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Exploring Critical Success Factors in Urban Housing Projects Using Fuzzy Analytic Network Process

Hessam Youneszadeh [a], Abdollah Ardeshir [a*], Mohammad Hassan Sebt [a]

[a] *Department of Civil and Environmental Engineering, Amirkabir University of Technology (Tehran Polytechnic), Iran.*

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Abstract

Population growth and increasing trend towards urbanization have caused housing demand to exceed its supply, particularly in urban areas in developing countries. Furthermore, housing industry motivates many subsidiary industries and plays a leading socio-economic role in such countries. Therefore, successful completion of housing projects is of great significance quantitatively and qualitatively.

This study aims to propose a framework to evaluate the critical success factors (CSFs) in housing projects considering the interrelationship among factors and criteria. The factors were initially identified through literature review and then refined and categorized using a two-round Delphi method and finally prioritized using fuzzy analytic network process (FANP). To demonstrate the implementation of the proposed model, a case study was carried out on an urban residential building project in Tehran. The framework proposed in this study can be applied as a decision support system for decision makers, project managers and practitioners involved in the housing sector.

Keywords: Project Management; Critical Success Factors; Housing; Building Projects; Fuzzy ANP.

1. Introduction

1.1. Housing Projects

Housing has been one of the fundamental necessities of human societies which provides shelter, identity, security and comfort, and facilitates human's activities in a built environment [1]. Housing plays an important role as a social aspect of sustainable development. Hence, quantity and quality of housing provision may be an indicator of the level of development of a society [2]. In United Nation Habitat Agenda 21 [3], provision of adequate shelter for all humankind was endorsed as a universal goal. In Istanbul declaration, it was emphasized that human settlements should be enhanced with regards to safety, health, livability, equity, sustainable development and productivity.

According to the World Cities Report [4], United Nation HABITAT declared that the world's urban population has increased dramatically from 2.6 billion (45%) in 1995 to 3.9 billion (54%) in 2014. The remarkable growth in the population of some developing countries and also, the increasing tendency towards urbanization has caused considerable demand for residential units in urban areas. On the other hand, housing provision rate has failed to keep pace with the above increasing demand, particularly in some developing countries. Therefore, housing provision has become a crucial issue in such developing countries. According to the United Nation Economic Commission for Africa, annual provision of 10 residential units per 1000 population is required in developing countries [5].

* Corresponding author: ardeshir@aut.ac.ir

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Housing industry can be a stimulus to subsidiary related industries resulting in national economic growth [6]. Once the construction industry in housing sector experiences booming era, many other small industries flourish and job creation index increases. Consequently, liquidity is steered towards housing market invigorating supply. Successful delivery of housing projects quantitatively as well as qualitatively, is a key solution to today's housing-related challenges in developing economies. In other words, to overcome the housing deficits, related critical success factors (CSFs) need to be initially identified and analyzed. Hence, many studies have investigated the enhancement of housing provision regarding different criteria and constraints particularly in developing nations [1, 2, 5, 6].

1.2. Critical Success Factors in Housing Projects

In the literature, there are several studies on success definition, success criteria, success factors and success measurement. Nevertheless, neither a constant definition of the term "project success" nor a unanimous methodology of measuring it has been presented.

Pinto and Slevin [7] opined that a project is considered as a successful one if it obtains acceptable level of performance in schedule and budget. Liu and Walker [8] emphasized on the necessity of reaching an agreement on success definition among project stakeholders since if no agreement is reached over the project success definition, the outputs of project will be difficult to be monitored or predicted. Therefore, in order to avoid disputes between project teams, agreed definition should be clarified in the initial phase of the project.

Baccarini [9] considered two separate concepts of project success: firstly, project management success, which deals with project processes resulting in successful implementation of time, cost and quality objectives; secondly, product success, which focuses on project goals and purposes to meet the stakeholders' satisfaction. In other words, two viewpoints of project success can be defined: macro and micro. Project stakeholders and users tend to consider the project success from macro viewpoint which deals with the project main goal and concept. Conversely, parties involved in construction phases look at the project success from micro viewpoint which deals with smaller objectives such as time, cost, quality and safety [10, 11].

In addition to ambiguities in success definition, which needs to be clarified, determination of critical success factors and criteria are of great importance because having known them, project managers can appropriately allocate project resources [12].

Critical success factors (CSFs) are key areas where favorable results play an important role in the success of a business, organization, system, program, project or process. Rockart [13] introduced this term for the first time in the field of data analysis and suggested that if an organization considers CSFs satisfactorily, it can perform successfully in competitive market. Lim and Mohamed [10] explained the difference between critical success factors and criteria. They defined CSFs as influential forces which either facilitate or impede project success. Howell [14] opined that if an organization intends to enhance its success chance in market, it should have a clear understanding of its objective-related CSFs, systematically assess CSFs, consider causal relationship among CSFs, and finally select appropriate method of implementation.

Several studies have been carried out on exploring CSFs in various construction fields. Many generic CSFs were investigated in these studies, which are common in all types of construction projects including inter alia, housing projects [11, 15-25]. In addition to these studies which investigated CSFs in construction projects considering different approaches, fields, criteria and categorizations; success factors and criteria in housing projects have been also specifically addressed in the literature.

Ahadzie et al. [5] presented a framework to evaluate 15 critical success criteria in mass house building projects. Baker Abu et al. [26] presented a framework of CSFs which are influential in housing projects in Malaysia with respect to sustainability criteria. Ademiluyi [6] investigated the housing CSFs with regards to the housing delivery strategies implemented by Nigerian government. Jiboye [2] investigated the factors needed to be considered in housing policy making to ensure adequate housing delivery, particularly in urban areas for ordinary Nigerian populace. Ihuah et al. [1] identified 22 critical success factors in the project management of sustainable social housing projects in Nigeria.

Since each project has its own unique characteristics, CSFs may not be transferable from one project to another. Nevertheless, generic CSFs (relating to all construction fields) and specific CSFs (relating to a known project) can be identified and used by project managers after getting tailored to a specific project in hand.

This study focuses on developing an evaluation framework which can be implemented as a decision support system (DSS) to evaluate CSFs in housing projects considering different viewpoints, contractual parties involved in the project, success criteria and project life-cycle phases. In addition, few studies in the literature have considered quantitatively, the interdependencies among the factors and criteria. This study aims to fill this knowledge gap by using fuzzy analytic network process. To deal with the vagueness of subjective judgments, fuzzy approach was implemented in this study.

1.3. Paper Layout

The rest of the paper is structured as follows:

In section 2, the proposed framework including three steps is represented. In section 3, the case study in which the evaluation model was implemented, is characterized. In section 4, the findings of this study including the output of each step are described. In section 5, the results of the study and comparison of the features of the proposed framework with previous ones are discussed. Finally, in section 6, the conclusion of this study together with its limitations and possible future works is presented.

2. Materials and Methods

A framework was proposed in this study to evaluate and prioritize the CSFs influencing housing project success through a 3-step evaluation process. This framework is depicted in Figure 1. The steps are as follows:

Step 1- Identifying CSFs through review of the literature.

Step 2- Refining and categorizing CSFs using Delphi method.

Step 3- Ranking CSFs using fuzzy analytic network process.

2.1. Step 1: Identifying CSFs Through Review of the Literature

According to the literature, CSFs can be considered from different perspectives. From one viewpoint, two types of CSFs can be considered: firstly, generic factors which are common in all types of projects and secondly, the specific factors which only affect housing projects. From another viewpoint, CSFs can be classified as tactical or strategic. They may also affect project outcome directly or indirectly. The significance of CSFs varies in different stages of project life-cycle and from one type of construction project to another. Each CSF has different degrees of influence on project success with respect to different success criteria such as time, cost, quality, stakeholders' satisfaction, safety, etc. Moreover, different parties have different perceptions of success and degree of importance of each CSF. Regardless of the different above-mentioned perspectives, in the first step of this study, all the CSFs in construction projects were extracted from the literature including studies in the last three decades. Both theoretical and empirical studies were considered.

