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Research Article

Appraisal of Industrial Plans with Expected Monetary Value Approach Using FAHP in the Ceramic and Tile Industry

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Abstract

One of the essential issues existing in the industry section and long term investments is the procedure of evaluation and selection of industrial projects. Since selection of the optimum and appropriate project, is followed by economic efficiency and conversely the failure of a project causes time and cost wastage and will be followed by huge adverse consequences. Hence, decision making in this field is complicated and various tangible, intangible, qualitative and quantitative factors are involved in it and for this reason identification, study and analysis of them is necessary. In order to evaluate the projects in this article, initially technical and financial studies are considered and analyzed and its results are posed. Technical studies include estimation of investment constant costs, estimation of the plan income, costs before usage, capital turnover and production charges and financial studies include estimation of net current value indices, internal output rate, profitability index, capital return period, break – even analysis and other factors which contribute to economic evaluation of the project. The case study in this research is construction of a tile factory which five plans which in fact involve the research options are considered with indices and various technical and economic factors which through Fuzzy Hierarchical Analysis Technique which is Fuzzy Multivariate Decision Making Methods, have been compared so that the best option is selected and the projects are ranked. The considered indices involve four financial indices including net current value, capital return period, investment output, sales output and the ratio of numerical break – even. The research result indicates that the projects ranking results is very close to the ranking on the basis of internal output rate.

Keywords: Plans Evaluation; FMCDM; FAHP; Expected Monetary Value; Ceramic and Tile Industry

1. Introduction

The increase in quality and competition has motivated companies to offer products and services based on customer expectations.(Cardiel-Ortega & Baeza-Serrato, 2024) Execution of industrial projects beside its necessity to long time consumption and high costs, it is followed by many environmental, economic, social and political effects. Therefore, the failure of a project can be followed by financial and adverse implications in different dimensions which this affair reveals the importance and necessity of evaluation of industrial projects before execution. Success and failure of each project depends on conscious and logical decision making of the project custodian institutions and individuals. The starting point in any conscious effort for logical decision making is the process of problem finding, problem recognition through information collection and in selection of appropriate solution, awareness of techniques and methods is very important. Regarding the importance of project economical evaluation, project economic analysis is deemed as one of the crucial techniques of comparison and decision making and selection among a set of solutions based on the economic favorable conditions. Before execution, any project must be evaluated in financial and technical terms and its feasibility studied. The feasibility study process is conducted in the direction of ensuring and evaluation of the capability to meet the customer demands and by the projects evaluation amongst several projects with different conditions, select the best option. On the other hand, examining projects according to criteria requires data and expert opinions.. Due to the lack of sufficient data, ambiguity and the high impact of expert judgment on the project evaluation, fuzzy set theory has been used in this research. (Mahmoudian et al, 2023). So appropriate methods should be adopted for evaluating projects, Although there are several models, methods, and techniques to evaluate projects' success, the lack of structured information about them (e.g., characteristics, context, or results achieved in practice) may hinder their use by practitioners.(Varajão & et al., 2022).

2. Industrial Projects Evaluation

Evaluation of the plans especially industrial projects is one of the most important and necessary acts which must be performed before execution of a plan. Execution of a plan is followed by costs and a set of acts and efforts which in case of its failure, it will have consequence. Success and failure of each project depends on conscious and logical decision making of the project custodian

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institutions and individuals. The starting point in any conscious effort for logical decision making is the process of problem finding, and selection of appropriate solution to the problem. In the process of problem finding, problem recognition through information collection and in selection of appropriate solution, awareness of techniques and methods is very important. Regarding the importance of project economical evaluation, project economic analysis is deemed as one of the crucial techniques of comparison and decision making and selection among a set of solutions based on the economic favorable conditions. Evaluation of an industrial project in the mold of feasibility studies, regards different suggestions and considers that whether execution of the project is possible and appropriate or not and its result is a decision yes, for Starting the implementation of project and no, for Non-implementation of project. In fact project evaluation, is a controlled process for simultaneous specification of problems and advantages of execution of a project or entry in to an investment situation and is performed along with complete description of conditions and estimation of its revenues and costs (Analysis of cost - profit) (Salehi Zadeh, 2008).

3. Technical Consideration of the Plan

In this section subjects such as establishment of the place of the plan, number of the required buildings and installations, selection of machineries and manufacturing equipment, the procedure of usage of fuel energy, electricity, steam, water, manpower supply, the required raw material extent and other capital costs of the plan will be considered technically (Behrens, 2008).

4. Economic and Financial Consideration of the Plan

In this section, the financial supply resources are considered and all of the cases and financial indices of the plan are estimated. Even anticipation of the balance sheet and Profit and loss statement are performed at this stage. The projects evaluation usual procedures and indices which are considered in the financial section include:

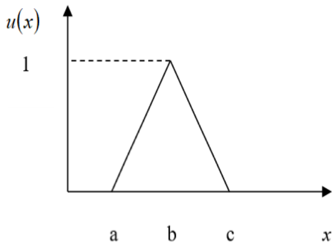
1. Pay Back Period (PBP)
2. Payback Period Reverse (PPR)
3. Accounting Revenue Rate (ARR)
4. Damping Accounting Revenue Rate (DARR)
5. Damping Pay Back Period (DPBP)
6. Current Net Value (NPV)
7. Profitability Index (PI)
8. Mean Current Value or Annual Profitability Index (API)
9. Damping Internal Revenue Rate - Internal Revenue Rate (DIRR-IRR)
10. Cash Profit, Cash Added Value and Economic Added Value (Behrens, 2008)

5. Fuzzy Theory

Fuzzy theory has been widely adopted in various modern engineering fields to solve many complex problems, where many influencing factors need to be considered with large uncertainties, and theoretical or numerical solutions are not available or at least difficult to find.(Cho & et all, 2017)

For the first time Professor Lotfi zadeh introduced the Theory of Fuzzy Sets and Fuzzy logic in a Dissertation named "Fuzzy Sets" Information and Control" in the year 1965 (Aruchsamy & et all, 2024), L.A. Zadeh a professor at the University of California, Berkeley, in the U.S.A. fuzzy logic or fuzzy theory could be used to deal with human psychological and emotional feelings, which are fuzzy and uncertain, and to quantify them into information that can be processed by computers. Unlike traditional set theory, which only uses binary logic (0 and 1), namely, the concept of "either yes or no", to describe things, the fuzzy theory is based on fuzzy sets; it determines "whether it is in an intermediate state", representing a fuzzy set by the concept of membership value, and it allows the states of "not completely belonging" and "not completely unbelonging" in the field, which is the concept of relatively belonging. Building upon the aforementioned theory, this study will not only adopt the descriptive statistical analysis but also utilize the fuzzy semantic method rooted in defuzzification to enable the statistical data for more detailed analysis and interpretation. (Liu & Lee, 2024) the fuzzy theory, linguistic variables are quantified by the fuzzy numbers, allowing the choice of linguistic wording for multiple affiliations of "both this and that". This viewpoint of linguistic quantification is called fuzzy linguistic variables.. the fuzzy set theory and fuzzy system theory as a return from holism back to reductionism in order to incorporate human cognitive, emotional and behavioral aspects in system controlled dynamics and output maps, in fuzzy membership functions of fuzzy state, control and output subsets.(Burstein & et al., 2014)

