CSCanada
International Business and Management
Vol. 11, No. 3, 2015, pp. 81-95
DOI:10.3968/7626

ISSN 1923-841X [Print]
ISSN 1923-8428 [Online]
www.cscanada.net
www.cscanada.org

Measuring the Relative Importance of Financial Ratios: An Integrated Approach of Fuzzy DEMATEL and Fuzzy ANP

Arash Goodarzi[a],*; Hamid Nourali Dokht[b]

[a]Lecturer, Financial Management, Faculty of Economics and Management, University of Sistan and Bluchestan, Zahedan, Iran. Ph.D Student in Finance, Faculty of Management, University of Tehran, Tehran, Iran.
[b]Ph.D Student in Finance, Faculty of Management, University of Tehran, Tehran, Iran.
*Corresponding author.

Received 27 September 2015; accepted 26 November 2015
Published online 31 December 2015

Abstract

Fuzzy set Theory presents a mathematical framework in which it's possible to systematically deal with ambiguous phenomena in human systems and decision making processes. This theory also decreases the need for accurate measurements and permits the gradual assessment of the membership of elements in a set. This paper uses the fuzzy set theory to measure the relative importance of financial ratios for assessment and selection of stocks. First, 39 financial ratios are categorized to 6 groups. Then, the integrated approach of fuzzy DEMATEL (Decision Making Trial and Evaluation Laboratory) and fuzzy ANP (Analytical Network Process) are used to determine the importance of each group of financial ratios, importance of each financial ratio to each other, and finally importance of each financial ratio to the group that it's in is measured. To measure the weight of each ratio a questionnaire is used that is completed by financial experts. The results show that the most important financial ratio is cost-related indicators. Current ratios, Capital Structure ratios, Profitability ratios, Activity ratios, and Investment ratios have less importance, respectively decreasing.

Key words: Financial ratios; Fuzzy ANP; Fuzzy DEMATEL; Ranking

Goodarzi, A., & Dokht, H. N. (2015). Measuring the Relative Importance of Financial Ratios: An Integrated Approach of Fuzzy DEMATEL and Fuzzy ANP. *International Business and Management, 11*(3), 81-95. Available from: http://www.cscanada.net/index.php/ibm/article/view/7626
DOI: http://dx.doi.org/10.3968/7626

INTRODUCTION

There has always been a mistake alongside science and scientists. Based on foundation and principle of science, everything is included in a fixed base and by this foundation a matter is either right or wrong. In the past scientists analyzed their surrounding world accordingly, although they were not sure what was right and what was wrong, and they could make mistakes about whether a thing is right or wrong. They were sure about one thing, that every phenomenon is either right or wrong. A lot of such instances can be presented that aren't totally wrong, but these examples shouldn't be generalized, and mistake of science has been generalizing this fact about all phenomena. There are examples of matters that we can't draw an exact boundary to say whether it is completely right and good or completely wrong and bad. Because an exact criteria for (desirability of financial statements) and (major weakness in internal control system) can't be specified. But in many scientific areas such as mathematics and logic, it is assumed that there are exact and defined boundaries and a certain topic is either included in that range or is not. (Kosko, 2001)

In this world, most of the things that seem right are almost right, and there is always a degree of uncertainty for rightness of real phenomena. In other words actual phenomena are not either white or black, but they are gray to some degree. Real phenomena are always fuzzy, ambiguous and inexact. Only mathematics was black and white, and this was not but a virtual system of rules and signs. Science was exhibiting gray or fuzzy realities with black and white tools, and that's why it seemed that realities are also black and white. And so, while we can't find a single phenomenon in the whole world that is a hundred percent right or wrong, mathematical science or tools, described every phenomena of the world in this manner.

Here science was mistaken. Fuzzy sets in modern mathematics refers to sets that their elements belong to their sets partially. For example, when it's said systematic risk is static, systematic risk is a member of a set called static, that its elements i.e. betas, with different values are members of this set. The degree of engagement of these betas in static set is shown with a number between zero and one that is called Membership Degree. Zero membership degree means betas in a set are zero and membership degree of one means that a beta is one hundred percent a set member, like a Zero-Volatility beta; on one hand if Beta volatility is 70% of its primary value, it is 0.7 a member of static Betas set. Unlike definite sets, in fuzzy sets elements are not divided in two groups of member and not-member, according to the definition their membership degree is variable between zero and one. Understanding fuzzy sets is the first step to enter fuzzy mathematics topic, vis-a-vis classical mathematics. Classical mathematics is based on Aristotelian logic, in which various phenomena have only two aspects: right or wrong, zero or one. In Aristotelian logic there is no middle ground, and approximate reasoning method, is not congruous with nature of human systems. In this type of reasoning, zero and one describe boundaries of reasoning and in fact approximate reasoning is the generalized version of definitive Aristotelian reasoning. Using fuzzy logic, in this study we aim to investigate which financial ratios, in experts' view, is the most important one in capital market, and what is the importance of each ratio in relation to other ratios.

1. LITERATURE REVIEW

The scientific contribution of fuzzy logic to business and finance has increased with a high rate in recent years. Sugeno (1985), Tanaka (1997), Bojadziev and Bojadziev (1997), and Von Altrock (1997), show that fuzzy logic can be safe and beneficial for business, finance and industrial applications. Zebda (1989, 1991) worked with ambiguity and accounting. Abdel-Kader, Dugdale, and Taylor (1998) described many immeasurable factors that companies consider important in making investment decisions. Buckley, Eslami, and Feuring (2002) investigated economic and engineering applications of fuzzy mathematics. Malagoli and Magni (2006) focused on rating and valuating companies and used fuzzy logic and expert systems to grade them, in order to identify companies with high value creation. Fuzzy expert system is able to work with quantitative and qualitative variables and includes finance, managerial and strategic variables. This system is chosen to rate and classify companies in each section. Some of regression analysis can be used for pricing of the target company. One of the practical implications of this study is that firms can be rated by expert systems and it is possible to put a price on the companies by financial analysts and potential customers. They introduce fuzzy expert systems for rating companies in one section and pricing them which was the first attempt as a substitute attempt to measure performance and value of companies.

Dourra and Siy (2002) presented a new method that develops indicators and new data so that they can be fed through fuzzy logic system. The only data needed for these indicators is historical prices of stocks. This method is based on fuzzy logic that formulates the decision making during certain price movements or certain price formations. Their design was adjusting hierarchical classifications of indicators of technical analysis with new input that was fed by fuzzy systems. Not all of these inputs have a yes/no answer. Fuzzy logic is very useful in such circumstances. Managers don't have the same understanding of technical indicators, and they don't have a clear answer for these indicators and their answer is not definitely right or wrong, but it's something in between. In fuzzy logic, each phrase is right to some extent. In their view, fuzzy logic blends with process of technical analysis very properly. Also, they suggest using technical indicators with fuzzy logic to develop fuzzy indicators that recommend ordering, sales, purchase, or storing. This prevents from overconfidence in quantitative data. This method includes some inputs (such as, rate of change, random indicators, and support/resistance limits), an output variable (such as, degree of certainty in decision-making), and some fuzzy rules that indicate the relation between financial indicators. Success of this system was measured by comparing system results with stock price movement. This new method of stock evaluation proved that it has a better performance than market method and can be recognized as a super tool in technical analysis. Quantitative fuzzy systems are developed to predict market activity by fundamental indicators (Deboeck (1996), Francis (1993), Lam, Chiu, and Chan (1996), William and O'Neil (1995), Simutis (2000), Singh and Fieldsend (2000), Ta, Chung, and Yeou (1996). In Table 1, a summery of studies on applications of fuzzy model is presented.