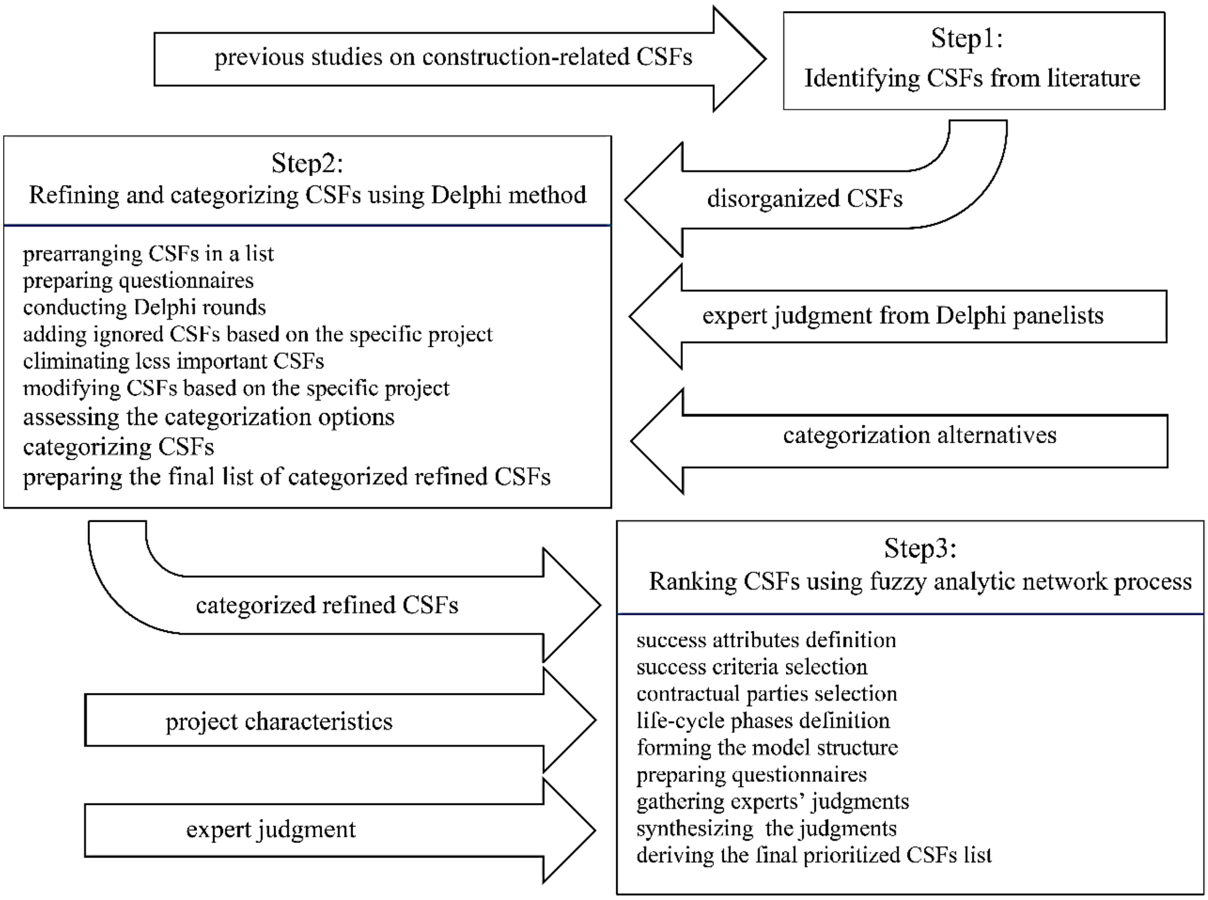

Figure 1. The proposed 3-step framework to evaluate CSFs in housing projects

2.2. Step 2: Refining and Categorizing CSFs Using Delphi Method

The Delphi method was developed by RAND Corporation for the first time in 1950's to reach the consensus of a panel of experts [27]. This method is a systematic and repeatable method for distributing questionnaire and data analysis. It is a systematic method to obtain information on a particular issue by providing connection between experts [28]. Okoli and Pawloski [29] opined that Delphi method is a technique to structure the communication among a group of participants to solve even complex problems and it is a versatile research tool particularly in exploratory researches. One of the characteristics of Delphi method is that participants can be geographically scattered and the study can be conducted without holding a session with all the participants present. Respondents filled the questionnaires anonymously during the stages of this method. The flow diagram used in this study is shown in Figure 2.

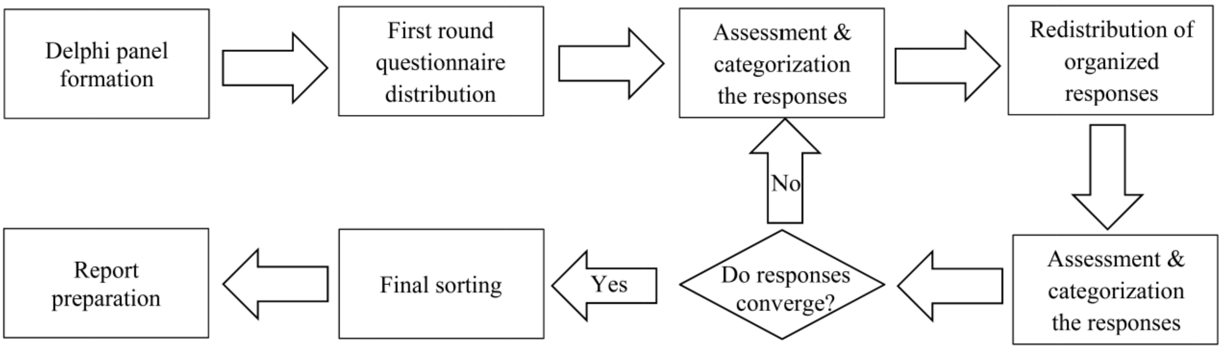

Figure 2. Delphi flow chart to refine and categorize CSFs influencing the success of housing projects

The CSFs which were identified from review of the literature in step 1 include both generic and specific factors with different level of influence on project success, and were refined and categorized based on the panelists' judgments in step 2.

In the first round of Delphi method, the initial factors were listed in a questionnaire and respondents were asked to eliminate irrelevant or ignorable CSFs, modify the existing CSFs if required, or add the CSFs which may be disregarded in the first step. Respondents were asked to justify the meaningful relationship between each CSF and project success. In addition, they were asked to assign a score to each CSF based on 5-point Likert scale (where the scores vary from 1, indicating "not important at all" to 5 denoting "extremely important"). After collecting the completed questionnaires in the first round, all the responses were assessed and reorganized. Furthermore, based on the relevancy to each other, the CSFs were categorized. Finally, revised questionnaires including synthesized responses were redistributed among the experts again. In the second round, the panelists were asked to reconsider their own responses according to all the comments gathered in the first round. Since the answers were convergent at the end of the second round, the final list of CSFs was derived, from which, all the experts reached a consensus.

2.3. Step 3: Ranking CSFs Using Fuzzy Analytic Network Process

Thomas L. Saaty introduced Analytic Network Process (ANP) in 1996 as a generalized form of Analytic Hierarchy Process (AHP). Unlike AHP, ANP considers the dependency and feedback among the elements of the problem [30]. Hence, ANP models provide more reliability and reality than AHP models [31] and can offer better solutions in a complex multi criteria decision environment [32, 33]. Two layers can be defined for an ANP model: 1- The control layer including goal, criteria and decision-making rules; 2- the network layer which includes the network structure which connects factors, sub-factors or alternatives [31, 34].

Many decision making problems are too complex due to imprecision in evaluating relative importance or rating model variables. This imprecision may be a result of unquantifiable, incomplete and unobtainable information [33]. To incorporate the uncertainty caused by vagueness and imprecision of decision makers' judgments, fuzzy set theory was applied in ANP method [35- 37]. Fuzzy ANP (FANP) makes judgments easier because decision makers are exposed to interval values instead of fixed values and they may be unable to express their judgments caused by vagueness involved in comparison process which is remedied in FANP [38]. Fuzzy theory enhances the synthesis of judgments resulting in derivation of more reliable outcome from heterogeneous groups [39]. In order to avoid biasing the results in decision making process, group decision making techniques should be employed [40].

Over the last decade, FANP was increasingly used in decision making problems because of its capability to handle interactions among and vagueness of model variables. Since the assessment of influencing factors, criteria and key performance indicators (KPIs) is dealt with, interactions and interdependency among factors and also imprecision and vagueness in subjective experts' judgments, FANP has been interestingly employed in this research area [32, 33, 38, 41].

In the literature, several FANP methods have been suggested. All these methods are based on two concepts: fuzzy set theory and analysis of network structure. The pairwise comparisons are elicited using fuzzy numbers in these methods, but different approaches are used to derive the local and global priority weights.

In this study, the ranking of CSFs by the means of FANP was implemented as follows:

1- Structuring the model of problem:

Based on the experts' comments in previous step and also review of the literature, the components of the model including goal, criteria and factors should be clarified in terms of clusters (nodes), elements and the relationship among them.

2- Establishing the fuzzy numbers:

A fuzzy number is a fuzzy set $\widetilde{A} = \{(x, \mu(x)), x \in R\}$, where x takes real values $R: -\infty < x < \infty$ and membership function $\mu(x)$ is a continuous mapping from R to the closed interval [0,1]. Monotonic, triangular and trapezoidal are the commonest membership functions used in fuzzy logic [38, 42]. Triangular fuzzy number (TFN) is the most convenient fuzzy number because of its simplicity in computation and data processing. In addition, TFN can appropriately represent the subjective linguistic evaluation in decision making problems [38, 43].

