental Factors

Table 1 Fuzzy weights, defuzzification weights and normalized weights of main-factors

Item	SUM	S_K (Fuzzy weight)	W_k (Defuzzification)	W_k (normalized)
En. F	(1/6,2/8,4)	(0/04648,0/16366,0/35048)	0/59269	0/17499
Ec. F	(2/533,3/9286,8/3)	(0/7358,0/2963,0/72725)	0/86124	0/25427
Sc. F	(3/783,5/6286,12/7)	(0/1099,0/32899,1/11277)	1/000	0/29524
Ph. F	(3/4973,4/75,9/4286)	(0/1016,0/27764,0/82613)	0/9331	0/27550

Note: Ph. F= Physical Factors, Sc. F= Social Factors, Ec. F= Economical Factors, En. F= Environmental Factors

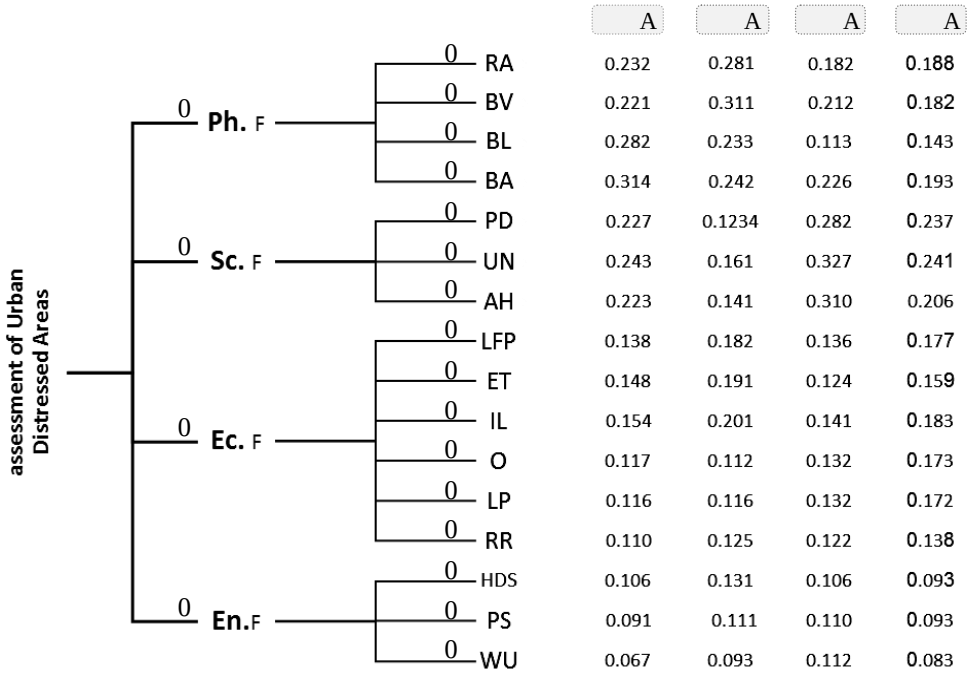

Fig. 3 Finalized Weights of Factors, Sub Factors and Alternatives

Note: Ph. F= Physical Factors, Sc. F= Social Factors, Ec. F= Economical Factors, En. F= Environmental Factors
RA= Road Access BV=Building Vulnerability BL=Building Lots sizes BA=Building Age PD=Population Density UN=UNsafety AH=Abandon Housing LFP=Labor Force Participation ET=Employment Type IL =Income Level O=Ownership LP=Land Price RR=Renewing Rate HDS=Housing Dump PS=Polluter Structures WU=Water utilities

This process was applied to sub factors and alternatives as well, for avoiding perplexity, just final results of calculations are presented in Fig. 3.

Step 6: determine the priority of factors and sub factors for each area. Based on the weights calculated in previous step, the sub factors with higher weights in a certain area was determined as the most important problem factors. They are depicted in separate Tables (No. 6 to 9) for each area.

4. DISCUSSION

Fig. 3 has provided a hierarchical decision model for prioritizing the most important factors. It can be observed that the weight of social factors is slightly higher than the others. Not surprisingly, experts emphasized more on social factors because distressed urban areas are often beset with social and physical problems, this phenomenon has instigated the urgent need for substantial improvement in the performance of local urban regeneration projects especially for social realm.