When fuzzy theory is applied to the measurement of linguistic meaning, the frequently used fuzzy numbers include Triangular fuzzy number, Trapezoidal fuzzy number, and Normal fuzzy number, and Triangular fuzzy number is the most common. A triangular fuzzy number assigns its membership function of likelihoods to form a triangle. Assuming the membership function μ(x) = (a, b, c), when a, b, and c are real numbers, and a ≤ b ≤ c, the membership function can be expressed as shown in Figure 1. (Liu & Lee, 2024)



$$u(x)=\begin{cases} 0 & , \; x\in[0,a] \\ x-a & , \; x\in(a,b) \\ 1 & , \; x=b \\ c-x & , \; x\in(b,c) \\ 0 & , \; x\in[c,\infty] \end{cases}$$

Fig.1. Function of triangular fuzzy number
(Burstein & et al., 2014)

In the classic multivariate decision makings it is tried that the effect of different factors in decision making to be calculated using math concepts. But expression of many factors is not possible with classical math logic. On the other hand there has been always uncertainty in the real

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world and unreliable condition always exists in various stages of study and consideration of an issue. Therefore, in many cases all and or part of the data of a Multivariate Decision Making problem, are fuzzy. In that case if the problem is modeled and formulated using the certain data, a correct and precise answer will not be achieved and as a result the preferred option won't be selected. In such imprecise decision makings the required objective and purpose cannot be achieved. Therefore, in the decision making models whose data are random or fuzzy, with existing calculations and operations must be faced more logically and precisely and regard uncertainty in the decision making model. Uncertainty modeling in decision making problems is performed by Theory of Fuzzy Sets. Insufficiencies and limitations which exist in classic Multivariate Decision Making methods have caused that fuzzy Multivariate Decision Makings to be introduced. (Liang and Wong, 1991) based on these Multivariate Decision Making techniques include this advantage that can evaluate the different options regarding the various criteria which don't have an equal unit and this is an important advantage compared to the traditional methods within which all of the criteria must be converted to an equal unit and the important advantage of fuzzy techniques is that they have this capability to simultaneously evaluate and analyze the qualitative and quantitative criteria (Samradjah, 2013).

5.1. Multiple-criteria decision-making(MCDM)

Multiple-criteria decision-making or multiple-criteria decision is considered a complex tool for balancing the goals, risks, and limitations of a problem.(Le, 2024) Multi-criteria decision-making (MCDM) tools can be of aid in supporting decision-makers reach a satisfying solution, especially when conflicting criteria are present. MCDM belongs to a variety of techniques able to determine a preference ordering among alternative solutions whose performance is scored against a series of criteria. among the MCDM methods AHP and TOPSIS being the first choice for decision-making.(Markatos & et al., 2023)

MCDM is a valuable tool that is applied to make or analyze complex problems and decisions based on some suitable alternative selections. It has all the features of an effective decision support tool. MCDM permits data storing, data analysis data modifying and data visualizing for decision-making (Jena et al., 2020a). MCDM helps to find the maximum significant factors. In this study, the MCDM method, specifically, AHP has been applied to explain the current situation. AHP is one of the most applicable decision making processes in industries and academia. Therefore, this research has used AHP method to evaluate the social and structural vulnerabilities.(Shakiba Tabar, 2022)

5.2. Fuzzy Analytical hierarchy process (AHP) method

Analytical Hierarchy Process (AHP) is one of the decision making methods based on Multi Criteria Decision Making which this method was posed in the year 1980 by Thomas L. Saaty and was noted because of efficiency. This method has been based upon couple compare and gives the possibility of considering various scenarios to the users. In this method initially the objective of analysis is specified and then we determine decision making criteria at different levels and specify the weight of each criterion by pairwise comparison between them and for each criterion we obtain a number as the priority of that criterion (Saaty, 1980).

Analytic hierarchy process is a decision-making tool that helps in breaking the complex problem in simple criteria AHP is based upon three principles i.e. decomposition of the problem, comparative judgment and synthesis of relative importance or rankings In AHP, the problem is broken into hierarchical criteria. These criteria are compared to each other. This process of relative comparison is called pair-wise comparison. eigenvector method is used to calculate the rankings and after that consistency of the solution is also checked by using consistency ratio. (Panchal & Shrivastava, 2022). However, AHP facilitates the decision-making procedure by pairwise comparisons, but pairwise comparisons are done with real (crisp) numbers. On the other hand, because the human evaluations may be vague and mental judgment –which is one of the typical features in decision-making problems- so it seems using AHP with real numbers for detailed evaluation of the relative importance of criteria and the performance of alternative towards criteria to be insufficient. Therefore, Fuzzy AHP was introduced to evaluate the problems in ambiguity and uncertainty situations. .(Shakiba Tabar, 2022)

The analytic hierarchy process (AHP) provides objective mathematical approach to process those preferences related to a specific person or a certain group that are inevitably subjective in nature. AHP is one of the decision-making processes that decomposes a complex problem into sub-problem levels in a hierarchical order, consisting of several (usually three to four) levels. The highest (top level) level in this structure defines the main goal. It is succeeded by a second level encompassing the criteria which are the major factors controlling the goal. Similarly, the third hierarchy level consists of sub-criteria affecting each major criterion, and so on. AHP process has to be as comprehensive as possible, but not that comprehensive as to lose sensitivity to change in the elements.(Raos & et al, 2024)

The framework of the AHP can be decomposed into different levels of the hierarchical structure, as shown in Figure 1. The first level of the framework indicates the decision's goal, i.e., purchasing or evaluation decision. The second level of the framework includes factors that affect the decision behavior of the goal, and these factors are composed of exclusive criteria on the third level. The fourth level contains the alternatives of the candidate set. Note that we can add more levels to consider sub-criteria in the framework. .(Shakiba Tabar, 2022)