Table 1
Some Studies on Application of Fuzzy Modes

Number	Researcher	Research domain
1	Wen and Iwamura (2008); Ishii, Lee, and Yeh (2007); Yang, Ji, Gao, and Li (2007); Li, Huang, Yang, and Nie (2008)	Locating
2	King, Radha, and Rughooputh (2004); Lotfi and Kashani (2004)	Electricity distribution network
3	Liu and Lai (2009)	Vehicle routing optimization
4	Dulmin and Mininno (2003); Amid, Ghodsypour, and O'Brien (2006); Bellman and Zadeh (1970)	Supply chain

To be continued

Continued

Number	Researcher	Research domain
5	Zimmermann (1995); Li et al. (2008)	Water resources management
6	Yager, Goldstein, and Mendels (1994)	Customers' purchase choice prediction
7	Abdullah and Jamal (2010)	Ranking
8	Merna and Al-Thani (2005); Karanovica (2012)	Capital cost estimate
9	Merton (1974); Elton, Gruber, Agrawal, and Mann (2004); Zhou (2001)	Default Bond valuation
10	Kamdem, Sadefo, Moussa, and Terraza (2012)	Hedge fund ranking
11	Götze, Northcott, and Schuster (2007)	Investment decision-making
12	Abdel-Kader, Dugdale, and Taylor (1998); Magni, Malagoli, and Mastroleo (2006)	Ranking of companies
13	Hussein and Pepe (2002); Simutis (2000)	Technical analysis

Results of this study is a major step in more accurate assessment of financial performance, predicting profitability and more accurate decision making of managers. The main objective of this study is to establish efficient regional funds and indicator funds. Also, portfolio managers, financial analysts, investors and rating companies can use results of this study and to specify successful companies their which stocks have positive Alfa and to making investment decisions.

2. METHODOLOGY AND DATA ANALYSIS

In this study, we specify and examine the criteria which are effective in selection of stock of corporations by means of fuzzy logic algorithm. The data needed for this study is collected in two steps. In first step, Library research method was used for codifying theoretical foundation of study and in second step, the financial analysts and experts' view about relative importance of financial ratios is evaluated by questionnaires. These financial analysts had over 3 years experiment.

2.1 Determining the Importance of Ranking Indicators by Fuzzy ANP and Fuzzy DEMATEL Integrated Approach

You can find hierarchical classification of companies' ranking Indicators in Figure 1, based on financial ratios and formation of index portfolio and sectional portfolio. As you can see, in order to determine the weight of these six indicators of financial ratios and their sub-criteria, their relation to one another should be considered. This will increase the number of paired table comparisons. To avoid this, fuzzy ANP and DEMATEL integrated approach will be used. To do so, we calculate internal effect of six financial ratio indicators and also their thirty nine sub-criteria, using DEMATEL technique. Then to obtain their final weight, we multiply matrix of normalized total relations from fuzzy DEMATEL technique to weight vector of indicators and sub-criteria that was obtained from fuzzy ANP method, Therefore, first we describe results of fuzzy DEMATEL technique and after determining eigenvectors by fuzzy ANP technique, we can determine the final weight of each criterion.

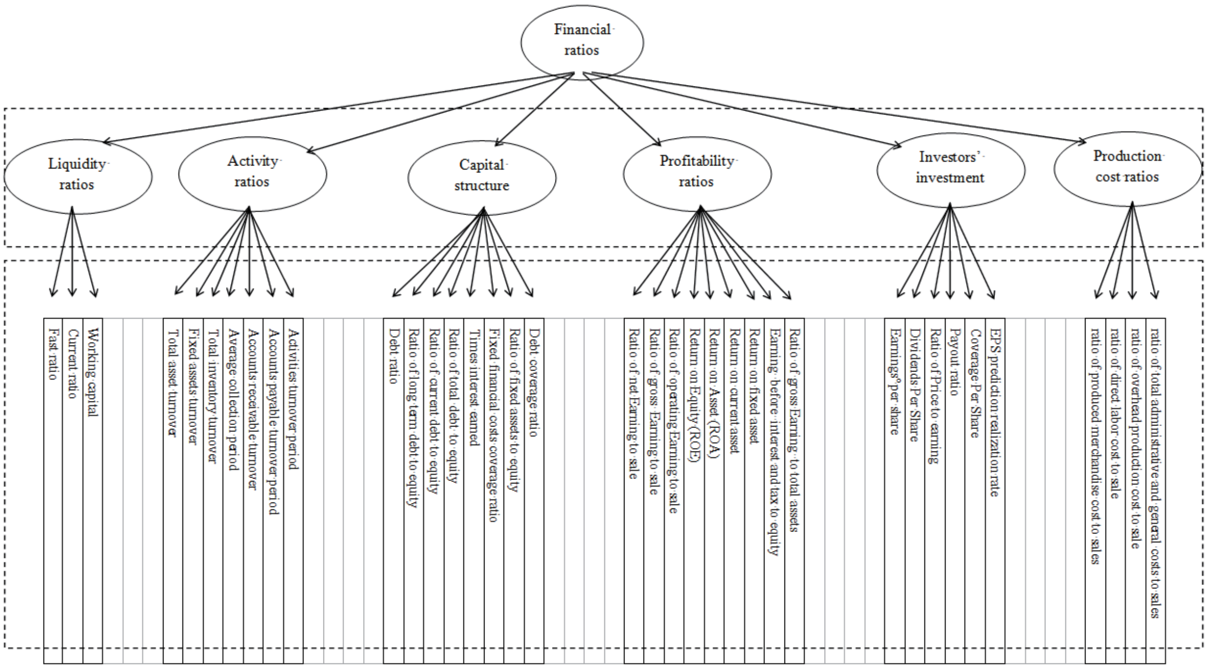

Figure 1
Conceptual Model of Research

2.2 Determining the Causal Relationships Between Financial Indicators and Forming Sectional Portfolio and Index Portfolio Using Fuzzy DEMATEL Technique

The fuzzy average of experts' view about the effect of sextet indicators on one another is shown in Table 2. This data is collected by the questionnaires.

Table 2
The Fuzzy Average of Experts' View About the Effect of Sextet Indicators on One Another

Total experts' view average	Liquidity ratios	Activity ratios	Capital structure ratios	Profitability ratios	Investors' investment ratios	Production cost ratios
Liquidity ratios	(0.000.0.000.0.000)	(0.300.0.500.0.700)	(0.300.0.500.0.686)	(0.300.0.500.0.700)	(0.329.0.529.0.714)	(0.271.0.471.0671)
Activity ratios	(0.357.0.557.0.757)	(0.000.0.000.0.000)	(0.414.0.614.0.800)	(0.414.0.614.0.814)	(0.386.0.586.0.771)	(0.243.0.443.0.643)
Capital structure ratios	(0.400.0.586.0.771)	(0.357.0.557.0.743)	(0.000.0.000.0.000)	(0.386.0.586.0.757)	(0.414.0.614.0.800)	(0.357.0.557.0.757)
Profitability ratios	(0.386.0.586.0.771)	(0.343.0.529.0.714)	(0.200.0.386.0.586)	(0.000.0.000.0.000)	(0.257.0.443.0.629)	(0.257.0.443.0.643)
Investors' investment ratios	(0.300.0.500.0.700)	(0.357.0.557.0.757)	(0.414.0.614.0.786)	(0.257.0.443.0.643)	(0.000.0.000.0.000)	(0.186.0.386.0.586)
Production cost ratios	(0.414.0.614.0.786)	(0.357.0.557.0.757)	(0.357.0.557.0.743)	(0.300.0.500.0.700)	(0.186.0.357.0.557)	(0.000.0.000.0.000)

