A FUZZY ANALYTIC NETWORK PROCESS APPROACH TO EVALUATE CONCRETE WASTE MANAGEMENT OPTIONS

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ABSTRACT

This research proposes an evaluation model using fuzzy analytic network process (FANP). Construction and Demolition (C&D) waste constitute a major portion of total solid waste production in the world, and most of it ends up in landfills. Among various types of materials, concrete waste accounts for about 50% of the total waste generation. The current practice of dumping construction materials to landfills generates a significant quantity of waste from construction sites. Due to increasing concrete waste volumes and shortage of landfills, waste management has become a significant concern. The main objective of this paper is to present a decision-making methodological framework using Fuzzy Analytical Network Process (FANP), which will prioritize recycling options. Given the complexity and difficulty of evaluating concrete waste management options toward competitive, quantitative and qualitative criteria with interactions and dependencies, the current study has employed the ANP method as one of the Multi-Criteria Decision-Making (MCDM) tools. Qualitative criteria are often accompanied by ambiguity during value judgment. To deal with this incompetency, the fuzzy approach has been used. The weight matrices of criteria and sub-criteria are constructed by using triangular fuzzy numbers. In addition, this evaluation is carried out by a group of decision-makers coming from different areas including government, NGOs (non-governmental organizations) and people with the intention of providing a more accurate and mutually acceptable solution. The results are not only a foundation to implement the sustainable concept and a recommendation for the government's related policy making, but also provide guidance for future planning and practices.

Keywords: *Fuzzy Analytic Network Process (FANP), concrete waste, waste management.*

1. Introduction and Background:

Concrete recycling is becoming an increasingly popular way to utilize aggregate left behind when structures or roadways are demolished. In the past, this rubble was disposed of in landfills, but with more attention being paid to environmental concerns, concrete recycling allows reuse of the rubble while also keeping construction costs down.

At present, almost all concrete waste in Iran is dumped into landfill areas which will be exhausted in the coming years. Reducing waste generation is thus a hard pressing issue [Eslami 2009]. The recycling system of concrete is now being significantly improved under enhanced awareness of environment and vociferous request for recycling along with the Iranian standard of recycled aggregate for widespread use.

Recycling of concrete demolition waste can provide opportunities for saving resources, energy, time, and money. Furthermore, recycling and controlled management of concrete demolition waste will save use of land and create better opportunities for handling of other kinds of waste.

Concrete demolition waste must be considered as a specific type of waste associated with the building and construction industry. It is important that the management and handling of waste is carried out by the

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industry itself. Generally, the building and construction industry is relatively conservative, and changes in normal procedures often take time and need long-term policies and strategies.

The demand for decision support tools that could help decision makers in selecting the most appropriate concrete recycling options has consequently increased. These decision support tools are designed to help decision makers to assess available opportunities and preliminarily select the preferred options. The analysis for the identification of the most suitable options in this project is based on technical, financial, environmental, operational, and social criteria. These criteria are ranked by all parties involved in the decision process to determine their relative importance for concrete recycling management. The aim of the present paper is to present the new approach for decision support tool to evaluate different concrete recycling options for the waste management system.

One of the most important barriers is the many different interests. It is usually the politicians, departments and public offices concerned with environmental issues that prepare the policies concerning waste recycling and reduction, whereas the building and construction industry is controlled by politicians, departments and offices concerned with housing, construction and public works. To coordinate the interests of all parties, it is necessary that different actors, with respect to achieving goals for recycling of concrete demolition waste should be participated. The Fuzzy Analytic Network Process (FANP) could handle this sort of decision making problem effectively. This study proposes the Fuzzy Analytic Network Process (FANP) model to handle the multi-criteria concrete waste management.

The proposed decision making model is based on a type of Multi-Criteria Decision Making (MCDM) method, Analytic Network Process (ANP). ANP is a variation of the analytical hierarchy process (AHP), which developed in the early 1970s, as a general theory of measurement that derives ratio scales from paired comparisons in multilevel hierarchic structures. A fundamental assumption of the AHP is that all indicators and criteria within the structure are independent of each other. The AHP does cater for the identification of individual criteria, but it does not allow for inter-dependencies among these criteria to be modeled (McCowan and Mohamed 2004). The variation of AHP, ANP, was then developed in order to cater for the dependence of individual elements, both within and in-between criteria (Saaty, 2001), thus making it an ideal technique for modeling interaction and inter-dependency among indicators. The ANP employs the same fundamental scale of comparison as the AHP in order to generate relative priorities of criteria with respect to the goal, i.e. selecting the project or design that mostly contributes to the attainment of standard deviation over its life-cycle, and the preference of different alternatives, with respect to criteria. However, it adds a third dimension to the decision problem by allowing for any element such as goal, criteria, alternative to influence any other elements within the network (Saaty, 2001).

Another methodology, fuzzy numbers, is also employed in assessing the sustainable performance. In the context of additive weighting which, in its various forms, is perhaps the most commonly used method for evaluating alternatives characterized in terms of multiple criteria (Smith, 1995). Fuzzy additive weighting has been successfully used in the evaluation of projects in terms of multiple criteria in which the fuzzy outcomes of each project with respect to each criterion are multiplied by respective fuzzy importance weights and summed to yield an aggregate score (Goodwin and Wright, 1991). Also it is a useful method for combining linguistic expressions of performance (e.g. 'moderate' wildlife impact) or in many situations, linguistic expressions of performance and quantitative data (e.g. total volume of water discharged into waterways).