Social factors with a weight of about 30% were the most important causes of problems in distressed urban areas of Karaj. Among the areas, social problems were the most prominent issues in Hesarak (Area 3). The rate of crime and vandalism in this area was high, leading to feelings of insecurity and enhancing the sense of isolation. The social costs of distressed urban areas are high. When people of different socioeconomic groups no longer share the same neighborhoods, they interact with each other less, understand each other less well and fear each other more [4].

Physical factors also had great effects on the problems in distressed urban areas of Karaj and were the second important factors. Central Karaj is one of the oldest areas in Karaj (Area 1) and building decline, small sized building lots and inappropriate access caused migration of local neighbors which leads to social problems was the second issue.

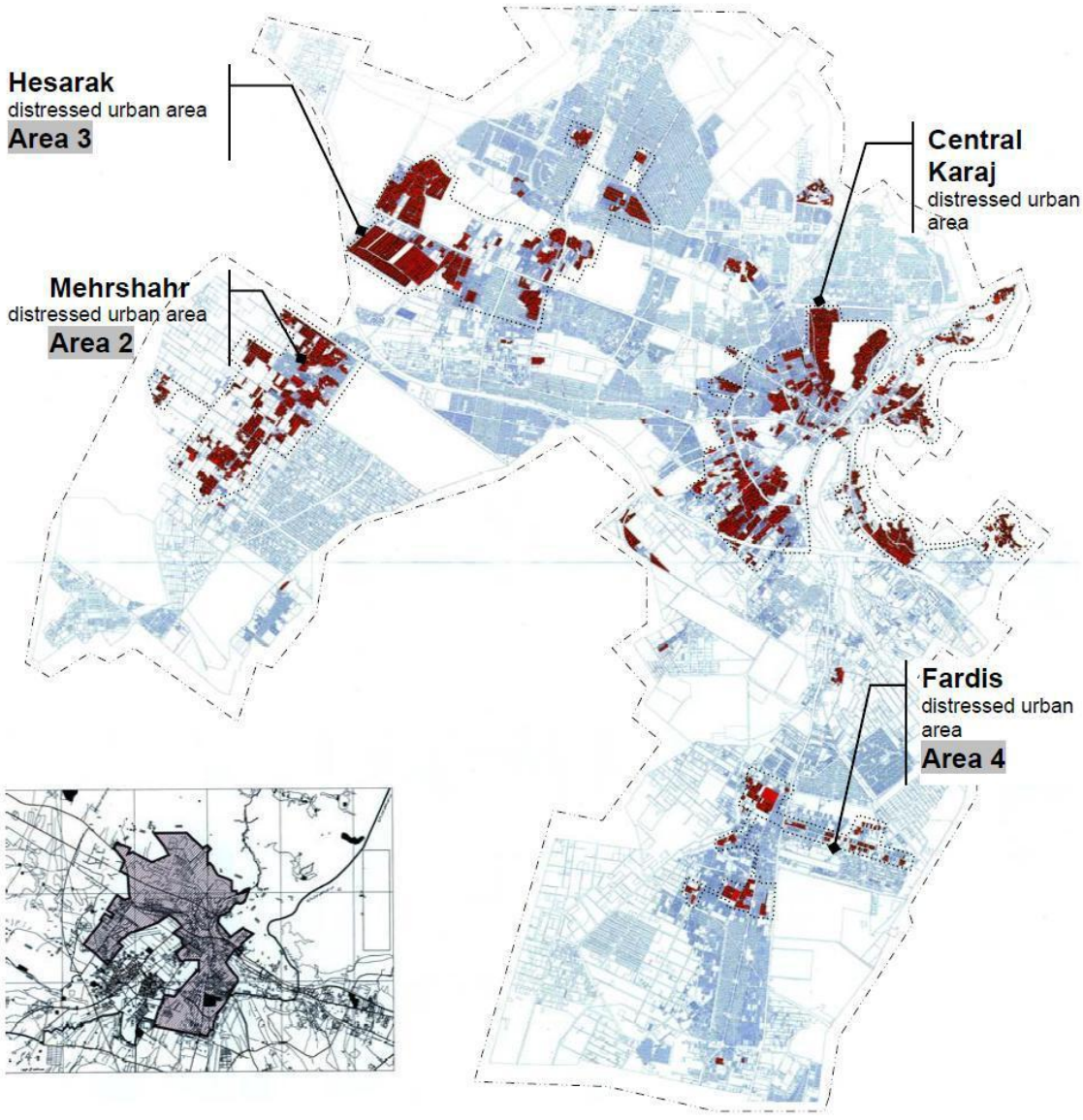

Fig. 4 Distressed Urban Areas of Karaj City

Mehshahr area (Area 2) also suffered most from Physical factors; a low quality compound in building structure without proper consistency caused concern about the long term viability in such housing. This deterioration in housing quality encourages the departure of better off residents, eventually generating areas of concentrated poverty and brings in the economic problems as the second issue. In contrast with other areas, Fardis (Area 4) had the lowest weight in factors and sub factors, showing a better condition among the areas. But its most important issues originated from social factors and economic factors.

The most important factors and sub factors in distressed urban areas of Karaj are shown in Table 6 to 9.

Table 2 priorities of Factors and sub Factors in Hesarak area

Area	Main factors	weight	priority	Sub factors	weight	priority
Hesarak	**Social F.**	**0.295**	**1**	Insecurity	0.041	**1**
				Abandon Housing	0.031	**2**
				Population density	0.025	**3**
	Physical F.	0.275	2			
	Economic F.	0.254	3			
	Environmental F.	0.174	4			

Table 7 Priorities of factors and sub factors in Fardis area

Area	Main factors	weight	priority	Sub factors	weight	priority
Fardis	**Social F.**	**0.295**	**1**	Insecurity	0.030	**1**
				Population density	0.021	**2**
				Abandon Housing	0.020	**3**
	Economic F.	0.254	2			
	Physical F.	0.275	3			
	Environmental F.	0.174	4			

Table 8 Priorities of Factors and sub Factors in Central Karaj area

Area	Main factors	weight	priority	Sub factors	weight	priority
Central Karaj	**physical F.**	**0.275**	**1**	Building age	0.018	**1**
				Building lot size	0.015	**2**
				Building vulnerability	0.014	**3**
				Road access	0.012	**4**
	Social F.	0.295	2			
	Economic F.	0.254	3			