To normalize the obtained matrix we use formula 1 and 2:

$$\tilde{H}_{ij} = \frac{\tilde{z}_{ij}}{r} = \left(\frac{l'_{ij}}{r}, \frac{m'_{ij}}{r}, \frac{u'_{ij}}{r}\right) = (l''_{ij}, m \qquad (1)$$

Where r calculated as following:

$$r = max_{1 \le i \le n}\left(\textstyle\sum_{j=1}^{n} u_{ij}\right) \qquad (2)$$

The normalized matrix presented in Table 3:

Table 3
Normalized Matrix of Sextet Indicators

Normalized matrix	Liquidity ratios	Activity ratios	Capital structure ratios	Profitability ratios	Investment ratios	Production cost indicators
Liquidity ratios	0.000.0.000.0.000	(0.078.0.131.0.183)	(0.078.0.131.0.183)	(0.078.0.131.0.183)	(0.086.0.138.0.187)	(0.071.0123.0.175)
Activity ratios	(0.093.0.146.0.198)	0.000.0.000.0.000	(0.108.0.160.0.209)	(0.108.0.160.0.213)	(0.101.0.153.0.201)	(0.063.0.116.0.168)
Capital structure ratios	(0.104.0.153.0.201)	(0.093.0.146.0.194)	0.000.0.000.0.000	(0.101.0.153.0.198)	(0.108.0.160.0.209)	(0.093.0.146.0.198)
Profitability ratios	(0.101.0.153.0.201)	(0.090.0.138.0.187)	(0.052.0.101.0.153)	(0.000.0.000.0.000)	(0.067.0.116.0.164)	(0.067.0.116.0.168)
Investment ratios	(0.078.0.131.0.183)	(0.093.0.146.0.198)	(0.108.0.160.0.205)	(0.067.0.116.0.168)	(0.000.0.000.0.000)	(0.049.0.101.0.153)
Production cost indicators	(0.108.0.160.0.205)	(0.093.0.146.0.198)	(0.093.0.146.0.194)	(0.078.0.131.0.183)	(0.049.0.093.0.146)	(0.000.0.000.0.000)

After calculating above mentioned matrices, matrix of total fuzzy relations is obtained, through equations 3 to 6:

$$T = \lim_{k \to +\infty}(\tilde{H}^1 \oplus \tilde{H}^2 \oplus \ldots \oplus \tilde{H}^k) \qquad (3)$$

That each element of that is a fuzzy number as $\tilde{t}_{ij} = (l^t_{ij}, m^t_{ij}, u^t_{ij})$ and is calculated as following:

$$l^t_{ij} = H_l \times (I - H_l)^{-1} \qquad (4)$$

$$m^t_{ij} = H_m \times (I - H_m)^{-1} \qquad (5)$$

$$u^t_{ij} = H_u \times (I - H_u)^{-1} \qquad (6)$$

In this formulas, I is unit matrix, and H_l, H_m, and H_u are n×n matrix which their elements are lower, middle, and upper numbers of fuzzy triangular numbers of H matrix , respectively. Table 4 shows t matrix.

Table 4
Matrix of Total Relations of Sextet Indicators

Normalized matrix	Liquidity ratios	Activity ratios	Capital structure ratios	Profitability ratios	Investment ratios	Production cost indicators
Liquidity ratios	(0.061.0.267.2.263)	(0.129.0.371.2.359)	(0.128.0.369.2.320)	(0.127.0.367.2.334)	(0.132.0.364.2.267)	(0.110.0.332.2.166)
Activity ratios	(0.157.0.424.2.600)	(0.067.0.284.2.371)	(0.164.0.419.2.505)	(0.164.0.418.2.520)	(0.155.0.403.2.438)	(0.113.0.351.2.313)
Capital structure ratios	(0.170.0.437.2.625)	(0.156.0.418.2.556)	(0.069.0.288.2.354)	(0.160.0.419.2.531)	(0.164.0.415.2.463)	(0.140.0.380.2.354)
Profitability ratios	(0.150.0.389.2.358)	(0.136.0.366.2.290)	(0.104.0.334.2.231)	(0.053.0.241.2.109)	(0.114.0.336.2.183)	(0.105.0.316.2.095)
Investment ratios	(0.134.0.384.2.424)	(0.143.0.384.2.376)	(0.155.0.394.2.345)	(0.120.0.357.2.330)	(0.055.0.246.2.117)	(0.092.0.316.2.156)
Production cost indicators	(0.164.0.415.2.477)	(0.146.0.391.2.411)	(0.145.0.388.2.371)	(0.132.0.376.2.376)	(0.104.0.338.2.278)	(0.048.0.230.2.056)

The next step is to calculate total rows and columns of the matrix T. Total rows and columns of the matrix are calculated by formulas 7 and 8:

$$\tilde{D} = (\tilde{D}_i \ )_{n\times 1} = \left[\sum_{j=1}^{n} \tilde{T}_{ij}\right]_{n\times 1} \qquad (7)$$

$$\tilde{R} = (\tilde{R}_i \ )_{1\times n} = \left[\sum_{i=1}^{n} \tilde{T}_{ij}\right]_{1\times n} \qquad (8)$$

Where D and R are matrices of $n \times 1$ and $1 \times n$, respectively.

In the next step, degree of importance of indicators $(\tilde{D}_i + \tilde{R}_i)$ and relationship between criteria $(\tilde{D}_i - \tilde{R}_i)$ is determined.

If $\tilde{D}_i - \tilde{R}_i > 0$, the respective criterion is effective and if $\tilde{D}_i - \tilde{R}_i < 0$, the respective criterion is impressible.

Table 5 shows $\tilde{D}_i + \tilde{R}_i$ and $\tilde{D}_i - \tilde{R}_i$:

Table 5
Effectiveness of the Sextet Indicators (Fuzzy Numbers)

Criteria	$\tilde{D}_i + \tilde{R}_i$	$\tilde{D}_i - \tilde{R}_i$
Liquidity ratios	(1.524.4.387.28.455)	(-14.059.-0.246.12.873)
Activity ratios	(1.596.4.512.29.109)	(-13.542.0.085.13.970)
Capital structure ratios	(1.624.4.549.29.008)	(-13.266.0.165.14.118)
Profitability ratios	(1.417.4.160.27.465)	(-13.538.-0.195.12.510)
Investors' investment ratios	(1.423.4.183.27.495)	(-13.048.-0.021.13.025)
Production cost indicators	(1.347.4.063.27.109)	(-12.402.0.213.13.360)

Next, we should defuzzify the fuzzy numbers of $\tilde{D}_i + \tilde{R}_i$ and $\tilde{D}_i - \tilde{R}_i$, that was obtained from the previous step as

$$B = \frac{(a_1+a_3+2\times a_2)}{4} \qquad (9)$$

B is defuzzified of $\tilde{A} = (a_1, a_2, a_3)$. In Table 6 you can see the defuzzified numbers of Table 5.

Table 6
Importance and Effectiveness of the Sextet Indicators (Definite Numbers)

Criteria	$(\tilde{D}_i + \tilde{R}_i)^{def}$	$(\tilde{D}_i - \tilde{R}_i)^{def}$
Liquidity ratios	9.688	-0.420
Activity ratios	9.932	0.149
capital structure ratios	9.933	0.295
Profitability ratios	9.301	-0.355
Investors' investment ratios	9.321	-0.016
Production cost ratios	9.146	0.346

Also, rate of importance and effectiveness and impressibility between aspects are presented in Figure 2. The vertical vector is importance of aspects and horizontal vector is effectiveness or impressibility.