In the rest of this paper, the FANP model is presented, and the network components and interrelationships among them are demonstrated in detail in Section 2. Section 3 demonstrates the methodology of ANP and construction of pair-wise matrices. In section 4, analytic model framework based on interdependency and feedback relationships is proposed for this study, and also a brief calculation process is described. Section 5 includes result tables and discussion. Finally, Section 6 summarizes conclusions.

2. The proposed Fuzzy ANP Model

Due to various quantitative and qualitative criteria (such as costs and social aspects respectively), direct effects of decision on the local government, NGOs and the people, determining the best recycling option became a challenge. Since it was necessary to provide a reliable, easy-to-use method for background of future decision making problems, ANP-based model was proposed. The proposed model selects the most convenient concrete recycling regarding the effects of actors and main-criteria on the alternative options (as explained below) and relations among the main-criteria clusters and sub-criteria. The selection process of the selected FANP for concrete recycling management option selection is shown in Figure 1. The process of applying the proposed FANP model includes the following main steps. The first step is to define the main goal and options for selection of the best technique for concrete recycling management that meets the requirements of the decision maker according to local conditions of the case study, Iran.

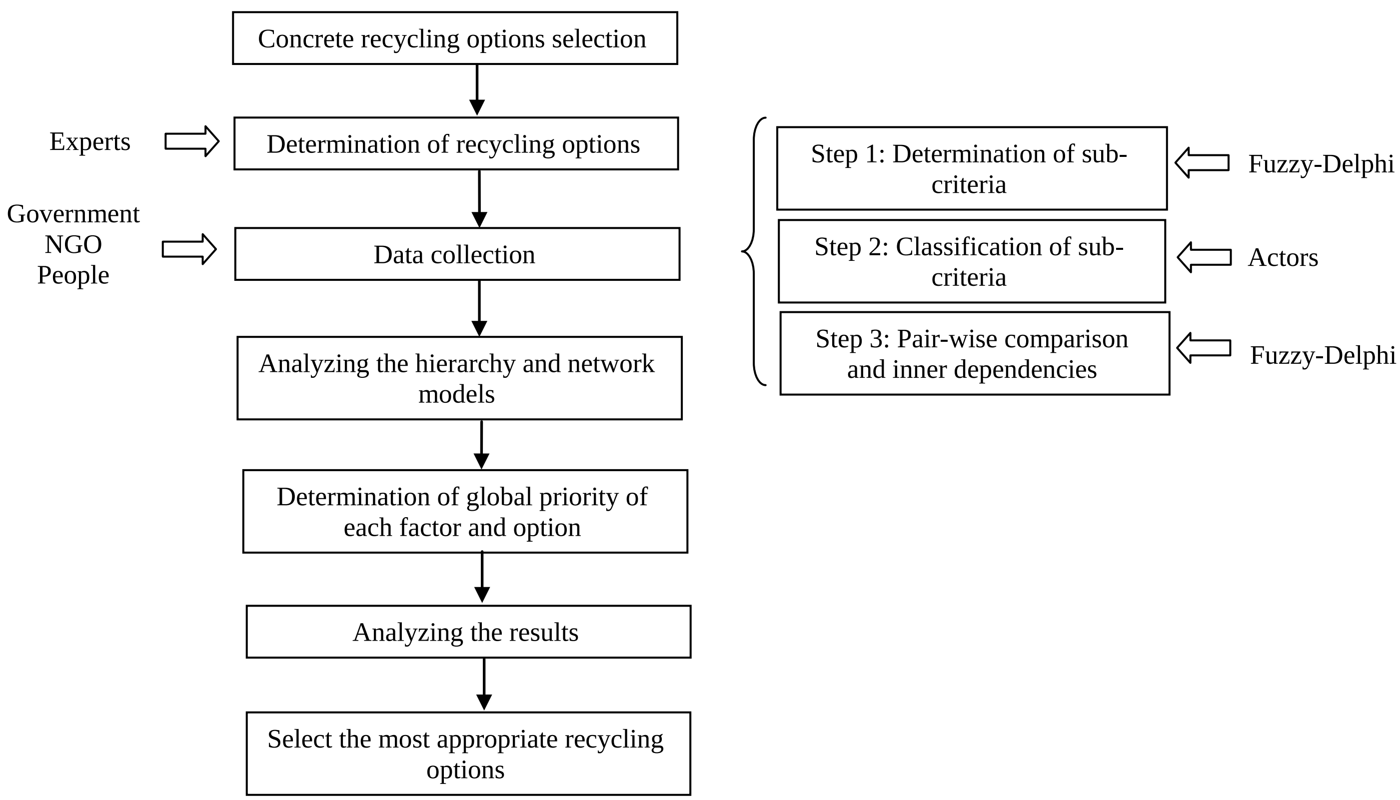


Figure 1. process for concrete recycling management option selection.