According to the aforementioned characteristics, TFN was employed in this study. A TFN is denoted as $\tilde{a}$= (l, m, u) where l, m and u are the smallest possible value, the most promising value, and the largest possible value, respectively. Equation 1 and Figure 3 present a TFN. In addition, $1/\tilde{a}$= (1/u, 1/m, 1/l) is used for reciprocal values.

$$\mu(x) = \begin{cases} 0 & x < l \\ \dfrac{x-l}{m-l} & l \leq x \leq u \\ \dfrac{u-x}{u-m} & m \leq x \leq u \\ 0 & u > x \end{cases} \quad (1)$$

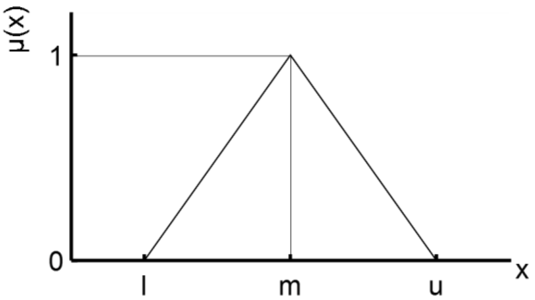

Figure 3. A fuzzy triangular number, ã (TFN)

Each expert expresses his/her judgment using a linguistic scale which is equivalent to a TFN. In Table 1 and Figure 4, the linguistic scales with corresponding TFNs and reciprocal values suggested by Kahraman et al. [35] are shown.

Table 1. Linguistic scale for relative importance [35]

Linguistic scale	Corresponding TFN	Reciprocal TFN
Just equal (JE)	(1,1,1)	(1,1,1)
Equally important (EI)	(1/2,1,3/2)	(2/3,1,2)
Weakly more important (WMI)	(1,3/2,2)	(1/2,2/3,1)
Strongly more important (SMI)	(3/2,2,5/2)	(2/5,1/2,2/3)
Very strongly more important (VSMI)	(2,5/2,3)	(1/3,2/5,1/2)
Absolutely more important (AMI)	(5/2,3,7/2)	(2/7,1/3,2/5)

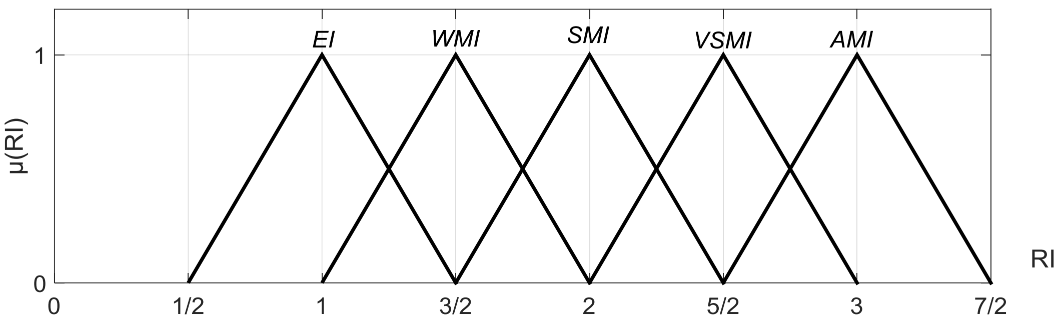

Figure 4. Membership functions for relative importance

3- Making pairwise comparison and aggregating the judgments:

Based on the relationships between clusters and elements in the model, each decision-making expert is asked to compare element i with element j with respect to a controlling criterion or factor. This pairwise comparison results in a matrix denoting the relative importance of elements. The experts' opinions are expressed by linguistic statements which are then converted to TFNs defined in Table 1. A relative importance matrix which is on the basis of subjective judgment of expert k is shown in Equation 2:

$$A = [\tilde{a}_{ij}^{k}] = \begin{array}{c} \\ e_1 \\ e_2 \\ \vdots \\ e_n \end{array} \begin{array}{c} \begin{array}{cccc} e_1 & e_2 & \cdots & e_n \end{array} \\ \begin{bmatrix} (1,1,1) & \tilde{a}_{12}^{k} & \cdots & \tilde{a}_{1n}^{k} \\ 1/\tilde{a}_{12}^{k} & (1,1,1) & \cdots & \tilde{a}_{2n}^{k} \\ \vdots & \vdots & \ddots & \vdots \\ 1/\tilde{a}_{1n}^{k} & 1/\tilde{a}_{2n}^{k} & \cdots & (1,1,1) \end{bmatrix} \end{array} \quad (2)$$

After collecting all the experts' judgments on comparison of the elements with each other in a cluster (node), the opinions should be aggregated. $\tilde{a}_{ij}^{k} = (l_{ij}^{k}, m_{ij}^{k}, u_{ij}^{k})$ denotes an individual opinion of expert k. Equations 3 to 6 can be employed to aggregate the opinions of p experts [31, 33, 40].

$$\tilde{a}_{ij}^{agg} = (L_{ij}, M_{ij}, U_{ij}) \quad (3)$$

$$L_{ij} = min_p(l_{ij}^{k}) \quad (4)$$

$$M_{ij} = (\prod_{k=1}^{p} m_{ij}^{k})^{1/p} \quad (5)$$

$$U_{ij} = max_p(u_{ij}^{k}) \quad (6)$$

For homogeneous group of experts, min and max operators are suitable. But extreme judgments result in large span of fuzzy numbers and aggregated values may exceed a tolerable range. Hence, in such cases, it is recommended to use geometric mean instead of min and max operators [39]. In this study, the geometric mean was used for lower and upper bounds of the scale. In other words, the aggregated fuzzy judgment is derived by the means of Equation 7.

$$\tilde{a}_{ij}^{agg} = \left((\prod_{k=1}^{p} l_{ij}^{k})^{1/p}, (\prod_{k=1}^{p} m_{ij}^{k})^{1/p}, (\prod_{k=1}^{p} u_{ij}^{k})^{1/p} \right) \quad (7)$$

Pairwise comparisons were carried out in FANP for two purposes: firstly, to determine the local weights or relative importance of elements assuming there is no dependency among them; secondly, to determine the interaction among elements with respect to other elements considering the dependency among them.

4- Defuzzification of aggregated pairwise comparison matrices and determination of eigenvectors:

Wu et al. [33] suggested Equations 8 to 10 to defuzzify the relative importance matrix. Notably, two parameters, α and β, are considered in these equations. α denotesDenotes the degree of stability of problem condition and β denotes the level of risk up to which decision-makers can tolerate. Both parameters are between 0 and 1. When α=0, the decision making environment is more uncertain and consequently, the lower (L_{ij}) and upper bounds (U_{ij}) of aggregated TFN is represented. Conversely, when α=1, the decision making environment is more stable and the midpoint (M_{ij}) of aggregated TFN is represented. β=0 implies the decision makers' optimism and upper bound (U_{ij}) of aggregated TFN is obtained. Conversely, when β=1, the decision makers are pessimistic and lower bound (L_{ij}) of aggregated TFN is derived (Figure 5). Finally, the non-fuzzy aggregated comparison matrix is formed as Equation 11.

$$g_{\alpha,\beta}(\tilde{a}_{ij}^{agg}) = [\beta . f_\alpha(L_{ij}) + (1-\beta). f_\alpha(U_{ij})] \tag{8}$$

$$f_\alpha(L_{ij}) = (M_{ij} - L_{ij}).\alpha + L_{ij} \tag{9}$$

$$f_\alpha(U_{ij}) = U_{ij} - (U_{ij} - M_{ij}).\alpha \tag{10}$$

$$G = \left[g_{\alpha,\beta}(\tilde{a}_{ij}^{agg})\right] = \begin{matrix} \\ e_1 \\ e_2 \\ \vdots \\ e_n \end{matrix} \begin{matrix} e_1 & e_2 & \cdots & e_n \\ \left[\begin{matrix} 1 \\ g_{\alpha,\beta}(1/\tilde{a}_{12}^{agg}) \\ \vdots \\ g_{\alpha,\beta}(1/\tilde{a}_{1n}^{agg}) \end{matrix}\right. & \begin{matrix} g_{\alpha,\beta}(\tilde{a}_{12}^{agg}) \\ 1 \\ \vdots \\ g_{\alpha,\beta}(1/\tilde{a}_{2n}^{agg}) \end{matrix} & \begin{matrix} \cdots \\ \cdots \\ \ddots \\ \cdots \end{matrix} & \left.\begin{matrix} g_{\alpha,\beta}(\tilde{a}_{1n}^{agg}) \\ g_{\alpha,\beta}(\tilde{a}_{2n}^{agg}) \\ \vdots \\ 1 \end{matrix}\right] \end{matrix} \tag{11}$$