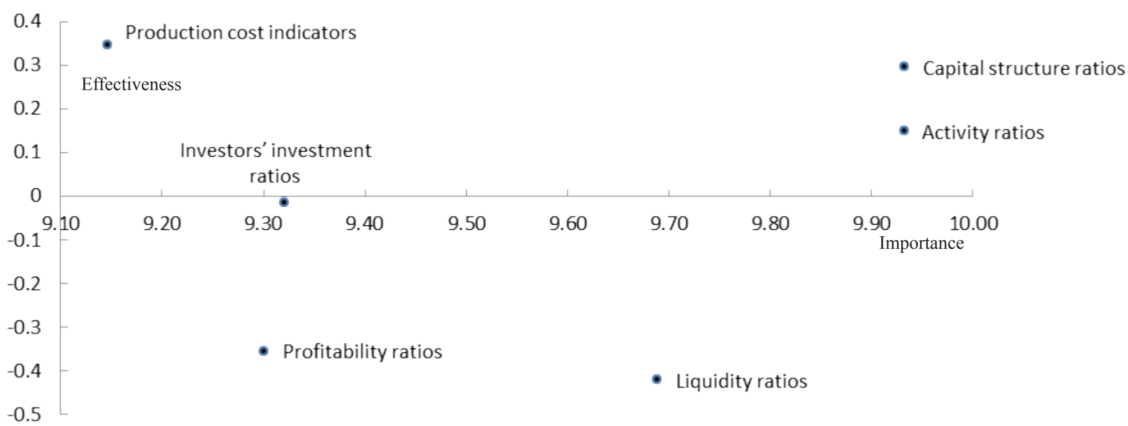

Figure 2
Effectiveness and Importance of Main Criteria

The above picture shows the position of main criteria based on importance and effectiveness. As you can see in Figure 2, capital structure activity ratios and costs of production indicators are effective, and liquidity ratios, profitability of stockers, and investments indicators are impressible. Also, Indicator of capital structure is farther from the origin in comparison to others, this means that indicator of capital structure in affecting and being affected is more important than other indicators.

2.3 Determining Causal Relationships Between Sub-criteria of Activity Ratios Indicators Using Fuzzy DEMATEL Technique

Fuzzy numbers, importance, effectiveness and impressibility of sub-criteria of activity ratios indicator, are presented in Table 7. Table 8 shows exact number of importance, effectiveness and impressibility of activity ratios indicator.

Results of the table shows that sub-criteria of operation cycle , accounts payable turnover, inventory turnover, accounts receivable turnover, and period of inventory turnover have a positive value $((\tilde{D}_i - \tilde{R}_i)^{def})$, thus they are highly effective. While, total fixed assets turnover, payment period of accounts payable, total assets turnover, and average of collection period, have negative values in this parameter and are impressible.

Table 7
Importance and Effectiveness of Sub-criteria (Fuzzy Numbers)—Indicator of Activity Ratios

Criteria	$\tilde{D}_i + \tilde{R}_i$	$\tilde{D}_i - \tilde{R}_i$
Total asset turnover	(1.904.5.100.28.649)	(-13.713.-0.144.13.032)
Fixed assets turnover	(1.692.4.672.26.849)	(-12.969.-0.179.12.188)
Total asset turnover	(2.032.5.314.29.390)	(-13.421.0.146.13.937)
Total merchandise inventory Turnover period	(1.963.5.198.29.003)	(-13.436.0.012.13.604)
Accounts payable turnover	(1.950.5.154.28.819)	(-13.317.0.024.13.552)
Average collection period	(1.762.4.816.27.548)	(-13.085.-0.100.12.701)
Accounts payable turnover	(1.761.4.815.27.335)	(-12.438.0.187.13.136)
Accounts payable turnover period	(1.680.4.630.26.621)	(-12.838.-0.132.12.102)
Activities turnover period	(1.750.4.822.27.630)	(-12.458.0.186.13.422)

Table 8
Importance and Effectiveness of Criteria (Exact Numbers)—Indicator of Activity Ratios

Criteria	$(\tilde{D}_i + \tilde{R}_i)^{def}$	$(\tilde{D}_i - \tilde{R}_i)^{def}$
TOTAL ASSET TURNOVER	10.188	-0.242
Fixed assets turnover	9.471	-0.284
Total inventory turnover	10.513	0.202
Total inventory turnover period	10.340	0.048
Accounts receivable turnover	10.269	0.071
Average collection period	9.736	-0.146
Accounts payable turnover	9.681	0.268
Accounts payable turnover period	9.390	-0.250
Activities turnover period	9.756	0.334

On one hand, since sub-criteria of total assets turnover is farther from origin than other sub-criteria, it is of higher importance. You can see this in following figure.

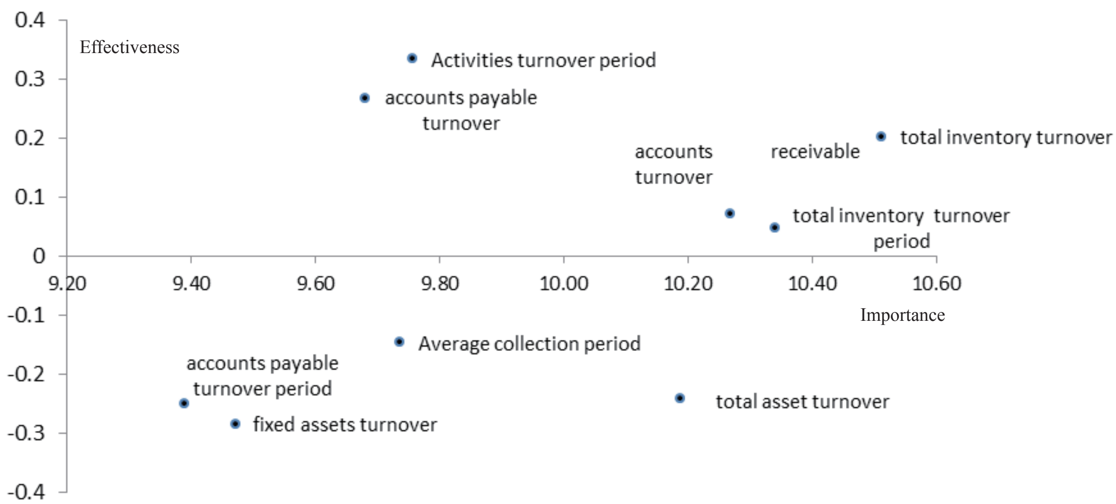

Figure 3
Effectiveness and Importance of Sub-criteria of Activity Ratios Indicator

Note. The process of calculating importance and effectiveness for other financial ratios is same as above. To keep the story short, only the final diagram of each group is presented.