For this reason, first, a group of experts, who were well-known in the field of concrete recycling methods were interviewed and their proposals collected with regard to possible concrete recycling options. The alternatives for recycling management were selected according to current demand and expected future prospective. Then, the best proposed methods were chosen by experts for final decision making. **Aggregate base course (road base)**, or the untreated aggregates used as foundation for roadway pavement, is the underlying layer (under pavement surfacing) which forms a structural foundation for paving. **Recycled aggregate for concrete** must meet a quality level to be used in construction sites and the concrete producer must make a quality end product. Similarly, recycled concrete can be used as **recycled aggregate in new asphalt pavement** as a substitute for virgin aggregate. The additional asphalt cement required must be offset by the cost savings of the virgin aggregate. Recycled concrete can be used as **backfill material** in various landscape settings. Sized concrete rubble can serve as landscape feature; an attractive support that offer different architectural texture and color while contributing to Built Green architecture. To date, recycled concrete aggregate has been used as boulder/stacked rock walls, underpass abutment structures, erosion structures, water features, retaining walls, and more.

Afterward, the criteria included into the FANP model were determined based on the evaluation obtained from a 31-member group of experts that was founded by members comprising distinguished construction managers and engineers involved in designing and implementation, by means of fuzzy-Delphi method, along with using some technical references [R.Kitagaki ,2008], [Masaki , 2005] , [Tamura,2002]. Using the results of the first session, main-criteria and sub-criteria were classified and final criteria were indicated by the first experts for the second session. Indicated criteria were introduced to the contributors in the second session to conclude their evaluations. Then, final set of criteria, and their connections and interdependency between the elements were arranged by experts for using in FANP model (W1-W7). Eventually, the FANP model was developed in five parts, as shown in Figure 2.

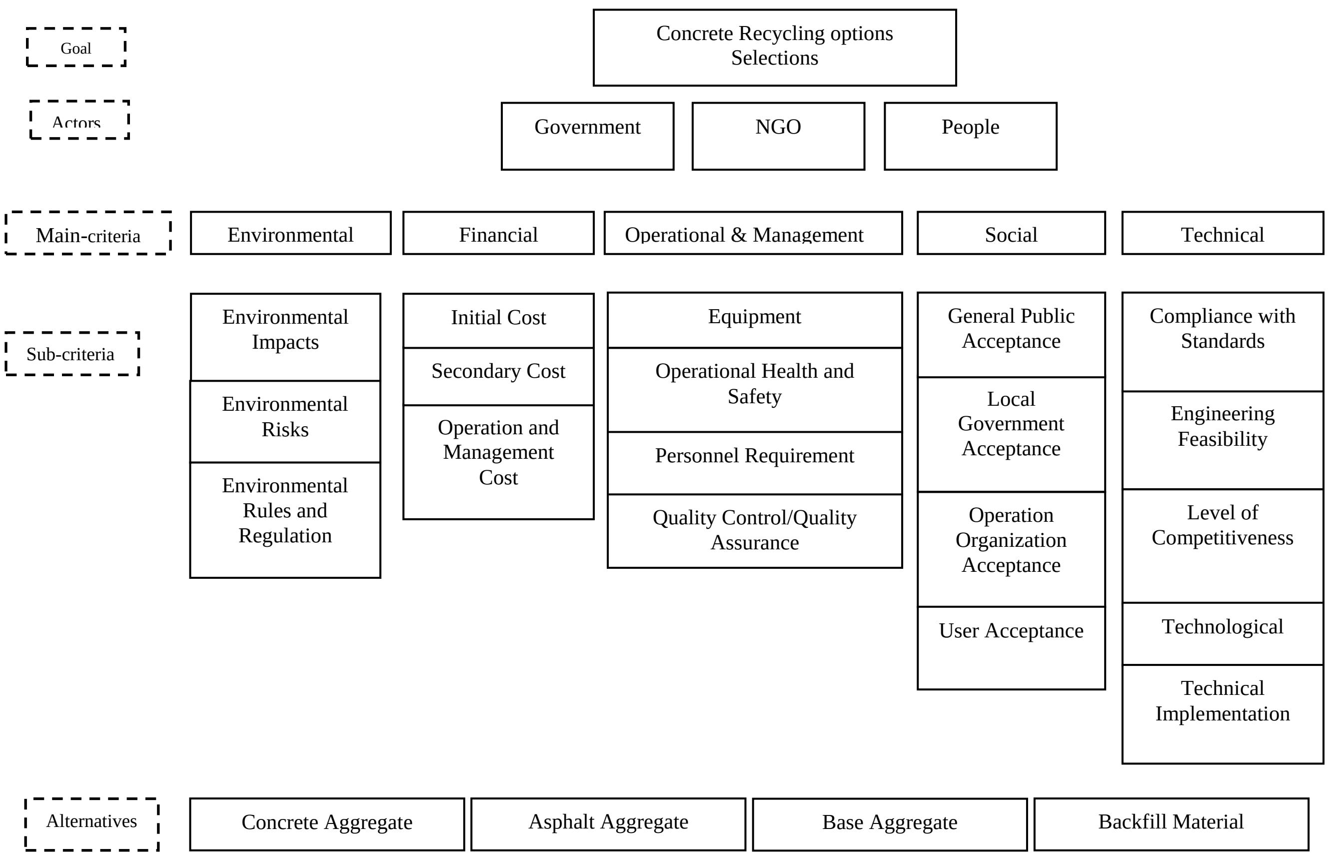


Figure 2. Analytic model.