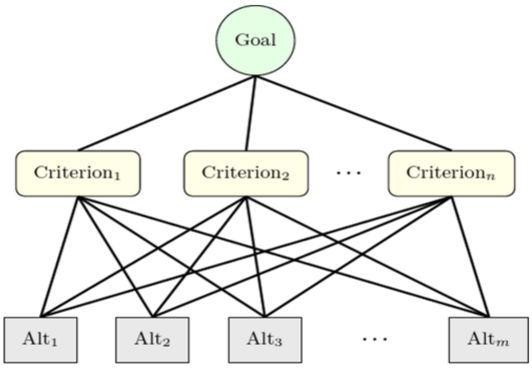

Fig.2. A Generic Three-Layer AHP Hierarchy

Now at the time that there is the intention for decision making we will face personal preferences and judgments, e.g. when we want to compare two criteria of A and B with each other we say that A is absolutely preferred to B or A is a little more favorable than B. These words are not certain words and depend on the individuals' personal point of view; therefore, in comparison, the analyzer must regard the spirits and personal characteristics as well. There are different methods for fuzzification of a number whose two main methods include triangular and bell shape which in the triangular method the fuzzy number of M is equal to M={l, m, u} which l is the low limit and u include the up limit of the base of the triangle and in the bell shaped method of fuzzification around the number of m equals with µA = 1/ (1+d(x-m)2) which d is the factor of bell shape. The more the fuzzy number is closer to certainty, we use larger d. Fuzzy Analytical Hierarchy Process (AHP) is an extension of AHP which sufficiently modifies fuzzification of the datum. Makes its perception easier and administration of qualitative and quantitative datum in multi data decision making issues is simple. In this method triangular fuzzy numbers for preference of a criterion on the other on is used. (zhang and Sung, 2007) Analytical Hierarchy Process (AHP) involves principles of analysis, pairwise comparison and production of priority and combination vector. Therefore, this objective of Analytical Hierarchy Process (AHP) is using the information of experts' information but the classic Analytical Hierarchy Process (AHP) cannot reflect human thought.

So the fuzzy Analytical Hierarchy Process (AHP) and a fuzzy extension of Analytical Hierarchy Process (AHP) developed to solve the Hierarchical Fuzzy problems. In the stages of Analytical Hierarchy Process (AHP), the pairwise comparison in the final matrix is fuzzy figures which are described by the designer (Ezdes Glu, 2007).

6. Case Study

There are five options of tile factory construction project with different hypothesis in this research which regarding the five indices including specific current value, Capital return period, investment output, sales output and the numerical break – even ratio and by utilization of Fuzzy Hierarchical Analysis Method and the financial and technical considerations results and existing of three experts are performed and the projects prioritizing include as followings:

For the project of "A" with the practical capacity of 1,650,000 cost of the total investment regarding 4,344 million Rials capital turnover and a sum of 123,511 million Rials constant investment will be over 127,854 million Rials. The plan sum of selling in the first year of usage will reach out to 115,632 million Rials and in the fifth year to 249,765 million Rials. The plan net profit in the first year of usage equivalent to 33,676 Million Rials and in the fifth year will increase to 126,027 Million Rials. Also the cost of production in the first year 68,581 Million Rials and in the last year is estimated as 79,683 Million Rials which of this amount 25,681 Million Rials is the constant cost and 54,002 Million Rials is the variable cost. Also evaluation results of the project "A" and the financial indices amounts regarding the conducted analyses using Computer Model for Feasibility Analysis and Reporting (COMFAR) software include as followings:

The current net value of the plan in the discount rate is 25 percent, equivalent to 11,513 Million Rials. Internal output rate of the plan is estimated as 28 percent. Capital return period is 2.62 years. As for profitability ratio, sales output is 0.5 and investment output 0.48. Rial break – even is estimated as 32,765 Million Rials and the numerical break – even 216453. For the project of "B" with the practical capacity of 1,550,000 cost of the total investment regarding 4,116 million Rials capital turnover and a sum of 120,001 million Rials constant investment will be over 124,117 million Rials. The plan sales sum in the first year of usage will reach out to 108,624 million Rials and in the fifth year to 234,628 million Rials. The plan net profit in the first year of usage equivalent to 30,308 Million Rials and in the fifth year will increase to 116,700 Million Rials. Also the cost of production in the first year 68,581 Million Rials and in the last year is estimated as 79,683 Million Rials which of this amount 25,681 Million Rials is the constant cost and 54,002 Million Rials is the variable cost. Also evaluation results of the project "B" and the financial indices amounts regarding the conducted analyses using Computer Model for Feasibility Analysis and Reporting (COMFAR) software include as followings:

The current net value of the plan in the discount rate is 25 percent, equivalent to 5,134 Million Rials. Internal output rate of the plan is estimated as 27 percent. Capital return period is 2.73 years. As for profitability ratio, sales output is 0.5 and investment output 0.46. Rial break – even is estimated as 32,684 Million Rials and the numerical break – even 215919.

For the project of "C" with the practical capacity of 1,600,000 cost of the total investment regarding ,4498 million Rials capital turnover and a sum of 129,591 million Rials constant investment will be over 13,4089 million Rials. The plan sales sum in the first year of usage will reach out to 112,128 million Rials and in the fifth year to 242,196 million Rials. The plan net profit in the first year of usage equivalent to 31,992 Million Rials