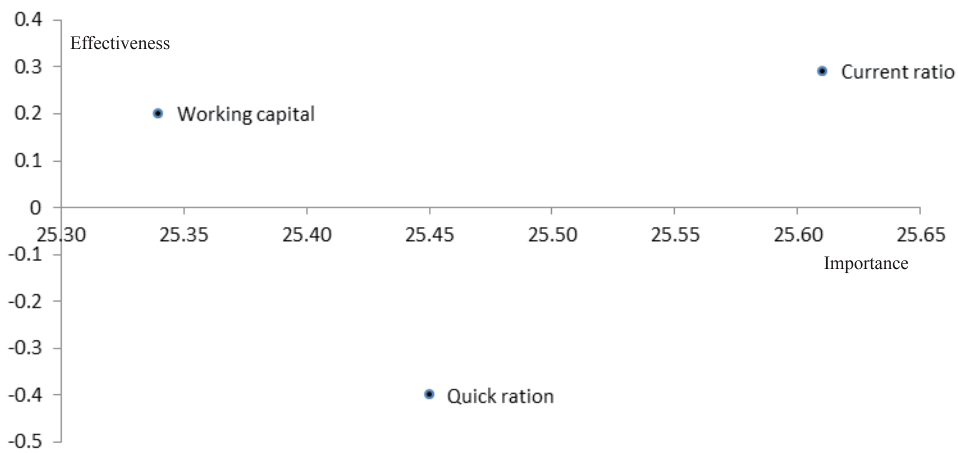

Figure 4
Effectiveness and Importance of Sub-criteria of Liquidity Indicator

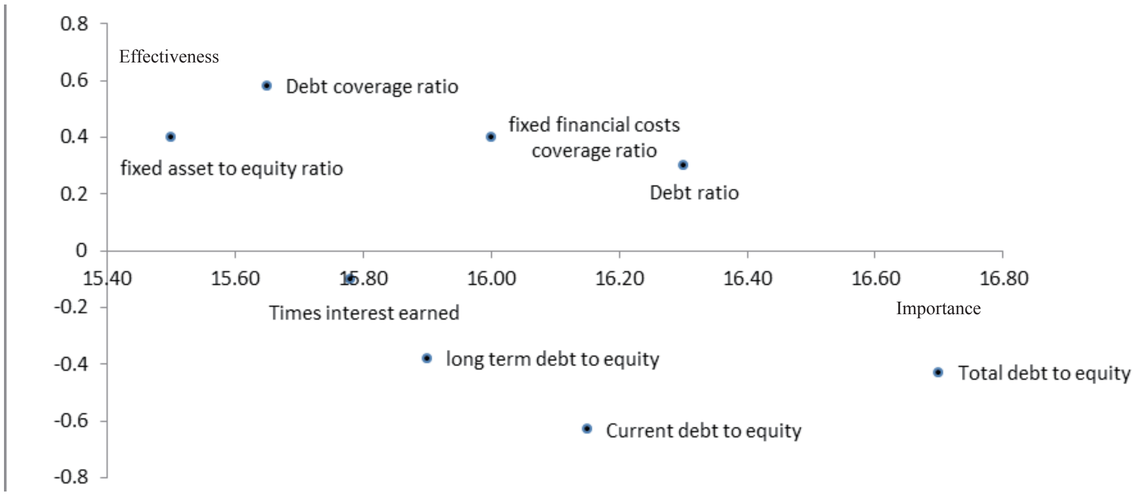

Figure 5
Effectiveness and Importance of Sub-criteria of Capital Structure Ratio Indicator

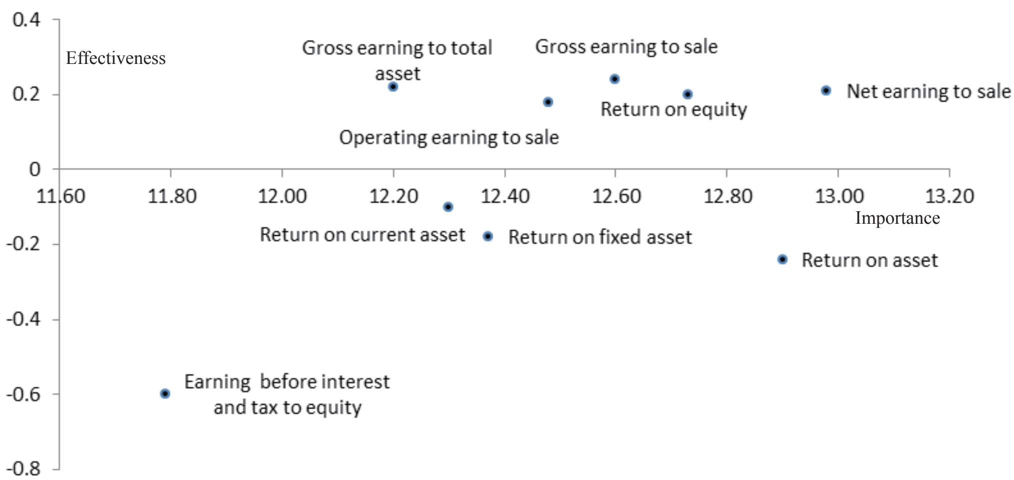

Figure 6
Effectiveness and Importance of Sub-criteria of Profitability Ratios Indicator

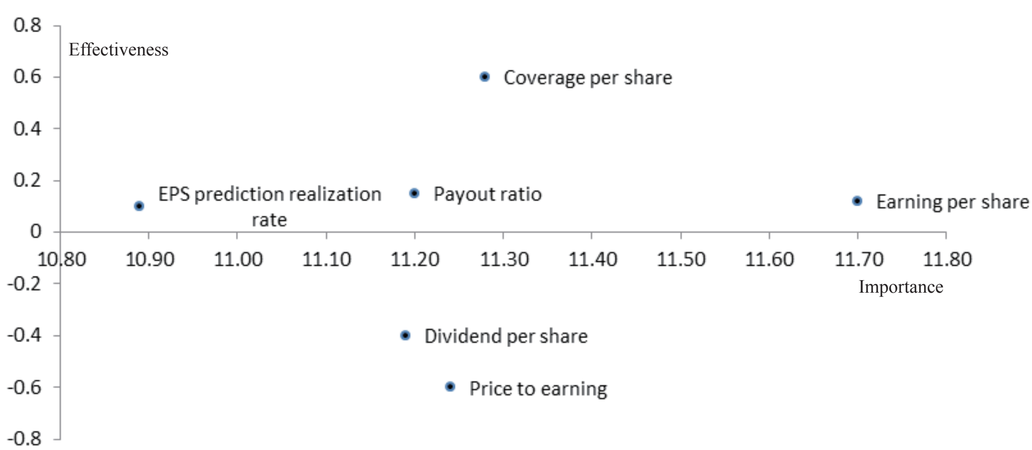

Figure 7
Effectiveness and Importance of Sub-criteria of Shareholders Indicator of Investment Ratios

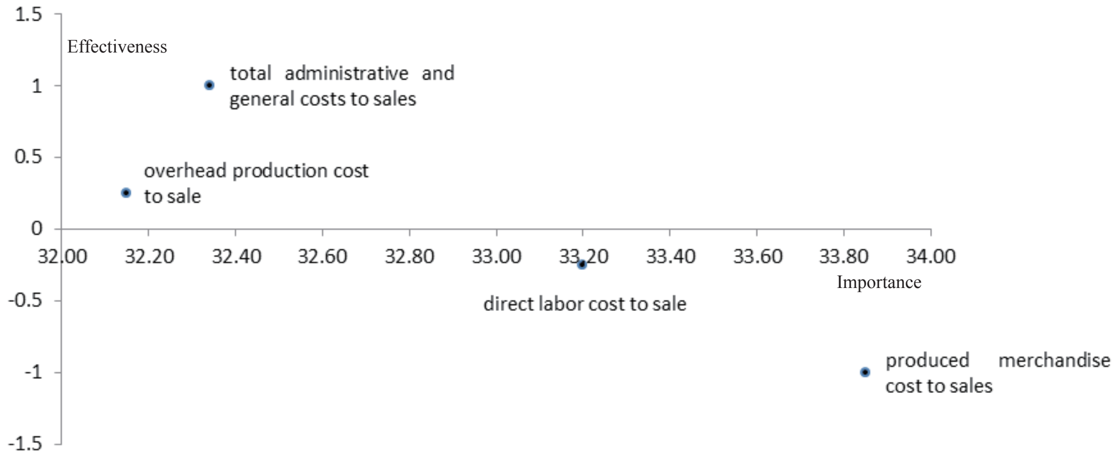

Figure 8
Effectiveness and Importance of Sub-criteria of Indicator of Profitability Ratios

2.4 Results of Fuzzy ANP Technique

To this end, paired comparison questionnaires were designed and distributed among experts. According to fuzzy approach, we used verbal phases and fuzzy numbers. Method suggested by Gogus and Boucher (1998) was used for calculating consistency. They suggested that in order to investigate consistency of two matrices (middle number and fuzzy numbers limits) we differentiate each matrix and then calculate consistency of each matrix based on Saaty' method. Consistency rate of fuzzy matrices of paired comparisons can be calculated is as follows:

Step 1: First divide the fuzzy triangular matrix in two.