In the rest of model, the network of hierarchy among the actors, the sub-criteria of five main- criteria, and the alternatives, and also interdependency of each control criteria are shown. Furthermore, details of interconnection of actors and main-criteria are demonstrated in Figures 3-4. Besides, interdependency network for each sub-criterion are indicated in Figures 5-8. In the network, two types of connection including one-way dependence and two-way dependence are shown with directed dashed arrow and bi-direct solid arrows [E. Eslami][T. Nikoo, N. Ghaffari, E. Eslami].

Triangular fuzzy numbers are used to investigate the ambiguities involved in the linguistic-data assessment process. Because there are many main-criteria and sub-criteria for the issue involving a suitable recycling option selection and because most of these are qualitative, it is difficult to assess these criteria quantitatively. Fuzzy numbers reflect the relative strength of each pair of network elements [R. Tuzkaya, S. Önüt]. After comparing the performance score, the fuzzy pair-wise comparison matrices with fuzzy-ratio judgments are constructed according to the network given in Figure 2. Triangular fuzzy weights are derived from fuzzy pair-wise comparison matrices. While assessing the relative importance of the criteria, criteria feedback and the alternatives according to the individual criteria are converted to the triangular fuzzy-importance weights from each matrix. The logarithmic least-squares method is used to calculate the triangular fuzzy weights in this study [S.J. Chen, C.L. Hwang].

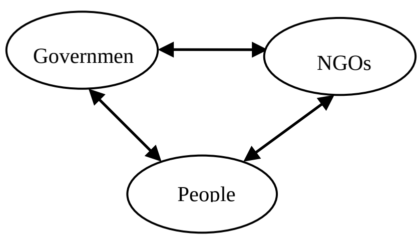


Figure 3. Actors interdependency network.

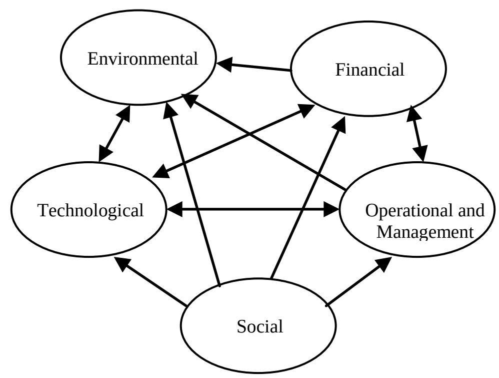


Figure 4. Main-criteria interdependency network.

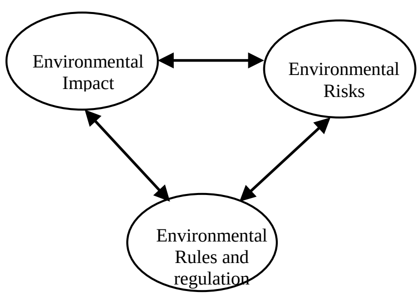


Figure 5. "Environmental" interdependency network.

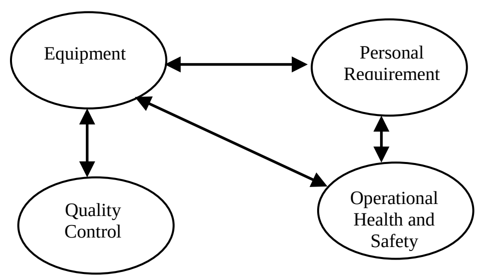
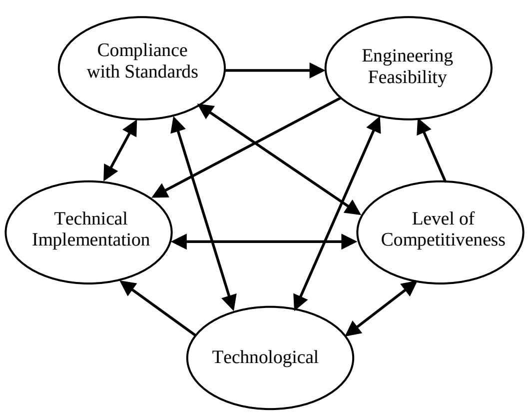


Figure 6. "Operational & Management" interdependency network.



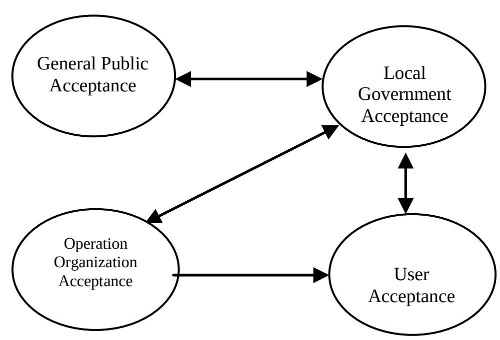


Figure 7. “Technical” interdependency network. Figure 8. “Social” interdependency network.