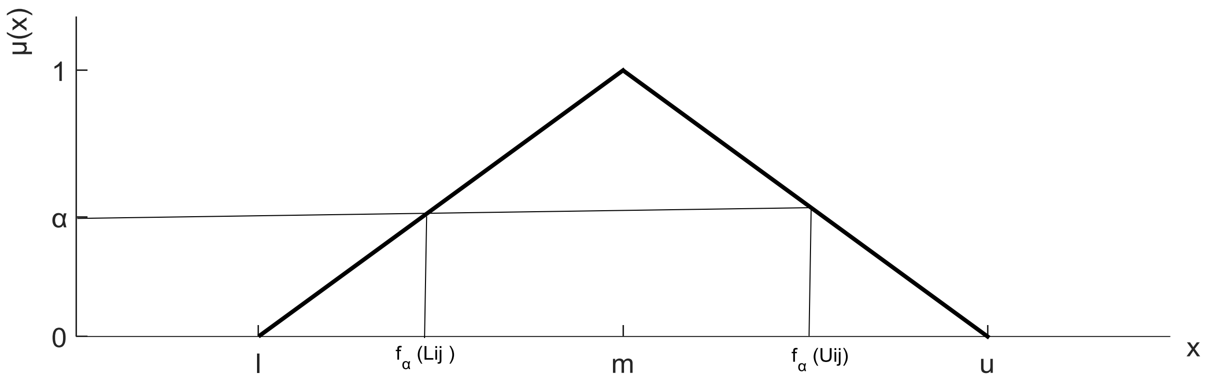

Figure 5. α-Cut used in defuzzification of aggregated TFN

To determine the local priority vector of comparison matrix, G, eigenvector method was used by the means of Equations 12 and 13.

$$G.W = \lambda_{max}.W \tag{12}$$

$$[G - \lambda_{max} I]W = 0 \tag{13}$$

5- Forming the stochastic supermatrix:

The supermatrix, which is a partitioned matrix, was formed to analyze the transmission of influences along the paths in a network structure [39] resulting in determination of the global priority weights. For this purpose, the local priority vectors were placed in the corresponding columns in the supermatrix. Each segment in the supermatrix represents the relationship between two clusters (components or nodes) in the network structure [33]. The general form of a supermatrix is shown in Equation 14.

$$SM = \begin{matrix} \\ C_1 \\ C_2 \\ \vdots \\ C_N \end{matrix} \begin{matrix} C_1 & C_2 & \cdots & C_N \\ \left[\begin{matrix} W_{11} \\ W_{21} \\ \vdots \\ W_{N1} \end{matrix}\right. & \begin{matrix} W_{12} \\ W_{22} \\ \vdots \\ W_{N2} \end{matrix} & \begin{matrix} \cdots \\ \cdots \\ \ddots \\ \cdots \end{matrix} & \left.\begin{matrix} W_{1N} \\ W_{2N} \\ \vdots \\ W_{NN} \end{matrix}\right] \end{matrix} \tag{14}$$

Where, W_{IJ} is the weight vectors matrix derived from Equations 12 and 13; matrix W_{IJ} represents the impact of cluster C_J on cluster C_I . If the number of elements in clusters C_I and C_J is are assumed as n_I and n_J, respectively, the dimension of matrix W_{IJ} will be $n_I \times n_J$. Entries of zeros denote no influence. The supermatrix obtained so far is unweighted and its columns may not sum to unity, in other words, the supermatrix is not stochastic. Hence, the supermatrix should first be reduced to a column stochastic matrix (that is, weighted supermatrix) in which the summation of each column is one.

6- Obtaining the final limit supermatrix:

To consider the cumulative influence of each element, the stochastic supermatrix should be raised to powers resulting in limit supermatrix. Raising the supermatrix to the powers continues until it converges and the difference between elements of a column in two successive powers is less than a very small number. Finally, the limit supermatrix which includes the global weights of elements is obtained.

3. Case Study

The implementation of the framework proposed in this study was assessed in Tehran, the capital of Iran.

Total housing demand in Iran consists of two parts: firstly, real demand which is due to actual household need, particularly, the newlyweds providing themselves a shelter and demolition and reconstruction of dilapidated buildings. Secondly, capital demand which is caused by greater profit margin of investment in housing industry in comparison with other investments. The annual housing supply has rarely met the annual real demand but the total demand of housing in Iran has always exceeded its supply. To maintain the balance between demand and supply in housing market, building about one million residential units is required per annum [44].

According to the latest official census taken by Statistical Center of Iran (SCI) in 2011 [45], from a population of 75 million, about 71.4% (about 54 million) were resident in urban areas. In addition, the urbanization between the years 2006 and 2011 had 4.2% growth, which indicates the tendency to live in urban areas, particularly in metropolises. Consequently, the number of cities has also increased. Conversely, ruralization has declined constantly (Figures 6 and 7). Based on SCI's report, the number of building permits issued by municipalities in Iran has slightly declined in recent years due to economic recession. Tehran has a significant proportion of total permits issued annually (Figure 8).

Although, considerable investment is attracted in housing sector in Tehran, total demand is greater than housing supply. Therefore, the reduction of housing provision in Tehran alarms policymakers about the contingent occurrence of gap between supply and demand. Hence, successful completion of housing projects is a key solution to this problem.

The procedures mentioned in section 2 were carried out under the construction circumstances of Tehran and in a housing developing project entitled "Asef residential project" including 120 residential apartment units being constructed by OT Construction Company. To refine, categorize and rank the CSFs, a panel of 15 experts including project managers, practitioners, academics, site engineers and PMO members with more than 12 years of experience in housing development projects were selected. The results are presented step by step in the next section.

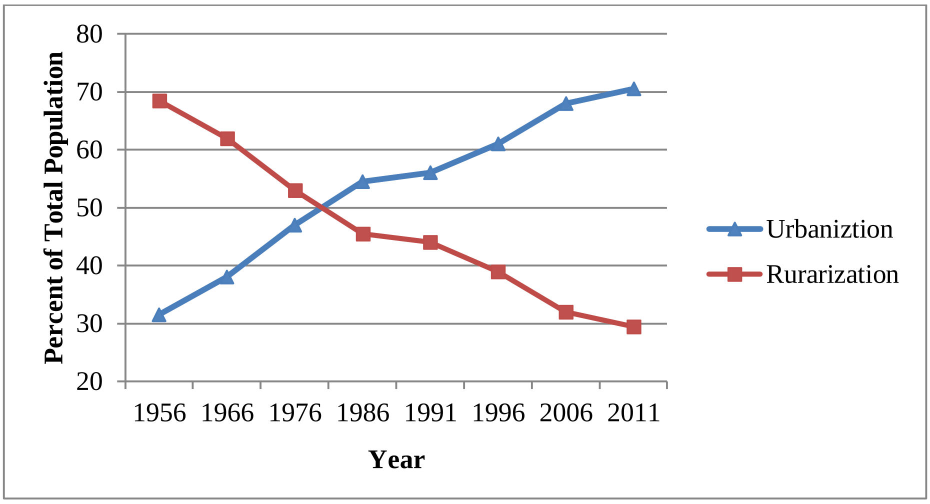

Figure 6. Urbanization and ruralization trends in Iran [45]

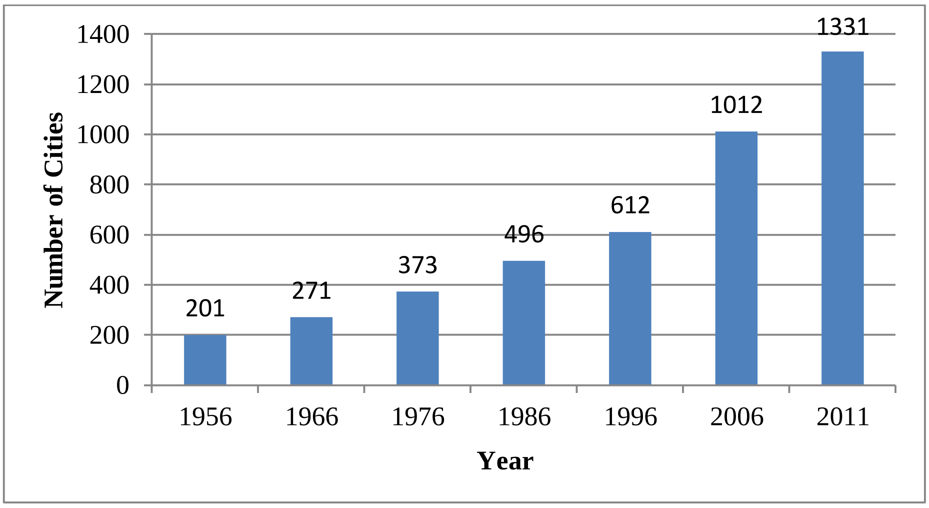

Figure 7. Growth in the number of cities in Iran from 1956-2011 [45]