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and in the fifth year will increase to 121,363 Million Rials.
Also the cost of production in the first year 67,322 Million Rials and in the last year is estimated as 78,333 Million Rials which of this amount ,25598 Million Rials is the constant cost and 52,735 Million Rials involve the variable cost.
Also evaluation results of the project “C” and the financial indices amounts regarding the conducted analyses using Computer Model for Feasibility Analysis and Reporting (COMFAR) software include as followings:
The current net value of the plan in the discount rate is 25 percent, equivalent to 1,923 Million Rials. Internal output rate of the plan is estimated as 26 percent. Capital return period is 2.79 years. As for profitability ratio, sales output is 0.5 and investment output 0.45. Rial break – even is estimated as 32,723 Million Rials and the numerical break – even 216173.
For the project of “D” with the practical capacity of 1,530,000 cost of the total investment regarding 3,967 million Rials capital turnover and a sum of 109,762 million Rials constant investment will be over 113,729 million Rials.
The plan sales sum in the first year of usage will reach out to 107,222 million Rials and in the fifth year to 231,600 million Rials. The plan net profit in the first year of usage equivalent to 29,634 Million Rials and in the fifth year will increase to 114,834 Million Rials.
Also the cost of production in the first year 65,560 Million Rials and in the last year is estimated as 76,442 Million Rials which of this amount 25,481 Million Rials is the constant cost and 50,961 Million Rials is the variable cost.
Also evaluation results of the project “D” and the financial indices amounts regarding the conducted analyses using Computer Model for Feasibility Analysis and Reporting (COMFAR) software include as followings:
The current net value of the plan in the discount rate is 25 percent, equivalent to 11,471 Million Rials. Internal output rate of the plan is estimated as 29 percent. Capital return period is 2.61 years. As for profitability ratio, sales output is 0.5 and investment output 0.48. Rial break – even is estimated as 32,670 Million Rials and the numerical break – even 215825.
For the project of “H” with the practical capacity of 1,690,000 cost of the total investment regarding 4, 956million Rials capital turnover and a sum of 129,123 million Rials constant investment will be over 134,079 million Rials. The plan sales sum in the first year of usage will reach out to 118,435 million Rials and in the fifth year to 255,820 million Rials. The plan net profit in the first year of usage equivalent to 35,023 Million Rials and in the fifth year will increase to 129,758 Million Rials. Also the cost of production in the first year 69,588 Million Rials and in the last year is estimated as 80,763 Million Rials which of this amount 25,748 Million Rials is the constant cost and 55,016 Million Rials is the variable cost.
Also evaluation results of the project “H” and the financial indices amounts regarding the conducted analyses using Computer Model for Feasibility Analysis and Reporting (COMFAR) software include as followings:
The current net value of the plan in the discount rate is 25 percent, equivalent to 10,325 Million Rials. Internal output rate of the plan is estimated as 28 percent. Capital return period is 2.64 years. As for profitability ratio, sales output is 0.51 and investment output 0.47. Rial break – even is estimated as 32,802 Million Rials and the numerical break – even 216695.

7. Prioritization of the projects using the Fuzzy AHP method include as followings

In the year 1992, Chung provided a very simple method for Hierarchical Analysis Process Extension to Fuzzy Space. This method which is based on arithmetic mean of experts’ opinions and Saaty normalizing method and was developed using fuzzy triangular numbers, was welcomed by the researchers (Zanjirchi, 2011). The stages of performance of this method include as follows:

Stage 1; drawing the hierarchical tree: in this stage draw the decision hierarchy structure using
the levels of objective, criterion and option.

Stage 2; couple compares matrix formation: using the decision maker opinion, compares matrix was formed using triangular fuzzy numbers

$$\tilde{t}_{ij} = (a_{ij}, b_{ij}, c_{ij})$$

On the basis of various decision makers

8. Fuzzy Judgment Matrix

$$\tilde{A} = \begin{bmatrix} (1,1,1) & \begin{Bmatrix} \tilde{a}_{121} \\ \tilde{a}_{122} \\ \vdots \\ \tilde{a}_{12P_{12}} \end{Bmatrix} & \cdots & \cdots & \begin{Bmatrix} \tilde{a}_{1n1} \\ \tilde{a}_{1n2} \\ \vdots \\ \tilde{a}_{1nP_{1n}} \end{Bmatrix} \\ \begin{Bmatrix} \tilde{a}_{211} \\ \tilde{a}_{212} \\ \vdots \\ \tilde{a}_{21P_{21}} \end{Bmatrix} & (1,1,1) & \cdots & \cdots & \begin{Bmatrix} \tilde{a}_{2n1} \\ \tilde{a}_{2n2} \\ \vdots \\ \tilde{a}_{2nP_{2n}} \end{Bmatrix} \\ \vdots & \vdots & \vdots & \vdots & \vdots \\ \begin{Bmatrix} \tilde{a}_{n11} \\ \tilde{a}_{n12} \\ \vdots \\ \tilde{a}_{n1P_{n1}} \end{Bmatrix} & \begin{Bmatrix} \tilde{a}_{n21} \\ \tilde{a}_{n22} \\ \vdots \\ \tilde{a}_{n2P_{n2}} \end{Bmatrix} & \cdots & \cdots & (1,1,1) \end{bmatrix} \quad (1)$$

Which in this matrix p_{ij} is the number of individuals expressing their opinions about the priority entry i in relation to j.
Stage 3; arithmetic mean of the opinions: Calculate the arithmetic mean of the opinions of the decision makers in the form of the following matrix:

$$\tilde{A} = \begin{bmatrix} (1,1,1) & \tilde{a}_{12} & \tilde{a}_{1n} \\ \tilde{a}_{21} & (1,1,1) & \tilde{a}_{2n} \\ \vdots & \vdots & \vdots \\ \tilde{a}_{n1} & \tilde{a}_{n2} & (1,1,1) \end{bmatrix} \quad (2)$$

Arithmetic mean of the decision-makers' opinions:

$$\tilde{a}_{ij} = \frac{\sum_{k=1}^{p_{ij}} a_{ijk}}{p_{ij}} \qquad i,j = 1,2,\ldots,n \quad (3)$$

Step 4: Calculation of the sum of the total elements of row: Calculate the total elements of the rows:

$$\tilde{s}_i = \sum_{j=1}^{n} \tilde{a}_{ij} \qquad i = 1,2,\ldots,n \quad (4)$$

Stage 5: Normalizing: Normalize the total of the rows by the following method.

$$\tilde{M}_i = \tilde{s}_i \otimes \left[\sum_{i=1}^{n} \tilde{s}_i\right]^{-1} \quad i = 1,2,\ldots,n \quad (5)$$

In case that we show $\tilde{s}_i$ in the form of (li , mi , ui) the above mentioned relationship is accounted as followings.

$$\tilde{M}_i = \left(\frac{l_i}{\sum_{i=1}^{n} u_i}, \frac{m_i}{\sum_{i=1}^{n} m_i}, \frac{u_i}{\sum_{i=1}^{n} l_i}\right) \quad (6)$$

Stage 6; Possibility degree determination of being greater: we calculate the possibility degree of being greater of each iμ in relation to other iμs and call it d'(Ai).
the possibility degree of fuzzy triangular number of μ2=(l2,m2,u2) being greater compared to fuzzy triangular number of μ1=(l1,m1,u1) is equal to :

$$V(M_2 > M_1) = \mathrm{Sub}_{y \ge x}\left[\min\left(\mu_{M_1}(x), \mu_{M_2}(y)\right)\right] \quad (7)$$

This equation can be expressed synonymously as followings:

$$V(M_2 \ge M_1) = hgt(M_2 \cap M_1) = \mu_{M_2}(d) = \begin{cases} 1 & m_2 \ge m_1 \\ 0 & l_2 \ge u_1 \\ \dfrac{l_1 - u_2}{(m_2 - u_2) - (m_1 - l_1)} & \text{Otherwise} \end{cases} \quad (8)$$

Which d is the coordinate of the highest point in the shared area and impact of the two membership functions of μ_{M1} and μ_{M2}.