After the comparisons were carried out by the decision-making group, the consistency ratios of all the pair-wise comparison matrices were calculated. If the inconsistency ratios of all the pair-wise comparison matrices were less than 0.1, all comparison matrices were deemed to be consistent and the judgments were considered reliable [T.L. Saaty]. In this study, the inconsistency ratios for all the comparison matrices were calculated for the mean values of the fuzzy numbers. Because the lower and upper values provide flexibility for human judgments, they are not expected to have rigid consistency. The inconsistency ratios of the mean values of the comparison matrices were less than 0.1 in the herein-presented experiments, and all the judgments were hence considered reliable.

After calculating the triangular fuzzy weights, the fuzzy evaluations of the alternative modes are aggregated using the approximate formula as mentioned in Section 3[J. Ramik][U.R. Tuzkaya, S. Önüt]. Essentially, this step is the synthesis of the limiting priorities and it limits previously weighted matrices by aggregating fuzzy evaluations of the individual alternative modes until they converge into stable matrices. The results are then compared with each other, and the concrete recycling option with the highest priority is chosen.

3. Fuzzy-ANP

In this study, the fuzzy-ANP (FANP) method has been used to select the best method in concrete recycling. Earlier selection models generally used crisp data to evaluate the alternatives. However, a large amount of uncertainty is associated with various parameters in the selection models. The values of qualitative parameters such as social are transformed into triangular fuzzy numbers and are used to calculate fuzzy values. Furthermore, a scale of 1-9 is used to state the preferences of the decision maker. When comparing criterion *i* with criterion *j*, 1, 3, 5, 7, and 9 indicate equal importance among the compared criteria; moderate importance of *i* over *j*; strong importance of i over j; very strong importance of *i* over *j*; and extreme importance of *i* over *j*, respectively, where $i = 1, 2, \dots, n$, and $j = 1, 2, \dots, m$ [R.P. Mohanty][U.R. Tuzkaya, S. Önüt].

To evaluate the decision-maker preferences, pair-wise comparison matrices are structured using triangular fuzzy numbers (l,m,u). The $m \times n$ triangular fuzzy matrix can be given as follows:

$$\widetilde{A} = \begin{pmatrix} (a_{11}^l, a_{11}^m, a_{11}^u) & (a_{12}^l, a_{12}^m, a_{12}^u) & \cdots & (a_{1n}^l, a_{1n}^m, a_{1n}^u) \\ (a_{21}^l, a_{21}^m, a_{21}^u) & (a_{22}^l, a_{22}^m, a_{22}^u) & \cdots & (a_{2n}^l, a_{2n}^m, a_{2n}^u) \\ \vdots & \vdots & \vdots & \vdots \\ (a_{m1}^l, a_{m1}^m, a_{m1}^u) & (a_{m2}^l, a_{m2}^m, a_{m2}^u) & \cdots & (a_{mn}^l, a_{mn}^m, a_{mn}^u) \end{pmatrix} \quad (1)$$

The element a_{mn} represents the comparison of the component m (row element) with component n (column element). If $\tilde{A}$ is a pair-wise comparison matrix (as shown in Eq. 2), it is assumed that it is reciprocal, and the reciprocal value, i.e. 1/ a_{mn},is assigned to the element a_{mn},

$$\widetilde{A} \approx \begin{pmatrix} (1,1,1) & (a_{11}^l, a_{11}^m, a_{11}^u) & \cdots & (a_{1n}^l, a_{1n}^m, a_{1n}^u) \\ \left(\frac{1}{a_{11}^u}, \frac{1}{a_{11}^m}, \frac{1}{a_{11}^l}\right) & (1,1,1) & \cdots & (a_{2n}^l, a_{2n}^m, a_{2n}^u) \\ \vdots & \vdots & \vdots & \vdots \\ \left(\frac{1}{a_{1n}^u}, \frac{1}{a_{1n}^m}, \frac{1}{a_{1n}^l}\right) & \left(\frac{1}{a_{2n}^u}, \frac{1}{a_{2n}^m}, \frac{1}{a_{2n}^l}\right) & \cdots & (1,1,1) \end{pmatrix}$$

(2)

$\tilde{A}$ is also a triangular, fuzzy, pair-wise comparison matrix. There are several methods for getting estimates for the fuzzy priorities, w_i, where $w_i = (w_i^l, w_i^m, w_i^u)$ and i = 1, 2, …, n, from the judgment matrix, $\tilde{A}$, which approximates the fuzzy ratios a_{ij}, so that $a_{ij} \approx w_i / w_j$. One of these methods, the logarithmic least-squares method [S.J. Chen, C.L. Hwang][J. Ramik] is reasonable and effective and is used in this study. Hence, the triangular fuzzy weights representing the relative importance of the criteria, the feedback of the criteria, and the alternatives according to the individual criteria can be calculated. The logarithmic least-squares method for calculating triangular fuzzy weights can be given as follows:

$$w_k = (w_k^l, w_k^m, w_k^u), \qquad k = 1, 2, \ldots, n, \qquad (3)$$

where

$$w_k^s = \frac{\left(\prod_{j=1}^{n} a_{kj}^s\right)^{1/n}}{\sum_{i=1}^{n}\left(\prod_{j=1}^{n} a_{ij}^m\right)^{1/n}}, \qquad s ™ \{l, m, u\} \qquad (4)$$

After identifying the alternatives described as triangular fuzzy numbers, they must be ordered from the best to the worst using one of the ordering methods. The ordering methods transform the fuzzy numbers to crisp numbers by defuzzification. There are different defuzzification methods, such as center of gravity, maximum-membership principle, center of area, weighted average, smallest of maximum and largest of maximum. The center of gravity, center of area, and maximum-membership principle methods have been used herein because they are the most commonly used defuzzification techniques, and their usage is easy. The results are then compared with each other for differences and similarities [U.R. Tuzkaya, S. Önüt].