The first matrix is formed from middle numbers of triangular judgment ($A^m = [a_{ijm}]$) and the second matrix consists of geometric mean of high and low limit of triangular numbers ($A^g = \sqrt{a_{iju}.a_{ijl}}$).

Step 2: Calculate the weight vector by Saaty' method:

$$w_i^m = \frac{1}{n}\sum_{j=1}^{n}\frac{a_{ijm}}{\sum_{i=1}^{n} a_{ijm}} \tag{10}$$

Where

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

$$w_i^g = \frac{1}{n}\sum_{j=1}^{n}\frac{\sqrt{a_{iju}.a_{ijl}}}{\sum_{i=1}^{n}\sqrt{a_{iju}.a_{ijl}}} \tag{11}$$

Where

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

Step 3: Calculate the largest eigenvalue for each matrix by following equations:

$$\lambda_{\max}^m = \frac{1}{n}\sum_{i=1}^{n}\sum_{j=1}^{n} a_{ijm}\left(\frac{w_j^m}{w_i^m}\right) \tag{12}$$

$$\lambda_{\max}^g = \frac{1}{n}\sum_{i=1}^{n}\sum_{j=1}^{n}\sqrt{a_{iju}.a_{ijl}}\left(\frac{w_j^g}{w_i^g}\right) \tag{13}$$

Step 4: Calculate the compatibility indicator by these equations:

$$CI^m = \frac{(\lambda_{\max}^m - n)}{(n-1)} \tag{14}$$

$$CI^g = \frac{(\lambda_{\max}^g - n)}{(n-1)} \tag{15}$$

Step 5: To calculate consistency rate (CR), divide the CI indicator by random indicator (RI). If the value is less than 0.1, the matrix is consistent and practical. To calculate values of random indicators, Saaty (1998) formed 100 matrices with random numbers on condition of their mutuality and calculated consistency values and their mean.

But since numerical values of fuzzy comparisons are not always integer and if so geometric mean generally converts them into non-integers. Even by making use of Saaty' (1-9) measure, we can't take advantage from table of random indicators of Saaty. Therefore, Gogus and Boucher (1998) regenerated 400 random matrices, again developed Table 9 of random indicators (RI) for fuzzy paired comparison matrices.

Table 9
Random Indicators (RI)

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

To generate random matrices, first middle value of triangular fuzzy number was randomly generated in [1/9, 9] interval, reciprocally. Then lower limit of each triangular number in interval [1/9, generated middle value] and its upper limit in interval [generated middle value, 1/9] are generated randomly and eventually after dividing the obtained random matrix by two matrices of middle limit and geometric mean of upper and lower limit, their random indicator value was obtained. You should note that inconsistency in column RI^m is higher than column RI^g. This difference is because range of generated random numbers for middle limit [1/9, 9], but range of random numbers of lower and upper limits are more restricted based on middle number and so they are less probable to be inconsistent. By calculating inconsistency rate of the two matrices based on the below relations, we compare them with 0.1 threshold.

$$CR^g = \frac{CI^g}{RI^g} \tag{16}$$

$$CR^m = \frac{CI^m}{RI^m} \tag{17}$$

If both of these indicators were less than 0.1, the fuzzy matrix is consistent. If both were more than 0.1, the decision-maker will be asked to reconsider presented priorities, and if they were only $CR^m(CR^g)$ more than 0.1, decision maker can reconsider middle values (limit) of fuzzy judgments. Now based on these descriptions, we will have a look at results of fuzzy ANP.

Based on super matrix, steps of calculating weight of elements is as follows:

First Step: To compile views of experts, we calculate geometric mean of participants paired comparison.

Second Step: Calculating eigenvector: According to equation 9, to calculate the eigenvector of each compiled paired comparison table, we use algorithmic method of least squares. In a way that:

$$w_k^s = \frac{\left(\prod_{j=1}^{n} a_{kj}^s\right)^{1/n}}{\sum_{i=1}^{n}\left(\prod_{j=1}^{n} a_{j}^m\right)^{1/n}}, \quad s \in \{l, m, u\} \tag{18}$$

Where:

$$\tilde{w}_k = (w_k^l, w_k^m, w_k^u) \quad k = 1,2,3,...,n$$

Geometric mean of experts' view is presented in Table 10. In the last column of these tables, eigenvector is shown.

Table 10
Average of Paired Comparisons in Respect to Target

Goal	Liquidity ratios	Activity ratios	Capital structure ratios	Profitability ratio	Investment ratio	Production cost indicators	Eigenvector
Liquidity ratios	(1.1.1)	(0.394.0.696.1.28)	(0.234.0.349.0.65)	(0.13.0.17.0.3)	(1.1.96.3.192)	(0.64.1.02.1.5)	(0.06.0.087.0.134)
Activity ratios	(0.795.1.436.2.536)	(1.1.1)	(1.17.1.809.3.386)	(0.27.0.2.0.65)	(2.275.4.4.6.11)	(1.1.744.2.967)	(0.12.0.188.0.286)
Capital structure ratio	(1.526.2.863.4.266)	(0.295.0.553.0.85)	(1.1.1)	(0.26.0.28.0.4)	(1.83.2.95.3.86)	(0.95.1.62.2.4)	(0.1.0.149.0.20)
Profitability ratios	(3.433.5.634.7.702)	(1.526.2.36.3.687)	(2.302.3.51.4.061)	(1.1.1)	(4.66.6.53.7.93)	(2.47.3.96.5.3)	(0.29.0.427.0.5)
Investment ratios	(0.313.0.509.1)	(0.154.0.218.0.44)	(0.261.0.341.0.53)	(012.0.15.0.2)	(1.1.1)	(0.26.0.44.0.7)	(0.03.0.048.0.07)
Production cost indicator	(0.671.0.975.1.545)	(0.337.0.574.1)	(0.40.0.602.1.049)	(0.17.0.2.0.40)	(1.38.2.47.4.06)	(1.1.1)	(0.069.0.1.0.15)

Note. CRm =0.023; CRg =0.065; consistent.

Paired comparison average of sub-criteria is like Table 15. For example you can see one of indicators with its sub indicators in title 11, and to keep it short final results of other indicators is presented in Table 11.