	Environmental F.	0.174	4			

Table 9 priorities of Factors and sub Factors in Mehrshahr area

Area	Main factors	weight	priority	Sub factors	weight	priority
Mehrshahr	**Physical F.**	**0.275**	**1**	Building vulnerability	0.020	**1**
				Road access	0.014	**2**
				Building age	0.014	**3**
				Building lot size	0.013	**4**
	Economic F.	0.254	2			
	Social F.	0.295	3			
	Environmental F.	0.174	4			

5. CONCLUSION

In this research, it has been tried to apply the Fuzzy AHP model in evaluation of distressed fabric of Karaj for prioritizing the problems based on urban decline factors. The methodology has been discussed throughout the paper in details. Looking at the process and results of implementation of the fuzzy AHP model with case study and comparing to the simplistic process of pure AHP, showed that there are some evident advantage. For instance, in obtaining factors weight from experts, it has more accuracy in calculating the weight according the mathematical equations and it can express the expert's viewpoint more precisely especially in situations were the expert has some indecision, which classical AHP cannot handle. In this regard, using complicated and more accurate models discussed in this article will decrease the possibility of mistake, its consequences, and financial, social, and environmental damages. Therefore, it is recommended to all designers to analyze distressed areas coherently and comprehensively by utilizing fuzzy multi-dimensional measurement models.

With the factor weights found by using fuzzy AHP model (Fig. 1), it can be determined which factors have more effect on areas' problems. According to the findings, it is obvious that the social and physical factors have priority in distressed urban areas of Karaj. It means that the greatest benefit should be considered for owners,

residents, and users of spaces as a result of suggested development plans. The most influential sub-factors include: sense of Insecurity, Population density, Building age, Building vulnerability and using inappropriate material. The results of this study also suggest that Hesarak and Fardis areas have their most important issues from social factors that should be the focus of planning in these regions. Mehrshahr and central Karaj have their problems originated from physical factors.

NOTE

This paper was extracted from the first author's dissertation, under supervision of Marjan Nematimehr and advises of Abbas Shoeibi in the Faculty of Architecture and Urban Planning of Shahid Beheshti University (SBU).

CONFLICT OF INTEREST

The authors declare that there are no conflicts of interest regarding the publication of this manuscript.

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