4. Proposed FANP model framework:

The scenarios of FANP model proposed in this study are arranged with five levels, as shown in Figure 9. The goal (recycling option selection) is represented in the first level, the actors, main-criteria, and sub-criteria are placed in the second, third and forth levels respectively, and the last level is comprised the alternatives.

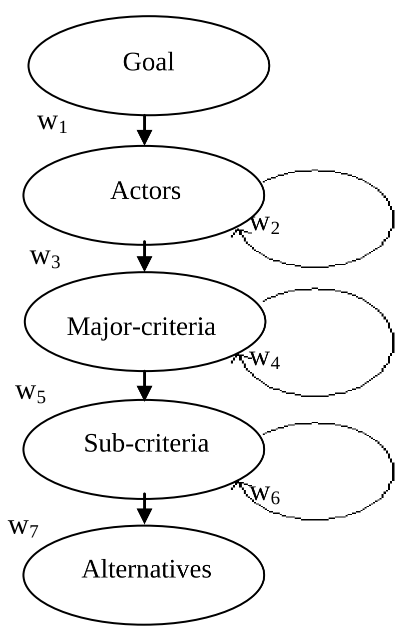


Figure 9. The scenario of Proposed FANP model

After calculating the triangular fuzzy weights, the fuzzy evaluations of the alternative modes are aggregated using the method as mentioned below. Essentially, this stage is the synthesis of the limiting priorities and it limits previously weighted matrices by aggregating fuzzy evaluations of the individual alternative modes until they converge into stable matrices. The results are then compared with each other, and the concrete recycling option with the highest priority is chosen. For proposed network model, the sub-matrixes are constructed as follow:

$$W = \begin{array}{r} \text{goal} \\ \text{actors} \\ \text{main-criteria} \\ \text{sub-criteria} \\ \text{alternatives} \end{array} \begin{bmatrix} 0 & 0 & 0 & 0 & 0 \\ w_1 & w_2 & 0 & 0 & 0 \\ 0 & w_3 & w_4 & w_5 & 0 \\ 0 & 0 & 0 & w_6 & 0 \\ 0 & 0 & 0 & w_7 & I \end{bmatrix} \quad (5)$$

where w_i for i=1, 2, …, 7 are calculated through the following steps:

step1. Determining the importance degree of actors with fuzzy numbers by assuming that there is no dependence among the actors. Calculating of w_1.

step2. Determining the inner dependency matrix of the actors with respect to each actor by fuzzy numbers by utilizing the schematic representation of inner dependency among actors. Calculation of w_2.

step3. Determining the importance of major criteria with respect to each actor with fuzzy numbers by assuming that there is no dependency among the main-criteria. Calculation w_3.

step4. Determining the inner dependency matrix of the main-criteria with respect to each main-criteria by fuzzy numbers, utilizing the schematic representation of inner dependency among major criteria. Calculation of w_4.

step5. Determining the importance of sub criteria with respect to each main-criteria with fuzzy numbers by assuming that there is no dependency among the sub criteria. Calculation w_5.

step6. Determining the inner dependency matrix of sub-criteria with respect to each sub-criteria by fuzzy numbers by utilizing the schematic representation of inner dependency among sub-criteria. Calculation of w_6.

step7. Determining the importance of alternatives with respect to each major sub- criteria with fuzzy numbers. Calculation w_7.

After calculation the w_i, the weights of alternative can be calculated through the following steps:

step8. Determining the interdependent priorities of the actors. Calculation $w_{actors} = w_2 \times w_1$.

step9. Determining the interdependent priorities of main-criteria. Calculation $w_{main\text{-}criteria} = w_4 \times w_3$.

step10. Determining the interdependent priorities of sub-criteria. Calculation $w_{sub\text{-}criteria} = w_6 \times w_5$.

step11. Determining the overall priorities of the alternatives. Calculation $w_{alternatives} = w_{main\text{-}criteria} \times w_{sub\text{-}criteria} \times w_{actors}$.

5. Results and discussion:

Du to limited space, only one pair-wise matrix in each level has been reported in this paper. The Table 1 shows the pair-wise comparison matrix for actors together with local weights. Tables 2 and 3 represent the pair-wise comparison matrices for the main-criteria with respect to "Government" and for

"Environmental" sub-criteria respectively. Tables 4 and 5 display Pair-wise comparison matrix for "Environmental" sub-criteria and inner dependence pair-wise matrices for Main-criterion "Social" a respectively. Inconsistency ratios of all our comparison matrices turned out to be less than 0.10, therefore, accepted as consistent. Table 6 represents the fuzzy weights of the actors' clusters according to the goal. Table 7 represents the fuzzy weights of the main-criteria according to the actors. Table 8 represents the fuzzy weights of the sub-criteria according to the main-criteria, and their local and global ranking. Table 9 represents the fuzzy weights of the alternatives and their ranking.