Table 11
Average of Paired Comparisons of Production Cost Ratio Sub-criteria

Production cost ratios	Ratio of produced merchandise cost to sales	Ratio of direct labor cost to sale	Ratio of production overhead to sale	Ratio of total administrative and general costs to sales	Eigenvector
Ratio of produced merchandise cost to sales	(1.1.1)	(1.66.2.935.4.319)	(1.873.3.312.5.23)	(2.863.5.174.7.081)	(0.339.0.523.0.699)
Ratio of direct labor cost to sale	(0.232.0.341.0.602)	(1.1.1)	(0.514.0.757.1.12)	(2.935.5.237.7.34)	(0.151.0.212.0.2)
Ratio of overhead production cost to sale	(0.191.0.302.0.534)	(0.886.1.32.1.944)	(1.1.1)	(1.601.2.536.3.39)	(0.142.0.197.0.26)
Ratio of total administrative and general costs to sales	(0.141.0.193.0.349)	(0.136.0.191.0.341)	(0.295.0.394.0.624)	(1.1.1)	(0.054.0.068.0.103)

Note. CRm =0.07; CRg =0.094; consistent

Third Step: Developing matrices of eigenvector (W_i): These matrices consist of eigenvectors that were obtained from paired comparisons of the second step. Generally these matrices can be divided into two groups:

1. Matrices that include eigenvectors, which show between-surface (vertical) relations. If there were no between-surface relations between the two components, (0, 0, 0) is placed in their intersection in matrix. In rest of the elements, considering vertical relation of elements, eigenvector's value that was obtained from second step is placed.

2. Matrices that include eigenvectors, that that show horizontal (inter surface) relations. These matrices are square and their main diameter is (1, 1, 1). If there were no inter surface relations between the two components, (0, 0, 0) is placed in their intersection in matrix. In rest of the elements, considering horizontal relation of elements, eigenvector's value that was obtained from second step is placed. Here we determine this matrix using DEMATEl technique. See Table 12 for details. Matrices of eigenvector are presented in Table 13 and 14.

Table 12
Results of Consistency of Paired Comparisons

Sub-criteria Comparison	CR^g	CR^m	Consistency
Paired Comparison of Sub-criteria of production costs ratios indicator	CR^g =0.094	CR^m =0.07	Consistent
Paired Comparison of Sub-criteria of liquidity ratios indicator	CR^g =0.005	CR^m =0.004	Consistent
Paired Comparison of Sub-criteria of activity ratios indicator	CR^g =0.053	CR^m0.022	Consistent
Paired Comparison of Sub-criteria of capital structure ratios indicator	CR^g =0.065	CR^m =0.05	Consistent
Paired Comparison of Sub-criteria of profitability ratios indicator	CR^g =0.091	CR^m =0.037	Consistent
Paired Comparison of Sub-criteria of investors investment ratios indicator	CR^g =0.03	CR^m0.02	Consistent

Table 13
Eigenvector Matrix of Sextet Indicators in Relation to Target

Indicators	Goal
Liquidity ratios	(0.058.0.087.0.134)
Activity ratios	(0.119.0.188.0.286)
Capital structure ratio	(0.1.0.149.0.205)
Profitability ratios	(0.293.0.427.0.547)
Investors' investment ratios	(0.035.0.048.0.076)
Production cost indicators	(0.069.0.101.0.154)

Table 14
Part of Matrix of Sub-criteria Eigenvector in Relation to Sextet Indicators

	Liquidity ratios	Activity ratios	Capital structure ratio	Profitability ratios	Investors' investment ratios	Production cost indicators
Current ratio	(0.21.0.27.0.45)	(0.0.0)	(0.0.0)	(0.0.0)	(0.0.0)	(0.0.0)
Fast ratio	(0.22.0.33.0.52)	(0.0.0)	(0.0.0)	(0.0.0)	(0.0.0)	(0.0.0)
Working capital	(0.26.0.36.0.44)	(0.0.0)	(0.0.0)	(0.0.0)	(0.0.0)	(0.0.0)
Total asset turnover	(0.0.0)	(0.04.0.06.0.11)	(0.0.0)	(0.0.0)	(0.0.0)	(0.0.0)
Fixed asset turnover	(0.0.0)	(0.03.0.04.0.078)	(0.0.0)	(0.0.0)	(0.0.0)	(0.0.0)
Total inventory turnover	(0.0.0)	(0.06.0.10.0.16)	(0.0.0)	(0.0.0)	(0.0.0)	(0.0.0)
Merchandise inventory turnover period	(0.0.0)	(0.06.0.1.0.15)	(0.0.0)	(0.0.0)	(0.0.0)	(0.0.0)
Accounts receivable turnover	(0.0.0)	(0.08.0.14.0.23)	(0.0.0)	(0.0.0)	(0.0.0)	(0.0.0)
Average collection period	(0.0.0)	(0.11.0.19.0.27)	(0.0.0)	(0.0.0)	(0.0.0)	(0.0.0)
Accounts payable turnover	(0.0.0)	(0.04.0.08.0.14)	(0.0.0)	(0.0.0)	(0.0.0)	(0.0.0)
Accounts payable turnover period	(0.0.0)	(0.06.0.09.0.17)	(0.0.0)	(0.0.0)	(0.0.0)	(0.0.0)
Activities turnover period	(0.0.0)	(0.09.0.16.0.23)	(0.0.0)	(0.0.0)	(0.0.0)	(0.0.0)
Debt ratio	(0.0.0)	(0.0.0)	(0.09.0.1.0.22)	(0.0.0)	(0.0.0)	(0.0.0)

2.5 Determining Final Weight of Model Variables

In this step we multiply weights obtained from fuzzy ANP and fuzzy DEMATEL, and the output is fuzzy weight of quadruplet dimensions with respect to target and internal relations. To multiply these two matrices, first matrix of main criteria total relations that was obtained from fuzzy DEMATEl should be normalized. Table 15 shows normalized matrices of total relations.

Table 15
Normalized Matrix of Total Relations-Sextet Indicators

Normalized matrix	Liquidity ratios	Liquidity ratios	Capital structure ratio	Profitability ratios	Investment ratios	Production cost indicator
Liquidity ratios	(0.026.0.115.0.979)	(0.058.0.168.1.064)	(0.058.0.168.1.060)	(0.058.0.168.1.070)	(0.062.0.173.1.078)	(0.057.0.173.1.125)
Activity ratios	(0.068.0.183.1.127)	(0.030.0.128.1.073)	(0.074.0.191.1.144)	(0.075.0.192.1.157)	(0.073.0.192.1.163)	(0.058.0.182.1.205)
capital structure ratio	(0.073.0.189.1.137)	(0.070.0.189.1.157)	(0.031.0.131.1.075)	(0.073.0.192.1.162)	(0.078.0.197.1.175)	(0.072.0.198.1.226)
Profitability ratio	(0.065.0.164.1.018)	(0.061.0.163.1.037)	(0.047.0.150.1.019)	(0.024.0.110.0.964)	(0.054.0.157.1.040)	(0.054.0.161.1.089)
investment ratios	(0.058.0.166.1.050)	(0.064.0.173.1.076)	(0.070.0.180.1.071)	(0.055.0.163.1.070)	(0.026.0.117.1.010)	(0.047.0.164.1.123)
production cost indicator	(0.071.0.179.1.073)	(0.066.0.177.1.091)	(0.066.0.177.1.083)	(0.060.0.172.1.091)	(0.049.0.161.1.086)	(0.025.0.119.1.071)

Note. After multiplying the above matrix in matrices of Table 15, we get Table 16 that shows the final weight of sextet indicators in relation to target.