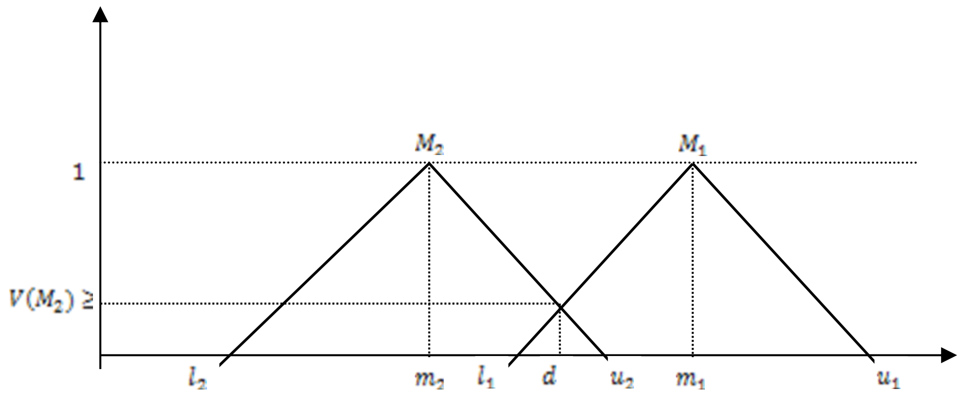

Fig. 3. Priority of two triangular fuzzy numbers: (Chung, 1996)

For comparison of M1 and M2, calculation of the two amounts of V(M2 ≥ M1) , V(M1≥M2)
is necessary. The possibility degree of a convex fuzzy number (M) being greater than K number of other convex fuzzy number (Mi ; i = 1,2,…,k) is distinct as followings:

d'(M)=V(M ≥ M1,M2,…,Mk) = V[(M ≥ M1) , (M ≥ M2) , … , (M ≥ Mk)]
= min V (M ≥ Mi) i = 1,2,…,k (9)

Stage 7; Normalizing: by normalizing the vector of weights, the normalizing weights are obtained.

$$W = \left[\frac{d'(A_1)}{\sum_{i=1}^{n} d'(A_i)}, \frac{d'(A_2)}{\sum_{i=1}^{n} d'(A_i)}, \ldots, \frac{d'(A_n)}{\sum_{i=1}^{n} d'(A_n)}\right]^T \quad (10)$$

The above mentioned weights are the final weights (non-fuzzy). By repetition of this process, the weights of all matrices are obtained.
By conducting these calculations the results as the following order are achieved.

Stage 8: combination of weights: by combination of weights of option and criteria, the final weights are obtained. (Chung, 1992)

$$\tilde{U}_i = \sum_{j=1}^{n} \tilde{w}_i \tilde{r}_{ij} \qquad \forall i \tag{11}$$

The procedure of considering the compatibility of GuGus and Boucher:

GuGus and Boucher (1998) suggested that for considering compatibility, two matrices of (the medium number and around fuzzy number) is emanated from any fuzzy matrix and then compatibility of each matrix is calculated on the basis of Saaty method. The calculation stages of the compatibility rate of the couple compares fuzzy matrices include as followings:

Stage 1: In the first stage, divide the fuzzy triangular matrix in to two matrices. The first matrix is form of medium numbers of triangular judgments $A^m = [a_{ijm}]$ and the second matrix include geometric mean limits of above and below triangular numbers $A^g = \sqrt{a_{iju}.a_{ijl}}$.

Stage 2: calculate the weight vector of any matrix using the Saaty method according to the following order.

$$w_i^m = \frac{1}{n}\sum_{j=1}^{n}\frac{a_{ijm}}{\sum_{i=1}^{n} a_{ijm}} \tag{12}$$

in which $w^m = [w_i^m]$

$$w_i^g = \frac{1}{n}\sum_{j=1}^{n}\frac{\sqrt{a_{iju}.a_{ijl}}}{\sum_{i=1}^{n}\sqrt{a_{iju}.a_{ijl}}} \tag{13}$$

in which $w^g = [w_i^g]$

Stage 3: calculate the largest especial amount for any matrix using the followings equations.

$$\lambda_{\max}^m = \frac{1}{n}\sum_{i=1}^{n}\sum_{j=1}^{n} a_{ijm}\left(\frac{w_j^m}{w_i^m}\right) \tag{14}$$

$$\lambda_{\max}^g = \frac{1}{n}\sum_{i=1}^{n}\sum_{j=1}^{n} \sqrt{a_{iju}.a_{ijl}}\left(\frac{w_j^g}{w_i^g}\right) \tag{15}$$

Stage 4: calculate the compatibility index using the following equations:

$$CI^m = \frac{(\lambda_{\max}^m - n)}{(n-1)} \tag{16}$$

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$$CI^g = \frac{(\lambda_{\max}^g - n)}{(n-1)} \tag{17}$$

Stage 5: for calculation of incompatibility rate (CR), divide CI index on the amount of Random Index of (RI). In case that the obtained amount is less than 0.1, the compatible and usable matrix is diagnosed.

Saaty scale for obtaining the amounts of random indices (RI), calculated 100 matrices with the random numbers and by the condition of mutuality of the formed matrices and the incompatibility amount and their means.

But since fuzzy compares numerical amounts are not always normal numbers and even in that case the geometric mean, generally converts them to abnormal numbers, even in case of using the Saaty scale of (1-9) also random indices (RI) table cannot be used.

Therefore, Gugus and Boucher by creation of 400 random matrices again produced the random indices (RI) table for couple compares fuzzy matrices.

Table 1
Random Indices (RI)

Matrix Size	RI^m	RI^g
1	0	0
2	0	0
3	0/4890	0/1796
4	0/7937	0/2627
5	1/0720	0/3597
6	1/1996	0/3818
7	1/2874	0/4090
8	1/3410	0/4164
9	1/3793	0/4348
10	1/4095	0/4455
11	1/4181	0/4536
12	1/4462	0/4776
13	1/4555	0/4691
14	1/4913	0/4804
15	1/4986	0/4880

For creation of random matrices initially the medium amount of triangular fuzzy number randomly in the range of $[\frac{1}{9},9]$ and was created mutually.