Table1. Pair-wise comparison matrix for Actors with respect to "Goal"

Goal	GOV	NGO	POP	Weights
Government(GOV)	(1,1,1)	(2,3,4)	(3,5,7)	(0.308,0.451,0.611)
NGO	(1/4,1/3,1/2)	(1,1,1)	(1,2,3)	(0.158,0.287,0.515)
People(POP)	(1/7,1/5,1/3)	(1/3,1/2,1)	(1,1,1)	(0l.139,0.261,0.507)

Table 2. Pair-wise comparison matrix for main-criteria with respect to "Government"

Government	ENV	FIN	OM	SOC	TECH	Weights
Environmental(Env)	(1,1,1)	(1/4,1/3,1/2)	(1/3.5,1/3,1/2.5)	(1/3,1,3)	(1/2,2,4)	(0.072,0.251,0.603)
Financial (Fin)	(2,3,4)	(1,1,1)	(1/2,1,3/2)	(2,3,4)	(3,5,7)	(0.071,0.221,0.518)
Operation and Management (OM)	(2.5,3,3.5)	(2/3,1,2)	(1,1,1)	(1,3,5)	(1,2,3)	(0.061,0.193,0.474)
Social (SOC)	(1/3,1,3)	(1/4,1/3,1/2)	(1/5,1/3,1)	(1,1,1)	(4,5,6)	(0.056,0.189,0.427)
Technical (Tech)	(1/4,1/2,2)	(1/7,1/5,1/3)	(1/3,1/2,1)	(1/6,1/5,1/4)	(1,1,1)	(0.044,0.144,0.375)

Table 3. Pair-wise comparison matrix for "Environmental" sub-criteria

	EI	ER	ERR	Weights
Environmental Impacts(EI)	(1,1,1)	(1/4.5,1/3,1/1.5)	(1/6.5,1/5,1/3.5)	(0.090,0.132,0.196)
Environmental Risks(ER)	(1.5,3,4.5)	(1,1,1)	(1/4.5,1/3,1/1.5)	(0.227,0.368,0.531)
Environmental Rules and Regulation(ERR)	(3.5,5,6.5)	(1.5,3,4.5)	(1,1,1)	(0.356,0.5,0.658)

Table 4. Pair-wise comparison matrix for inner-dependency in Main-criterion "Social"

Social	ENV	FIN	SOC	TECH	Weights
Environmental(Env)	(1,1,1)	(1.5,2,2.5)	(1.5,2,2.5)	(3,4,5)	(0.356,0.444,0.525)
Financial (Fin)	(1/2.5,1/2,1/1.5)	(1,1,1)	(0.5,1,1.5)	(1,2,3)	(0.148,0.222,0.292)
Operation and Management (OM)	(1/2.5,1/2,1/1.5)	(1/1.5,1,1/0.5)	(1,1,1)	(1,2,3)	(0.16,0.222,0.314)
Technical (Tech)	(1/5,1/4,1/3)	(1/3,1/2,1)	(1/3,1/2,1)	(1,1,1)	(0.086,0.111,0.169)

Table 5. Pair-wise comparison matrix for Alternatives with respect to "Environmental" sub-criterion "Environmental Impacts"

Environmental Impacts	AA	BA	BM	CA	Weights
Asphalt Aggregate(AA)	(1,1,1)	(2,3,4)	(2,3,4)	(1/2,1,3/2)	(0.269,0.391,0.500)
Base Aggregate(BA)	(1/4,1/3,1/2)	(1,1,1)	(1/2,1,2)	(1/3,1/2,1)	(0.102,0.144,0.226)
Backfill Material(BM)	(1/4,1/3,1/2)	(1/2,1,2)	(1,1,1)	(1/2.5,1/2,1/1.5)	(0.107,0.144,0.204)
Concrete Aggregate(CA)	(1/5,1,2)	(1,2,3)	(1.5,2,2.5)	(1,1,1)	(0.226,0.319,0.445)

Table 6. Fuzzy weights of the actors clusters according to the goal

	Lower	mean	Upper
Government	0.3086	0.4516	0.6119
NGOs	0.1585	0.2871	0.5157
People	0.1391	0.2614	0.5077

Table 7. Fuzzy weights of the main-criteria according to the actors

	lower	mean	upper
Environmental	0.0720	0.2512	0.6031
Financial	0.0714	0.2216	0.5180
Operational & management	0.0610	0.1934	0.4737
Social	0.0562	0.1890	0.4278
Technical	0.0441	0.1447	0.3750