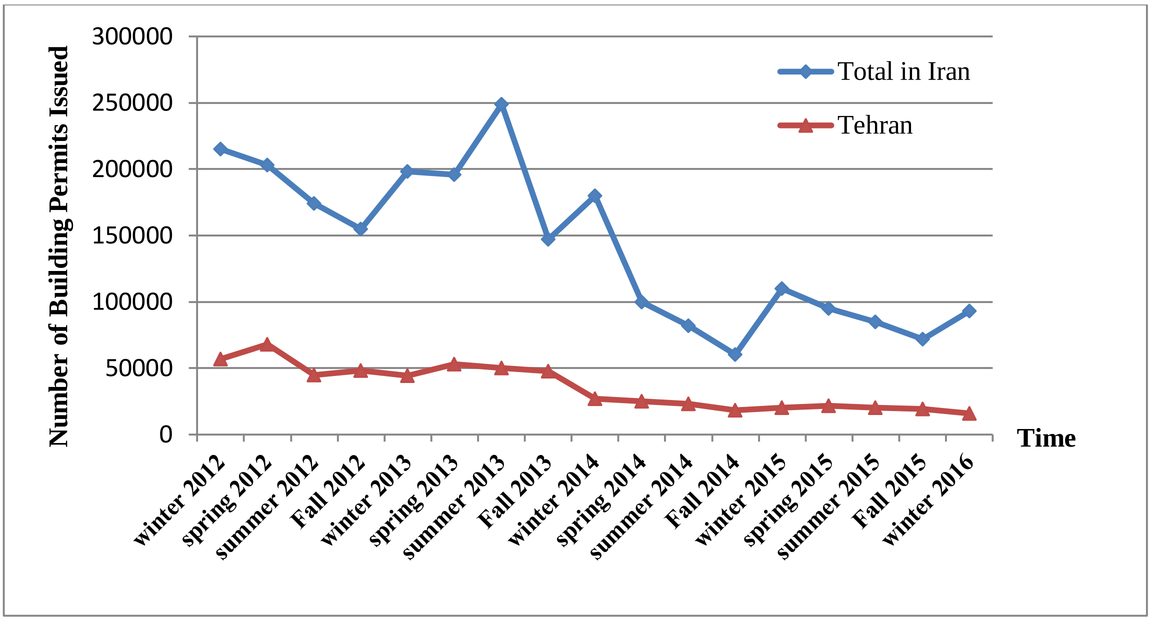

Figure 8. Trend of number of building permits for residential units issued countrywide in Iran vs. Tehran [45]

4. Results

For validating the present model, three different test cases including movable, stepped bed and overtopping conditions are chosen as follows:

4.1. Steps 1: Identifying CSFs

According to the literature and as described in section 2, a list of 54 CSFs affecting the project success in different construction fields was developed. These CSFs are both generic and specific.

4.2. The Second Test Case: Ideal Dam Break Over Stepped Bed

All the 54 identified CSFs were listed in a questionnaire and distributed among the panel of 15 experts according to the Delphi method described in section 2.2. The results converged after the second round. Four categories identified by the experts includes: 1- Project specification factors; 2- Organization-related factors; 3-Project team factors; and 4-External environment factors. In addition, some of the factors, which were similar, were merged and formed one factor. Some factors, which were ignored in the first step, were added. Finally, 56 refined CSFs were obtained and rated using 5-point Likert scale without considering the interdependency of factors. The results are shown in Table 2.

4.3. The Third Test Case: Earth Dam Erosion Due to Overtopping

As described in section 2, FANP approach was employed to evaluate the CSFs which are influential in housing projects. For this purpose, the procedure mentioned in section 2 was carried out as follows:

1- Structuring the model of problem:

In order to rank the CSFs, a model should be initially structured and should be able to properly represent the components of the problem. To exclude less important factors, the threshold of 3.5 out of 5 was considered and the CSFs with rating of less than 3.5 in Table 3 were omitted from the model. The proposed model is illustrated in Figure 9. The experts in the second step also confirmed the structure. As shown in this figure, the model consists of 6 levels as follows:

Table 2. Refined and categorized CSFs in housing projects

Category		CSF	Mean
Project specification factors	1	Project site condition/Type of soil/Land slope/Utilities available	3.17
	2	Quality and type of materials selected/Material Specification/	2.92
	3	Changes in plans and reworks/Changes in material specification/Working overtime	2.42
	4	Level of being optimal and elaborate in design phase/Practical design which can be executed without problem	3.58
	5	Technology applied in construction phase/High-tech machineries and equipment required	4.25
	6	Size of project/Total area of the building/Sub-projects included	4.00

Project specification factors	7	Number of underground floors/Excavation and soil stabilization activities	3.08
	8	Number of residential floors/Maximum height of material handling	2.58
	9	Urgency/Crucial project needs to be completed as soon as possible	3.00
	10	Project value	2.75
	11	Project complexity	4.08
Organization-related factors	1	Top management support	4.33
	2	Clarification of Project mission, vision, goal and commitments	3.42
	3	Project ownership/Private or public ownership	3.33
	4	Adequate and on-time project fund and resource allocation	4.50
	5	Organizational structure	3.25
	6	Taking account of past experience/Documentation of lesson learned	2.75
	7	Feasibility study/Conceptual design	3.33
	8	Organization culture	2.75
	9	Benchmarking firm's performance against successful projects	3.00
Project team factors	1	Project understanding	3.17
	2	Information and communication management/Regular progress meetings/Reduction or absence of bureaucracy	2.83
	3	Competent project team/Project team formation/Executive's experience and qualification/Personnel recruitment	4.50
	4	Project manager's authority, competency and leadership skills	4.58
	5	Realistic cost and time estimates	3.75
	6	Proper project control, monitoring and feedback/Supervision of construction phase	3.58
	7	Problem solving abilities/Technical innovation/Trouble-shooting	3.25
	8	Project risk management	3.08
	9	Proper project planning and scheduling	3.17
	10	Minimum start-up difficulties	2.25
	11	Implementing an effective quality assurance program	3.42
	12	Attention on contractor and sub-contractor selection/Tendering	4.58
	13	Compliance with safety regulations/Implementing safety programs	3.17
	14	Logistic requirements/Procurement	3.83
	15	Workforce development and training/Human resource management	3.00
	16	Adequate use of IT	2.33
	17	Effective change management	3.00
	18	Contract and legal problems/Proper dispute resolution	2.67
External environment factors	1	Accessibility of resources/Ease of resource provision	2.83
	2	Land issues and litigation on land ownership	3.42
	3	Effective housing policy/Governmental and municipal construction rules and regulations	4.25
	4	Rise or fluctuation in the price of construction material	3.58
	5	Climatic condition	2.08
	6	Cultural difference/Social environment	2.25
	7	Quality of region where the project is located in	2.75
	8	An increase in wages of construction manpower	3.42
	9	Municipal taxes/Utility charges/Insurance fee/Governmental taxes and tariff	2.75
	10	End user's affordability	2.33
	11	Housing market condition/Competitors/Status of housing supply and demand	3.42
	12	Political situation	3.42
	13	Economic condition and indicators/Annual inflation/Economic stability	3.83
	14	Traffic limits and Transportation of goods and materials/ Physical environment	2.92
	15	Project neighbors	2.58
	16	Technological environment/Technological advances	3.17
	17	Environmental impact of project	2.42
	18	Client or end user participation/Client consultation, Client's analysis	4.25