Then the low limit of each triangular number in the range of [$\frac{1}{9}$ and the produced medium amount] randomly is produced and ultimately by division of the emanated random matrix in to two matrices of the medium limit and geometric mean of up and down limits, their random index amount was achieved. The noticeable point is that

the incompatibility amount in the column RI^m is more than RI^g.
This difference is because that the range of created random numbers for the medium limit is $[\frac{1}{9},9]$ but the range of random numbers of the up and down limits have been created on the basis of the created medium number is more limited and; therefore, there is less possibility of incompatibility in them.

By calculation of the incompatibility rate for two matrices on the basis of the following equations, we compare them with the threshold of 0.1:

.

$$CR^g = \frac{CI^g}{RI^g} \tag{18}$$

$$CR^m = \frac{CI^m}{RI^m} \tag{19}$$

In case that both of these indices were less than 0.1, the fuzzy matrix is compatible. In case that both were more than 0.1, the decision maker is asked to reconsider the provided priorities and in case that only $CR^m(CR^g)$ was more than 0.1, the decision maker reconsiders the medium amounts (limits) of fuzzy judgments.
The results of the hierarchical model solution using the method of Chung for this research include as followings:
Stage 1: the decision hierarchical tree of this project is formed as in the figure 3.

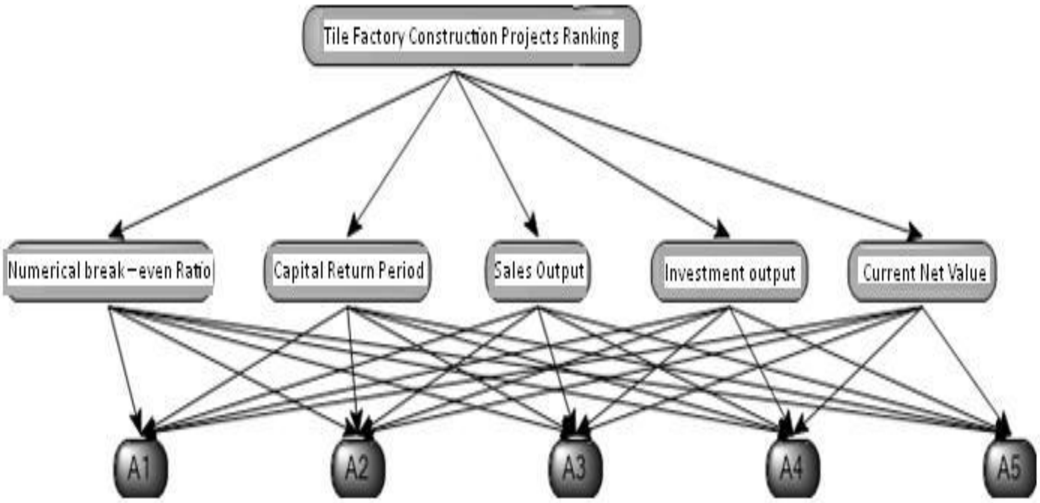

Fig. 3. Decision Hierarchical Tree

Stages of 2 & 3& 4: for conducting couple compares word phrases according to table 2 was utilized:

Table 2
Fuzzy Range and Corresponding Verbal Expression

Fuzzy Number	*Verbal Expression*	Code
(1,1,1)	Equal Preference	1
(1,3,5)	Less Preference	2
(3,5,7)	Much Preference	3
(5,7,9)	Very Much Preference	4
(7,9,9)	Absolutely Much Preference	5

The names of the options and their abbreviations have been provided in the table (3).

Table 3
The names of the options and their abbreviations

Name of the Option	Abbreviation
Project A	A1
Project B	A2
Project C	A3
Project D	A4
Project H	A5

Tables of 4 indicate the arithmetic mean of the experts' opinions. At the last column of these tables, the total rows elements have been indicated.

Table 4
Couple Compares Mean in Relation to the Raknking of the tile Factory Construction Projects

	Numerical break – even Ratio	Capital Return Period	Sales output	investment output	Current Net Value	Total	Normalized
Numerical	(1,1,1)	(0.122,0.151,0.225)	(0.2,0.333,1)	(0.181,0.289,0.778)	(0.151,0.225,0.511)	(1.654,1.998,3.514)	(0.021,0.035,0.093)
Capital Return	(5,7,8.333)	(1,1,1)	(4.333,6.333,8.333)	(4.333,6.333,8.333)	(2.333,4.333,6.333)	(16.999,24.999,32.332)	(0.22,0.438,0.857)
Sales output	(1,3,5)	(0.122,0.162,0.244)	(1,1,1)	(0.733,0.778,1)	(0.132,0.181,0.289)	(2.987,5.121,7.533)	(0.039,0.09,0.2)
investment output	(1.667,3.667,5.667)	(0.122,0.162,0.244)	(1,1.667,2.333)	(1,1,1)	(0.122,0.162,0.244)	(3.911,6.658,9.488)	(0.051,0.117,0.252)
Current Net Value	(3,5,7)	(0.162,0.244,0.556)	(3.667,5.667,7.667)	(4.333,6.333,8.333)	(1,1,1)	(12.162,18.244,24.556)	(0.157,0.32,0.651)
Total						(37.713,57.02,77.423)	
CRm =0.153 CRg =0.412 Incompatible							

Table 5
Calculation of Level 2 Substandards Preference Degree Compared to the Tile Factory Construction Projects Ranking

	Numerical Break – Even Ratio	Capital Return Period	Sales Output	Investment Output	Current Net Value	Final Greater Degree	Normalized Weights
Numerical Break – Even Ratio	_	0	0.499	0.343	0	0	0
Capital Return Period	1	_	1	1	1	1	0.533
Sales Output	1	0	_	0.847	0.156	0	0
Investment Output	1	0.091	1	_	0.317	0.091	0.048
Current Net Value	1	0.785	1	1	_	0.785	0.418
Total						1.875	1

On the basis of the results of table 5, prioritizing criteria level 2 compared to Tile Factory Construction projects ranking include:

1. Capital Return Period
2. Current Net Value
3. Investment Output
4. Numerical Break – Even Ratio
5. Sales Output

Table 6
Couple Compares Mean Compared to Numerical Break – Even Ratio

Current Net Value	A1	A2	A3	A4	A5	Total	Normalized
A1	(1,1,1)	(3,5,7)	(1,3,5)	(3.667,5.667,7.667)	(0.2,0.333,1)	(8.867,15,21.667)	(0.116,0.281,0.664)
A2	(0.143,0.2,0.333)	(1,1,1)	(0.2,0.333,1)	(1,3,5)	(0.111,0.143,0.2)	(2.454,4.676,7.533)	(0.032,0.087,0.231)
A3	(0.2,0.333,1)	(1,3,5)	(1,1,1)	(3,5,7)	(1.095,1.8,2.556)	(6.295,11.133,16.556)	(0.083,0.208,0.508)
A4	(0.141,0.206,0.467)	(0.2,0.333,1)	(0.143,0.2,0.333)	(1,1,1)	(0.132,0.17,0.27)	(1.616,1.909,3.07)	(0.021,0.036,0.094)
A5	(1,3,5)	(5,7,9)	(2.048,3.4,4.778)	(4.333,6.333,7.667)	(1,1,1)	(13.381,20.733,27.445)	(0.175,0.388,0.842)
Total						(32.613,53.451,76.271)	