Table 8. Fuzzy weights of the sub-criteria according to the main-criteria, and their local and global ranking

		lower	mean	Upper	Local Rank	Global Rank
Environmental	Environmental Impacts	0.0065	0.0332	0.1183	3	15
	Environmental Risks	0.0122	0.0925	0.4141	1	3
	Environmental Rules and Regulation	0.0256	0.1256	0.3971	2	1
Financial	Initial Cost	0.0103	0.0362	0.0990	3	14
	Operation and Management Cost	0.0179	0.0658	0.1824	2	6
	Secondary Cost	0.0330	0.1196	0.3170	1	2
Operational & management	Equipment	0.0115	0.0558	0.2106	2	8
	Operational Health and Safety	0.0070	0.0398	0.1855	3	12
	Personnel Requirement	0.0076	0.0483	0.2136	1	11
	Quality Control/Quality Assurance	0.0105	0.0495	0.1724	4	10
Social	General Public Acceptance	0.0032	0.0163	0.0603	4	18
	Local Government Acceptance	0.0155	0.0763	0.2411	1	4
	Operation Organization Acceptance	0.0130	0.0666	0.2176	2	5
	User Acceptance	0.0045	0.0298	0.1044	3	16
Technical	Compliance with Standards	0.0043	0.0208	0.0433	4	17
	Engineering Feasibility	0.0103	0.0631	0.2810	1	7
	Level of Competitiveness	0.0065	0.0379	0.1603	3	13
	Technological	0.0016	0.0531	0.0858	2	9
	Technical Implementation	0.0024	0.0104	0.0433	5	19

Table 9. Fuzzy weights of the alternatives and their ranking

	Lower	mean	Upper	Rank
Asphalt Aggregate	0.02385	0.165372	0.808064	4
Backfill Material	0.031109	0.232917	1.104089	3
Base Aggregate	0.042106	0.293448	1.357503	2
Concrete Aggregate	0.053093	0.348957	1.488958	1

The results of the present research could be listed as below:

- The multi-criteria decision analysis can provide an appropriate framework for solution of the complicated issues of waste management planning when it is integrated to fuzzy theory.

- The Fuzzy Analytic Network Process is very flexible and simple which many criteria could be analyzed to solve a waste management problem. However it needs to be mentioning that by increasing the number of criteria the process of weighting may encounter with some difficulties, so the given criteria should consider the limitation of the model.

- In the process of weighting the views of all interest groups could be asked with respect to their level of involvement. So this model can increase the professional participation in the construction waste management decision making. The future research can show the dimension of such opportunists.

- There are many criteria in concrete recycling option selection analysis which ignoring some of them can threat the sustainability such as "environmental aspect". Also some of the criteria such as "technological aspect" and "technical implementation" can be unseen in future decision making process.

- The recommended options for Iran construction projects reveals that the most appropriate option for future recycling management is the production of recycled aggregate for concrete constructions. This case should be considered by the planners and especially the consulting engineers who design the cities' master plans.

The results show that environmental aspects were associated with larger total score. When technical aspects are considered as a criterion, priority is shifted towards operational and management problems according to the documented experiments of selected recycling options. It should be noted, however, that the relative weight for financial feasibility is relatively high, while social aspects of recycling option selection is lower than environmental, financial, and operational and management aspects; therefore their consideration cannot significantly affect the selected set of alternatives.

Although concrete production hit a peak in 1990s and then leveled off, concrete waste continues to increase. An enormous amount of demolished concrete will be generated in the future from concrete structures mass-constructed during the economic growth, which are doomed to demolish due to durability problems. Moreover, road construction, which is currently their largest recipient, is decreasing and the method of repair is expected to shift from replacing to milling and applying an overlay. These trends will lead to an imbalance between the supply of demolished concrete and the demand of road bottoming. Also, the volumetric reduction of future infrastructures based on population estimation and the extension of the service life of the existing stock by measured succession, utilization, and conversion will keep on reducing the amount of new construction of structures and concrete production. Accordingly, this will culminate the need for recycling aggregate into aggregate for concrete, and it is no exaggeration to say that recycled aggregate can account for the greatest part of future aggregate for concrete. It is therefore vital to convert recycling them from quantity-oriented to quality-oriented recycling. It is necessary to find optimum recycling method with due consideration to the material balance, while promoting the production and supply of higher-quality recycle aggregate [timosawa 2005]..

6. Conclusion:

The demand for decision support tools that could help decision makers in selecting the most appropriate concrete recycling options has consequently increased. Therefore, this study attempts to propose the Fuzzy Analytic Network Process (FANP) model to handle the multi criteria concrete waste management.

Combining many detailed criteria in an evaluation study and synthesizing them to obtain a decision-making methodological framework for evaluating concrete waste management options is the main contribution of this study. These decision support tools are designed to help decision makers to assess available opportunities and preliminarily select the preferred options. The proposed decision making model is based on a type of Multi-Criteria Decision Making (MCDM) method, Analytic Network Process (ANP).The analysis for the identification of the most suitable options in this project is based on technical, financial, environmental, operational, and social criteria. The alternatives for recycling management have selected according to current demand and expected future prospective

Moreover, a decision making group from different management levels and from different areas including government, NGOs (non-governmental organizations) and people with the intention of providing a more accurate and mutually acceptable solution have been participated in the study.

The criteria are linked with each other and affect the selection of the best waste management alternatives. Instead of giving precise numbers as the comparison values, studying the situation using fuzzy numbers could provide accuracy in many real-world waste management decisions. The FANP model encompasses and solves the ambiguity and imprecision of the pair-wise comparison process substantially. Using this fuzzified structure also gives flexibility to the experts and represents probable changes in the nature of the comparisons. As a result, using FANP for the concrete waste management problem is another major contribution of this work. In future researches, the weights obtained in this study can be used in different waste management models. [Umut R, 2008]

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