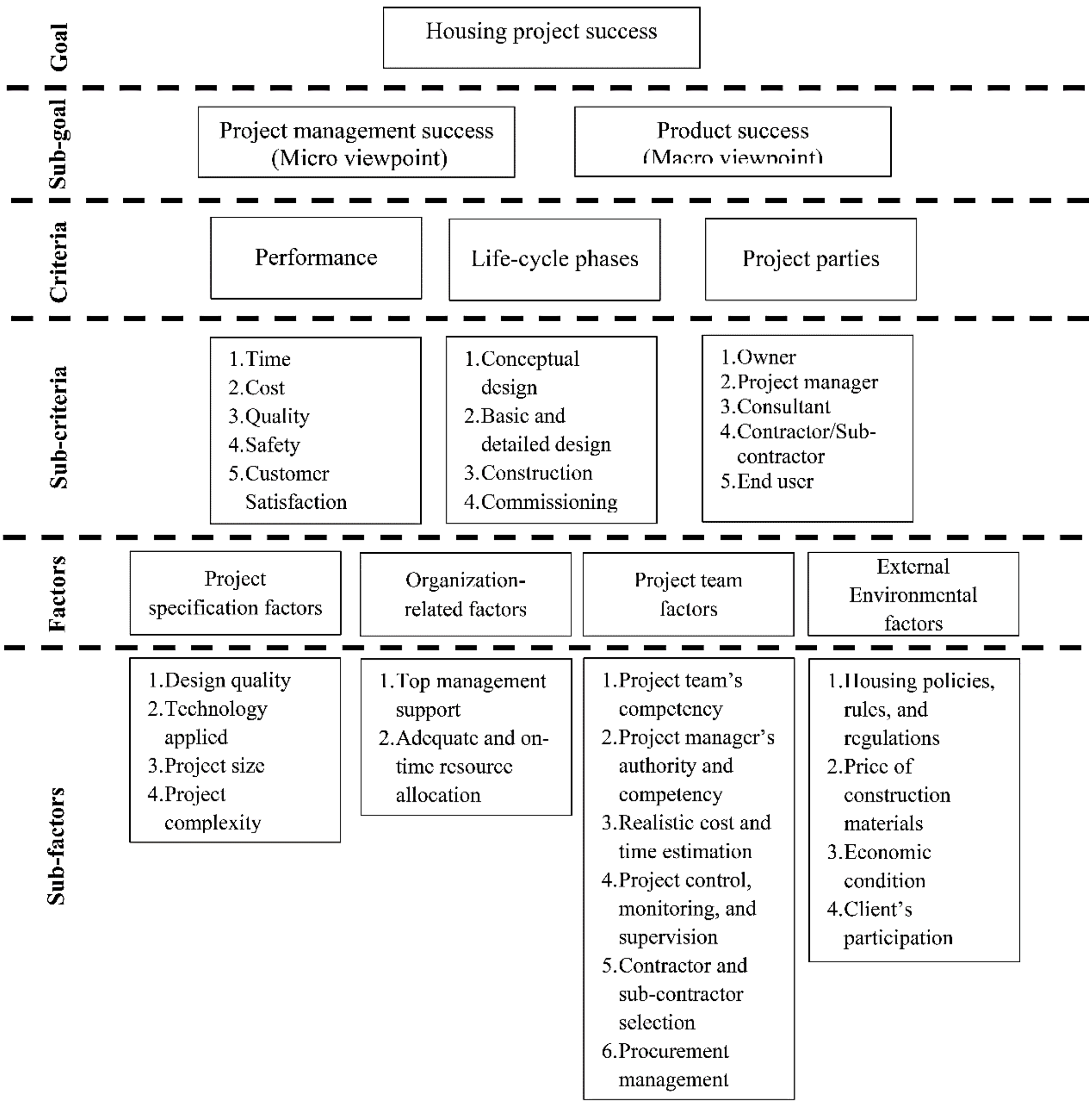

Figure 9. Components of the proposed FANP model for assessing CSFs in housing projects

Level 1- Goal: Success of the housing project is the ultimate goal of the model.

Level 2- Sub-goals: As suggested by Baccarini [9], two concepts can be considered when defining success: product success and project management success. These two attributes correspond to two macro and micro viewpoints, respectively, suggested by Lim and Mohamed [10] and also Toor and Ogunlana [11]. Hence, two sub-goals including product success and project management success were incorporated in the model.

Level 3- Criteria: Three groups of criteria are employed in the model with respect to which, the CSFs are evaluated: performance, life-cycle phases and project parties. The significance of a CSF varies according to different criteria.

Level 4- Sub-criteria: Each criterion consists of some sub-criteria. Once the CSFs are evaluated with regards to the criterion "performance", the sub-criteria including time, cost, quality, safety, and customer satisfaction are involved in evaluation. In the same manner, four sub-criteria namely conceptual design, basic and detailed design, construction and commissioning were assigned to the criterion (cluster) "Life-cycle phases". Finally, five main parties including owner, project manager (or project chief executive), consultant, contractor/sub-contractor and end user were determined as the elements of the criterion (cluster) "Project parties".

Level 5- Factors: The four categories, which were determined in step 2, were placed in level 5 of the FANP model.

Level 6- Sub-factors: All the 16 refined CSFs, which are shown in Table 2 with rating values not less than 3.5, were placed in level 6 of the FANP model.

One of the advantages of FANP is its capability to consider the interdependencies among the elements in decision-making process. The relationships in the model structure are depicted in Figure 10. For each of the elements in the model, an acronym was assigned (Table 3).

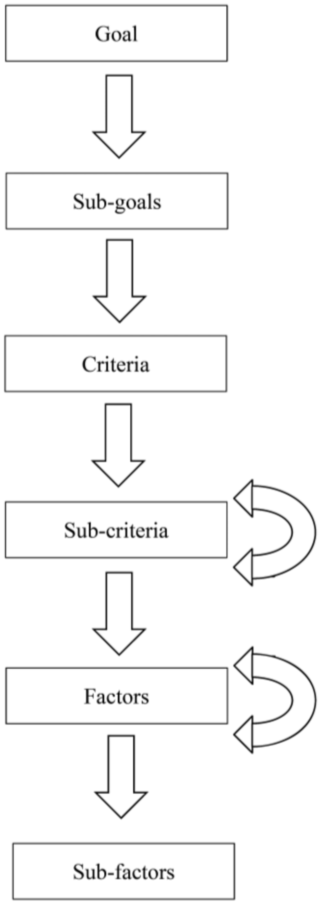

Figure 10. Relationships between the components of the proposed FANP model

2- Establishing the fuzzy numbers:

As described in section 2.3, in this study, fuzzy triangular number (TFN) was used in pairwise comparisons. The TFNs, which correspond to linguistic judgments, are presented in Table 1.

3- Making pairwise comparison and aggregating the judgments:

On the basis of the model structure and influence paths existing in the model, each of the experts responded to the questions when comparing the paired elements in the model. Finally, all the responses were aggregated according to Equation 7 mentioned in section 2.3. An example of individual and aggregated pairwise comparison is shown in Tables 4 and 5, respectively.

4- Defuzzification of aggregated pairwise comparison matrices and determination of eigenvectors:

According to the method described in section 2.3, the entries of fuzzy aggregated pairwise comparisons were transformed into crisp values by the means of Equations 8 to 11. In this study, based on the experts' consensus, 0.5 was assigned as the values of α and β. Consequently, the priority weight vectors were determined using Equations 12 and 13. The results are shown in Tables 5 to 11. The priority weight vectors are shown in the last columns of the tables. Pairwise comparisons were carried out for two purposes: firstly, to determine the local weights of components of a level with respect to a component in higher level, W_{IJ} (Tables 5-9) and secondly, to determine the interdependency weight matrices within components of a level, W_{II} (Tables 10 and 11).

Table 3. Acronyms used for model elements

Element type	Element description	Acronym
Goal	Housing project success	G
Sub-goals	Project management success	SG1
	Product success	SG2
Criteria	Performance	C1
	Life-cycle phases	C2
	Project parties	C3
Sub-criteria	Time	SC11
	Cost	SC12
	Quality	SC13
	Safety	SC14
	Customer satisfaction	SC15
	Conceptual design	SC21
	Basic and detailed design	SC22
	Construction	SC23
	Commissioning	SC24
	Owner	SC31
	Project manager	SC32
	Consultant	SC33
	Contractor/Sub-contractor	SC34
	End user	SC35
Factors	Project specification factors	F1
	Organization-related factors	F2
	Project team factors	F3
	External environmental factors	F4
Sub-factors	Design quality	SF11
	Technology applied	SF12
	Project size	SF13
	Project complexity	SF14
	Top management support	SF21
	Adequate and on-time resource allocation	SF22
	Project team's competency	SF31
	Project manager's authority and competency	SF32
	Realistic cost and time estimation	SF33
	Project control, monitoring and supervision	SF34
	Contractor and sub-contractor selection	SF35
	Procurement management	SF36
	Housing policies, rules and regulations	SF41
	Price of construction materials	SF42
	Economic condition	SF43
	Client's participation	SF44

Table 4. Individual fuzzy pairwise comparison of sub-goals with respect to goal (expressed by one expert)

Goal	Sub-goals	SG1	SG2
Housing project success (G)			
	Project management success (SG1)	(1,1,1)	(1,1.5,2)
	Product success (SG2)	(0.5,0.667,1)	(1,1,1)

Table 5. Aggregated fuzzy pairwise comparison and local weights of sub-goals with respect to goal (W_{21})*