CRm **=0.267** CRg **=0.614 Incompatible**

Table 7
Calculation Options Preference Degree Compared to Numerical Break – Even Ratio

Numerical Break – Even Ratio	A1	A2	A3	A4	A5	Final Greater Degree	Normalized Weights
A1	_	1	1	1	0.82	0.82	0.312
A2	0.373	_	0.551	1	0.156	0.156	0.059
A3	0.844	1	_	1	0.649	0.649	0.247
A4	0	0.545	0.063	_	0	0	0
A5	1	1	1	1	_	1	0.381
Total						2.625	1

On the basis of the results of table 7, level 3 prioritizing options compared to Numerical break – even Ratio include:

1. A5
2. A1
3. A3
4. A2
5. A4

Table 8
Couple Compares Mean Compared to the Capital Return Period

capital return period	A1	A2	A3	A4	A5	Total	Normalized
A1	(1,1,1)	(3,5,7)	(5,7,9)	(0.2,0.333,1)	(1,3,5)	(10.2,16.333,23)	(0.13,0.285,0.629)
A2	(0.143,0.2,0.333)	(1,1,1)	(1,3,5)	(0.111,0.143,0.2)	(0.2,0.333,1)	(2.454,4.676,7.533)	(0.031,0.082,0.206)
A3	(0.111,0.143,0.2)	(0.2,0.333,1)	(1,1,1)	(0.111,0.111,0.143)	(0.143,0.2,0.333)	(1.565,1.787,2.676)	(0.02,0.031,0.073)
A4	(1,3,5)	(5,7,9)	(7,9,9)	(1,1,1)	(3,5,7)	(17,25,31)	(0.216,0.436,0.848)
A5	(0.2,0.333,1)	(1,3,5)	(3,5,7)	(0.143,0.2,0.333)	(1,1,1)	(5.343,9.533,14.333)	(0.068,0.166,0.392)
Total						(36.562,57.329,78.542)	
CRm =0.056 CRg =0.071 **Compatible**							

Table 9
Calculation of Options Preference Degree Compared To the Capital Return Period

Capital Return Period	A1	A2	A3	A4	A5	Final Greater Degree	Weights Normalized
A1	_	1	1	0.732	1	0.732	0.344
A2	0.273	_	1	0	0.62	0	0
A3	0	0.454	_	0	0.037	0	0
A4	1	1	1	_	1	1	0.47
A5	0.688	1	1	0.394	_	0.394	0.185
Total						2.126	1

On the basis of the results of table 9, level 3 prioritizing options compared to the capital return period include:

1. A4
2. A1
3. A5
4. A2
5. A3

Table 10
Couple Compares Mean Compared To Sales Output

Sales Output	A1	A2	A3	A4	A5	Total	Normalized
A1	(1,1,1)	(1,3,5)	(1,3,5)	(0.181,0.289,0.778)	(1,1.667,2.333)	(4.181,8.956,14.111)	(0.073,0.237,0.657)
A2	(0.2,0.333,1)	(1,1,1)	(1,1.667,2.333)	(0.2,0.333,1)	(1,1,1)	(3.4,4.333,6.333)	(0.059,0.115,0.295)
A3	(0.2,0.333,1)	(0.733,0.778,1)	(1,1,1)	(0.17,0.259,0.714)	(0.2,0.333,1)	(2.303,2.703,4.714)	(0.04,0.072,0.219)
A4	(1.667,3.667,5.667)	(1,3,5)	(3,5,6.333)	(1,1,1)	(1,3,5)	(7.667,15.667,23)	(0.134,0.415,1.071)

:

A5	(0.733,0.778,1)	(1,1,1)	(1,3,5)	(0.2,0.333,1)	(1,1,1)	(3.933,6.111,9)	(0.069,0.162,0.419)
Total						(21.484,37.77,57.158)	
CRm **=0.086** CRg **=0.242 Incompatible**							

Table 11
Calculation of Options Preference Degree Compared To Sales Output

Sales Output	A1	A2	A3	A4	A5	Final Greater Degree	Weights Normalized
A1	_	1	1	0.746	1	0.746	0.264
A2	0.644	_	1	0.349	0.828	0.349	0.123
A3	0.469	0.788	_	0.199	0.625	0.199	0.07
A4	1	1	1	_	1	1	0.354
A5	0.821	1	1	0.53	_	0.53	0.188
Total						2.824	1

On the basis of the results of table 11 ,level 3 prioritizing options compared to sales output include:

1. A4
2. A1
3. A5
4. A2
5. A3

Table 12
Couple Compares Mean Compared To Investment Output

Investment Output	A1	A2	A3	A4	A5	Total	Normalized
A1	(1,1,1)	(3,5,7)	(5.667,7.667,9)	(1,1,1)	(1,3,5)	(11.667,17.667,23)	(0.163,0.343,0.702)
A2	(0.143,0.2,0.333)	(1,1,1)	(1,3,5)	(0.143,0.2,0.333)	(0.2,0.333,1)	(2.486,4.733,7.666)	(0.035,0.092,0.234)
A3	(0.111,0.132,0.181)	(0.2,0.333,1)	(1,1,1)	(0.111,0.132,0.181)	(0.143,0.2,0.333)	(1.565,1.797,2.695)	(0.022,0.035,0.082)
A4	(1,1,1)	(3,5,7)	(5.667,7.667,9)	(1,1,1)	(1,3,5)	(11.667,17.667,23)	(0.163,0.343,0.702)
A5	(0.2,0.333,1)	(1,3,5)	(3,5,7)	(0.2,0.333,1)	(1,1,1)	(5.4,9.666,15)	(0.076,0.188,0.458)
Total						(32.785,51.53,71.361)	
CRm **=0.029** CRg **=0.019 Compatible**							

Table 14
Calculation of Options Preference Degree Compared To Investment Output

Investment Output	A1	A2	A3	A4	A5	Final Greater Degree	Weights Normalized
A1	_	1	1	1	1	1	0.348
A2	0.219	_	1	0.219	0.623	0.219	0.076
A3	0	0.454	_	0	0.041	0	0
A4	1	1	1	_	1	1	0.348
A5	0.654	1	1	0.654	_	0.654	0.228
Total						2.873	1

On the basis of results Table 13 ,prioritizing options یlevel 3 compared to investment output include:

1. 1A
2. 4A
3. 5A
4. 2A
5. 3A

Table 14
Couple Compares Mean Compared To Current Net Value

Current Net	A1	A2	A3	A4	A5	Total	Normalized

Value							
A1	(1,1,1)	(5,7,9)	(6.333,8.333,9)	(1,1.667,2.333)	(3,5,7)	(16.333,23,28.333)	(0.215,0.412,0.778)
A2	(0.111,0.143,0.2)	(1,1,1)	(1,3,5)	(0.143,0.2,0.333)	(0.2,0.333,1)	(2.454,4.676,7.533)	(0.032,0.084,0.207)
A3	(0.111,0.122,0.162)	(0.2,0.333,1)	(1,1,1)	(0.111,0.143,0.2)	(0.143,0.2,0.333)	(1.565,1.798,2.695)	(0.021,0.032,0.074)
A4	(0.733,0.778,1)	(3,5,7)	(5,7,9)	(1,1,1)	(1,3,5)	(10.733,16.778,23)	(0.141,0.301,0.631)
A5	(0.143,0.2,0.333)	(1,3,5)	(3,5,7)	(0.2,0.333,1)	(1,1,1)	(5.343,9.533,14.333)	(0.07,0.171,0.393)
Total						(36.428,55.785,75.894)	
CRm =**0.058** CRg =**0.107** **Incompatible**							

Table 15
Calculation of Options Preference Degree Compared To Current Net Value

Current Net Value	A1	A2	A3	A4	A5	Final Greater Degree	Weights Normalized
A1	_	1	1	1	1	1	0.452
A2	0	_	1	0.232	0.61	0	0
A3	0	0.447	_	0	0.025	0	0
A4	0.789	1	1	_	1	0.789	0.356
A5	0.425	1	1	0.66	_	0.425	0.192
Total						2.213	1

On the basis of the results of table 15, level 3 prioritizing options compared to current Net value include:

1. A1
2. A4
3. A5
4. A2
5. A3

Table 16
Criteria Final Weights Matrix Compared To Tile Factory Construction Projects Ranking

Component	Final Weight Final Component
Numerical Break – Even Ratio	0
Capital Return Period	0.533
Sales Output	0
Investment Output	0.048
Current Net Value	0.418

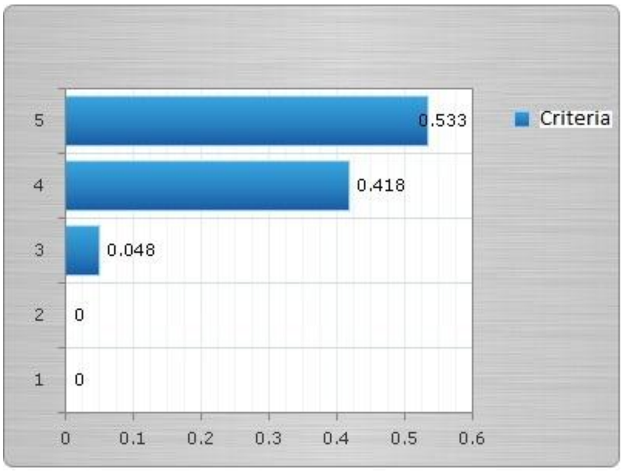

Fig. 4. Criteria Final Weights Diagram Compared To Tile Factory Construction Projects Ranking

Table 17
Options Final Weights Matrix Compared To Tile Factory Construction Projects Ranking

Prioritizing On The Basis of Final Weight	Options Final Weight	Component
2	0.389	A1
4	0.004	A2
5	0	A3
1	0.417	A4
3	0.19	A5

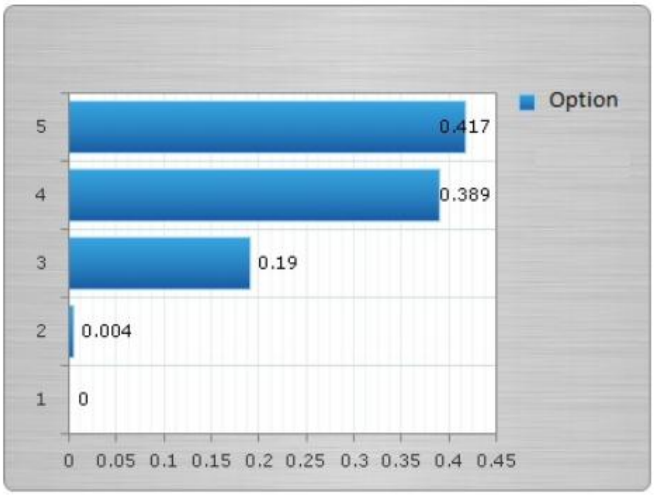

Fig. 5. Options Final Weights Diagram Compared To
Tile Factory Construction Projects Ranking

9. Conclusion

In this research after financial and technical consideration of five options project of Tile Factory Construction which each one had different hypotheses, data analysis was conducted by Computer Model for Feasibility Analysis and Reporting (COMFAR) Software. Then prioritizing of five projects of Tile Factory Construction using Fuzzy Hierarchical Analysis Technique and existence of three experts and based on five financial indices including current Net value , capital return period , sales output , Numerical break – even Ratio, and investment output were conducted. The results indicate that the project "D" with practical capacity of 1,530,000 and total investment cost of 113,729 Million Rials and capital turnover of 3,967 Million Rials and constant investment with a sum of 109,762 Million Rials is prior. The plan sales sum in the first year of usage will reach out to 107,222 million Rials and in the fifth year to 231,600 million Rials. The plan net profit in the first year of usage equivalent to 29,634 Million Rials and in the fifth year will increase to 114,834 Million Rials.
Also the cost of production in the first year 65,560 Million Rials and in the last year is estimated as 76,442 Million Rials which of this amount 25,681 Million Rials is the constant cost and 50,961 Million Rials is the variable cost.
The current net value of the project "D" in the discount rate is 25 percent, equivalent to 11,471 Million Rials. Internal output rate is 29 percent and its capital return period is 2.61 years. As for profitability ratio, sales output is 0.5 and investment output is 0.48. Rial break – even of this plan is also estimated as 32,670 Million Rials and the numerical break – even 215825. Considering the results of prioritizing, it is specified that these results are very close to the results emanated from ranking based on the internal output rate in such a way that the most favorable project involves the maximum internal output rate.

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