Goal	Sub-goals	SG1	SG2	Local weight
Housing project success (G)				
	Project management success (SG1)	(1,1,1)	(0.73,1.11,1.58)	**0.53**
	Product success (SG2)	(0.63,0.90,1.37)	(1,1,1)	**0.47**

* it is assumed: α=0.5, β=0.5

Table 6. Aggregated fuzzy pairwise comparison and local weights of criteria with respect to sub-goals (W_{32})

Sub-goals	Criteria	C1	C2	C3	Local weight
Project management success (SG1)	Performance (C1)	(1,1,1)	(1.43,1.94,2.44)	(1.62,2.12,2.62)	**0.50**
	Life-cycle phases (C2)	(0.41,0.52,0.70)	(1,1,1)	(0.69,1.08,1.43)	**0.26**
	Project parties (C3)	(0.38,0.47,0.62)	(0.70,0.92,1.45)	(1,1,1)	**0.24**
Product success (SG2)					
	Performance (C1)	(1,1,1)	(0.72,1.14,1.52)	(0.69,0.87,1.08)	**0.33**
	Life-cycle phases (C2)	(0.66,0.87,1.38)	(1,1,1)	(0.66,0.87,1.38)	**0.31**
	Project parties (C3)	(0.92,1.14,1.45)	(0.72,1.14,1.52)	(1,1,1)	**0.36**

Table 7. Aggregated fuzzy pairwise comparison and local weights of sub-criteria with respect to criteria (W_{43})

Criteria	Sub-criteria	Sub-criteria					Local weight
Performance (C1)		**SC11**	**SC12**	**SC13**	**SC14**	**SC15**	
	Time (SC11)	(1,1,1)	(0.56,0.78,1.32)	(0.57,0.81,1.38)	(0.70,0.92,1.45)	(0.50,0.67,1.28)	**0.18**
	Cost (SC12)	(0.76,1.28,1.78)	(1,1,1)	(0.77,1,1.30)	(0.97,1.49,2.00)	(0.68,0.92,1.30)	**0.22**
	Quality (SC13)	(0.72,1.24,1.75)	(0.78,1,1.30)	(1,1,1)	(0.87,1.28,1.64)	(0.72,1,1.50)	**0.21**
	Safety (SC14)	(0.69,1.08,1.43)	(0.50,0.67,1.03)	(0.61,0.78,1.15)	(1,1,1)	(0.66,0.87,1.38)	**0.17**
	Customer satisfaction (SC15)	(0.78,1.49,2.00)	(0.77,1.08,1.47)	(0.67,1,1.39)	(0.72,1.14,1.52)	(1,1,1)	**0.21**
Life-cycle phases (C2)		**SC21**	**SC22**	**SC23**	**SC24**		**0.35**
	Conceptual design (SC21)	(1,1,1)	(1.38,1.90,2.40)	(0.64,1,1.43)	(1.89,2.40,2.91)		**0.22**
	Basic and detailed design (SC22)	(0.42,0.53,0.72)	(1,1,1)	(0.62,0.81,1.20)	(1.21,1.72,2.22)		**0.30**
	Construction (SC23)	(0.70,1,1.57)	(0.83,1.24,1.61)	(1,1,1)	(1.89,2.39,2.89)		**0.13**
	Commissioning (SC24)	(0.34,0.42,0.53)	(0.45,0.58,0.83)	(0.35,0.42,0.53)	(1,1,1)		
Project parties (C3)		**SC31**	**SC32**	**SC33**	**SC34**	**SC35**	
	Owner (SC31)	(1,1,1)	(0.49,0.66,1.31)	(0.83,1,1.38)	(0.47,0.62,1.11)	(0.90,1.43,1.94)	**0.18**
	Project manager (SC32)	(0.76,1.52,2.03)	(1,1,1)	(1.43,1.94,2.44)	(1.28,1.82,2.34)	(2.22,2.72,3.22)	**0.31**
	Consultant (SC33)	(0.72,1,1.21)	(0.41,0.52,0.70)	(1,1,1)	(0.57,0.81,1.38)	(1.24,1.75,2.25)	**0.18**
	Contractor/Sub-contractor (SC34)	(0.90,1.62,2.12)	(0.42,0.55,0.78)	(0.72,1.24,1.75)	(1,1,1)	(1.75,2.25,2.76)	**0.22**
	End user (SC35)	(0.52,0.70,1.11)	(0.31,0.37,0.45)	(0.44,0.57,0.81)	(0.36,0.44,0.57)	(1,1,1)	**0.11**

Table 8. Local weights of factors with respect to sub-criteria (W_{54})

Sub-criteria	Project specification factors (F1)	Organization-related factors (F2)	Project team factors (F3)	External Environmental factors (F4)
Time (SC11)	0.24	0.31	0.26	0.20
Cost (SC12)	0.32	0.21	0.22	0.25
Quality (SC13)	0.26	0.19	0.37	0.18
Safety (SC14)	0.19	0.27	0.39	0.15
Customer satisfaction (SC15)	0.28	0.23	0.33	0.16
Conceptual design (SC21)	0.21	0.38	0.18	0.23
Basic and detailed design (SC22)	0.24	0.23	0.31	0.21
Construction (SC23)	0.24	0.30	0.32	0.14
Commissioning (SC24)	0.25	0.30	0.28	0.17
Owner (SC31)	0.21	0.24	0.25	0.30
Project manager (SC32)	0.19	0.39	0.24	0.17
Consultant (SC33)	0.35	0.20	0.30	0.15
Contractor/Sub-contractor (SC34)	0.19	0.29	0.37	0.14
End user (SC35)	0.25	0.17	0.24	0.34

Table 9. Local weights of sub-factors with respect to factors (W_{65})

Factors	Sub-factors	Local weight
Project specification factors (F1)	Design quality (SF11)	**0.23**
	Technology applied (SF12)	**0.32**
	Project size (SF13)	**0.25**
	Project complexity (SF14)	**0.21**
Organization-related factors (F2)	Top management support (SF21)	**0.44**
	Adequate and on-time resource allocation (SF22)	**0.56**
Project team factors (F3)	Project team's competency (SF31)	**0.17**
	Project manager's authority and competency (SF32)	**0.27**
	Realistic cost and time estimation (SF33)	**0.13**
	Project control, monitoring and supervision (SF34)	**0.14**
	Contractor and sub-contractor selection (SF35)	**0.19**
	Procurement management (SF36)	**0.10**
External Environmental factors (F4)	Housing policies, rules and regulations (SF41)	**0.34**
	Price of construction materials (SF42)	**0.16**
	Economic conditions (SF43)	**0.30**
	Client's participation (SF44)	**0.21**

Table 10. Interdependency weight matrix of sub-criteria (W_{44})

	SC11	SC12	SC13	SC14	SC15	SC21	SC22	SC23	SC24	SC31	SC32	SC33	SC34	SC35
SC11	0.25	0.22	0.18	0	0	0	0	0.16	0	0	0.13	0	0.16	0
SC12	0.36	0.15	0.23	0.24	0.22	0	0.19	0.21	0	0	0.10	0	0.11	0
SC13	0.22	0.36	0.14	0	0.15	0	0.13	0.12	0	0.21	0.16	0.19	0.20	0
SC14	0.17	0.13	0	0.24	0	0	0	0.17	0	0.14	0.11	0	0.14	0
SC15	0	0.15	0	0	0.36	0.15	0	0	0.43	0	0	0	0	0.26
SC21	0	0	0	0	0	0.14	0	0	0	0.31	0	0.23	0	0
SC22	0	0	0	0	0	0.33	0.15	0	0	0	0	0.28	0	0
SC23	0	0	0	0	0	0.24	0.29	0.18	0	0	0.22	0	0.22	0
SC24	0	0	0.23	0	0.13	0	0	0.16	0.25	0	0	0	0	0.36
SC31	0	0	0	0	0	0	0	0	0	0.16	0	0	0	0.18
SC32	0	0	0	0	0	0	0	0	0	0.18	0.11	0	0	0
SC33	0	0	0	0.20	0	0.13	0	0	0	0	0.17	0.14	0	0
SC34	0	0	0	0.33	0	0	0.25	0	0	0	0	0.16	0.16	0
SC35	0	0	0.23	0	0.15	0	0	0	0.32	0	0	0	0	0.20

Table 11. Interdependency weight matrix of factors (W_{55})

	F1	F2	F3	F4
F1	0.32	0.31	0.29	0.23
F2	0.24	0.20	0.19	0.17
F3	0.30	0.36	0.36	0.35
F4	0.15	0.14	0.16	0.25

5- Forming the stochastic supermatrix:

Each of the priority weight vectors was placed in appropriate segment in supermatrix. As mentioned in section 2.3 (Equation 14), the supermatrix is a partitioned matrix including the weights derived from pairwise comparisons. Since there are six levels in this study, based on the supermatrix formation suggested by Saaty [34] and Wu et al. [33], the general form of supermatrix for this study is given as Equation 15. According to the relationships among the model components, the supermatrix was reformed as Equation 16.

$$SM = \begin{matrix} & G & SG & C & SC & F & SF \\ G & W_{11} & W_{12} & W_{13} & W_{14} & W_{15} & W_{16} \\ SG & W_{21} & W_{22} & W_{23} & W_{24} & W_{25} & W_{26} \\ C & W_{31} & W_{32} & W_{33} & W_{34} & W_{35} & W_{36} \\ SC & W_{41} & W_{42} & W_{43} & W_{44} & W_{45} & W_{46} \\ F & W_{51} & W_{52} & W_{53} & W_{54} & W_{55} & W_{56} \\ SF & W_{61} & W_{62} & W_{63} & W_{64} & W_{65} & W_{66} \end{matrix} \qquad (15)$$

$$SM = \begin{matrix} G \\ SG \\ C \\ SC \\ F \\ SF \end{matrix} \overset{\begin{matrix} G & SG & C & SC & F & SF \end{matrix}}{\begin{bmatrix} 0 & 0 & 0 & 0 & 0 & 0 \\ W_{21} & 0 & 0 & 0 & 0 & 0 \\ 0 & W_{32} & 0 & 0 & 0 & 0 \\ 0 & 0 & W_{43} & W_{44} & 0 & 0 \\ 0 & 0 & 0 & W_{54} & W_{55} & 0 \\ 0 & 0 & 0 & 0 & W_{65} & I \end{bmatrix}} \quad (16)$$

By substituting the priority weight matrices, (W_{IJ}), for the values in Tables 5 to 11, the supermatrix which was not stochastic, was derived. Therefore, entries of each column of supermatrix are divided by the summation of that column to produce the stochastic matrix.

6- Obtaining the final limit supermatrix:

The stochastic supermatrix raised to large powers till it converged and finally, limit matrix was obtained. In limit supermatrix, the global weights of CSFs with respect to goal reached almost constant values. These global weights denote the importance of CSFs regarding all the sub-goals, criteria, sub-criteria, factors and the existing interaction among them. The final global weights and ranking of CSFs are listed in Table 12.

Table 12. Final global weights of CSFs

CSF	Acronym	Global weight	Rank
Adequate and on-time resource allocation	SF22	0.129	1
Top management support	SF21	0.101	2
Project manager’s authority and competency	SF32	0.086	3
Technology applied	SF12	0.086	3
Project size	SF13	0.067	5
Housing policies, rules and regulations	SF41	0.062	6
Design quality	SF11	0.062	6
Contractor and sub-contractor selection	SF35	0.060	8
Project complexity	SF14	0.056	9
Project team’s competency	SF31	0.054	10
Economic condition	SF43	0.054	10
Project control, monitoring and supervision	SF34	0.044	12
Realistic cost and time estimation	SF33	0.041	13
Client’s participation	SF44	0.038	14
Procurement management	SF36	0.032	15
Price of construction materials	SF42	0.029	16

5. Discussion

According to the findings of this study and after conducting the three steps mentioned in previous section, the first four most important CSFs among 56 CSFs in the case studied are: 1- adequate and on-time resource allocation (global weight=0.129), 2- top management support (global weight=0.101), 3- project manager’s authority and competency (global weight=0.086) and 4- technology applied (global weight=0.086).

Resource allocation and on-time funding play the most important role in success of housing projects. Since it is an organization-related factor, managers of construction companies should be well prepared to encounter any inadequacy of resources by the means of different precautionary measures such as pre-selling residential units, taking a loan, bonds and bartering. This CSF has been noted as a crucial factor by some researchers too [1, 2, 9, 11, 15, 16, 19, 20, 23, 26, 46, 47].

Top management support was ranked as the second most important CSF. It can be perceived that its high priority weight is due to its driving effect on other factors such as project manager’s authority, design quality, project procurement and project supervision. Several other studies have also emphasized on this factor [1, 2, 7, 11, 16, 19, 20, 22, 26, 46-48]. More support is provided by the firm managers, the higher possibility of success is achievable by the project manager and executive team in dealing with project obstacles. The first two CSFs in Table 12 originates from organization and this implies that strategic decision making is more influential in overall success of project in comparison with operational decision making.

Project manager and the technology utilized in housing project are ranked third in Table 12. A competent project manager can affect several other CSFs, particularly the internal factors such as project supervision and monitoring, procurement, contractor selection and performance, and project team formation and performance. In the literature, this

CSF was confirmed as a significant factor influencing project success [1, 7, 9, 11, 15, 16, 20, 22, 26, 46-48]. Several approved technologies have been announced by Building and Housing Research Center (BHRC) as methods allowed in building projects in Iran. Based on the project specifications, consultant and project team decide on the technologies required for each discipline (that is, surveying, excavation, soil stabilization, structural and architectural activities, electrical and mechanical installations, etc.). Consequently, the selected technologies may change the project schedule, budget required and other project objectives. Technology advances should be distinguished from technology applied in the project. The former is an external factor which is out of the control of project team, but the latter is an internal factor. In the literature, this CSF has not been highlighted as a specific CSF in housing projects.

Despite the fact that this study was carried out on the particular situation of a case study, it is believed that the results including the CSFs identified, the categories derived and the framework presented are applicable in all construction projects, particularly, urban housing projects. In addition, some aspects of the results are comparable with other studies in the field of success and critical success factors explorations. Comparing the findings of this study with others, some conflicts and consistencies can be observed with regards to factors categorization. For instance, the four categories concluded by the experts in the Delphi method (Step 2 of this study) were similar to groups proposed by Belassi and Tukel [46]. In the 5-category framework presented by Chan et al. [16], the factors of procurement method and tendering method were assigned to a group named "project procedures". Based on the output of step 2 of this study, since the project logistics are in the project manager's scope of responsibilities, project procurement and tendering included group of "project team factors". Bellasi and Tukel [46] suggested sub-contractors as an external environment factor. Since contractors or sub-contractors are usually selected and supervised within the project managers' authority, it also seems to be an internal factor and can be entitled, a project team factor.

In contrast to most of the previous researches in CSFs explorations, in this study, the interaction among factors was considered quantitatively in a 6-level model. The criteria and sub-criteria used in the model lend support to the work of Ahadzie et al. [5] and this study has taken the investigation a step further by incorporating other criteria, viewpoints and the interdependencies among them. Khang and Moe [20] suggested a life-cycle-based framework in which different criteria and CSFs are considered in each phase of project life-cycle. This issue was considered in this study in another way. By the means of pairwise comparisons, the relative importance of each CSF or criterion was determined with respect to life-cycle related sub-criteria (SC21-SC24). Hence, each life-cycle phase has its impact on the global weight of each CSF after synthesizing the judgments.

6. Conclusion

This study aimed to achieve the goals below:

1- Improve the previous studies on CSFs in housing projects particularly in developing countries.

2- Provide project managers and policy-makers in housing sector with a holistic framework to quantitatively identify and evaluate CSFs affecting the housing projects in hand.

3- Overcome the problem of considering interdependencies among critical success factors and criteria in housing projects.

4- Incorporate the relative importance of different project parties' viewpoints in CSFs ranking.

5- Include the influence of different project life-cycle phases on the global weights of CSFs.

6- Consider the priority of both project management success and product success in evaluation.

7- Handle the vagueness and imprecision of subjective judgments by the means of fuzzy approach.

8- Demonstrate the implementation of framework by a pragmatic case study in a city where successful completion of housing project is crucial.

9- Develop a 6-level FANP model which includes all possible levels and sub-levels.

This study was conducted on the particular situation of the case study. Nevertheless, the findings include the CSFs identified, the framework proposed, and the categorization can be applied in other housing projects, particularly in developing countries. The framework should be customized according to the circumstances of the internal and external situations of the specific project and the methodology presented in this study can be carried out step by step as mentioned in section 2. CSFs in each project can be ranked on the basis of the judgments of decision-makers or policy-makers in that particular project by means of the method presented in this paper.

This study seems to shed light on the explorations of critical success factors in housing projects. For future directions, the following issues are suggested:

1- Ranking the treatments corresponding to identified CSFs to enhance the success of projects.

2- Scoring the projects based on the FANP model presented in this study as a project health monitoring tool.

3- Considering the interdependencies among the sub-factors in the lowest level of the model.

4- Predicting success of the housing projects by means of integrating the framework proposed in this paper with other techniques such as multi attribute regression or artificial neural networks.

7. Conflict of Interest

The authors declare that the study presented has no conflict of interest.

8. Funding

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