Table 16
Final Weight of Main Criteria in Relation to Target

Indicator	Goal	Final indicator weight
Liquidity ratios	(0.037.0.163.1.482)	0.163555
Activity ratios	(0.043.0.177.1.587)	0.176036
Capital structure ratio	(0.045.0.182.1.605)	0.179001
Profitability ratios	(0.028.0.137.1.405)	0.149356
Investors' investment ratios	(0.038.0.165.1.491)	0.164863
Production cost indicators	(0.039.0.167.1.510)	0.167188

2.6 Calculating Final Weight of Sub-criteria of Sextet Indicators

In this step as well, we normalize the matrix of total relations of Sub-criteria obtained from fuzzy DEMATEl. Table 17 shows part of normalized matrix of sextet indicators sub-criteria. After multiplying this matrix in matrix (14), we get matrix 18 which shows the final weight of sextet indicators' sub-criteria in relation to sextet indicators. Table 17. Normalized matrix of total relations of sextet indicators' sub-criteria

Table 17
Normalized Matrix of Total Relations of Sextet Indicators' Sub-criteria

Sub-criteria	Current ratio	Fast ratio	Working capital	...	Ratio of produced merchandise cost to sales	Ratio of direct labor cost to sale	Ratio of overhead production cost to sale	Ratio of total administrative and general costs to sales
Current ratio	(0.077.0.29.3.0)	(0.13.0.36.3.18)	(0.1.0.36.3.3)	...	0.0000	0.0000	0.0000	0.0000
Fast ratio	(0.125.0.35.3.0)	(0.07.0.28.3.05)	(0.12.0.38.3.)	...	0.0000	0.0000	0.0000	0.0000
Working capital	(0.12.0.35.3.1)	(0.12.0.35.3.12)	(0.07.0.28.3.)	...	0.0000	0.0000	0.0000	0.0000
.	.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.	.
Produced inventory cost to sales	0.0000	0.0000	0.0000	...	(0.04.0.20.4.5)	(0.09.0.26.4.7)	(0.09.0.26.4.8)	(0.09.0.27.4.94)
Direct labor cost to sale	0.0000	0.0000	0.0000	...	(0.11.0.26.4.6)	(0.04.0.2.4.7)	(0.08.0.26.4.8)	(0.08.0.26.4.94)
Overhead production cost to sale	0.0000	0.0000	0.0000	...	(0.09.0.26.4.57)	(0.09.0.25.4.7)	(0.04.0.1.4.6)	(0.08.0.25.4.81)
Total administrative and General costs to sales	0.0000	0.0000	0.0000	...	(0.09.0.26.4.68)	(0.09.0.27.4.8)	(0.09.0.26.4.8)	(0.04.0.20.4.9)

Finally, to determine final weight of sextet sub-criteria in relation to target, matrix of Table 18 is multiplied in final weight of sextet indicators in relation to target (Table 16). Final weight of sextet sub-criteria in relation to target is presented in Table 19. See Table 18 and Table 19 for details.

Table 18
Final Weight of Sub-criteria in Relation to Sextet Indicators

Sub-criteria \ Sextet indicators	Liquidity ratios	Activity ratios	Capital structure ratio	Investment ratio	Profitability ratio	Production cost indicators
Current ratio	(0.082.0.343.4.39)	(0.0.0)	(0.0.0)	(0.0.0)	(0.0.0)	(0.0.0)
Fast ratio	(0.077.0.326.4.24)	(0.0.0)	(0.0.0)	(0.0.0)	(0.0.0)	(0.0.0)
Working capital	(0.076.0.329.4.32)	(0.0.0)	(0.0.0)	(0.0.0)	(0.0.0)	(0.0.0)
Total asset turnover	(0.0.0)	(0.025.0.113.1.)	(0.0.0)	(0.0.0)	(0.0.0)	(0.0.0)
Fixed assets turnover	(0.0.0)	(0.022.0.102.0.93)	(0.0.0)	(0.0.0)	(0.0.0)	(0.0.0)
Total inventory turnover	(0.0.0)	(0.029.0.123.1.05)	(0.0.0)	(0.0.0)	(0.0.0)	(0.0.0)
Dividends profit per share	(0.0.0)	(0.0.0)	(0.0.0)	(0.037.0.15.1.53)	(0.0.0)	(0.0.0)
…	…	…	…	…	…	…
Coverage per share	(0.0.0)	(0.0.0)	(0.0.0)	(0.043.0.176.1.69)	(0.0.0)	(0.0.0)
EPS prediction realization rate	(0.0.0)	(0.0.0)	(0.0.0)	(0.037.0.16.1.59)	(0.0.0)	(0.0.0)
Ratio of produced merchandise cost to sales	(0.0.0)	(0.0.0)	(0.0.0)	(0.0.0)	(0.0.0)	(0.049.0.233.6.344)
Ratio of direct labor cost to sale	(0.0.0)	(0.0.0)	(0.0.0)	(0.0.0)	(0.0.0)	(0.059.0.253.6.373)
Ratio of overhead production cost to sale	(0.0.0)	(0.0.0)	(0.0.0)	(0.0.0)	(0.0.0)	(0.056.0.246.6.313)
Ratio of total administrative and general costs to Sales	(0.0.0)	(0.0.0)	(0.0.0)	(0.0.0)	(0.0.0)	(0.062.0.263.6.476)

Table 19
Final Weight of the Sextet Indicators Sub-criteria in Relation to Target

	Sub-criteria	Goal	Final definite weight of indicators
1	Ratio of total administrative and general costs to sales	(0.002.0.044.9.785)	0.077121
2	Ratio of direct labor cost to sale	(0.002.0.042.9.629)	0.0764356
3	Ratio of produced merchandise cost to sales	(0.001.0.039.9.586)	0.076384
4	Ratio of overhead production cost to sale	(0.002.0.041.9.539)	0.076093
5	Current ratio	(0.003.0.056.6.517)	0.052866
6	Working capital	(0.002.0.053.6.407)	0.051937
7	Fast ratio	(0.002.0.053.6.296)	0.05105
8	Debt ratio	(0.001.0.023.3.243)	0.026174
9	Fixed financial costs coverage ratio	(0.001.0.023.3.197)	0.025828
10	Debt coverage ratio	(0.001.0.023.3.181)	0.025681
11	Ratio of total debt to equity	(0.001.0.022.3.182)	0.025666
12	Ratio of fixed assets to equity	(0.001.0.022.3.131)	0.025261
13	Times interest earned	(0.001.0.021.3.090)	0.024923
14	Ratio of long term debt to equity	(0.001.0.022.3.063)	0.024712
15	Ratio of current debt to equity	(0.001.0.021.3.044)	0.024557
16	Coverage Per Share	(0.001.0.029.2.525)	0.020724
17	Earnings per share	(0.001.0.029.2.498)	0.020537
18	Payout ratio	(0.001.0.027.2.427)	0.019905
19	EPS prediction realization rate	(0.001.0.026.2.371)	0.01943
20	Dividends Per Share	(0.001.0.026.2.317)	0.018995
21	Ratio of Price to earning	(0.001.0.025.2.305)	0.018886
22	Total inventory turnover	(0.001.0.021.1.691)	0.013957
23	Total merchandise inventory turnover period	(0.001.0.020.1.655)	0.013646
24	Accounts receivable turnover	(0.001.0.020.1.640)	0.01351
25	Activities turnover period	(0.001.0.019.1.609)	0.013235
26	Total asset turnover	(0.001.0.020.1.594)	0.013131
27	Accounts payable turnover	(0.001.0.020.1.584)	0.013057
28	Average collection period	(0.000.0.018.1.536)	0.012627
29	Fixed assets turnover	(0.000.0.018.1.486)	0.012224
30	Accounts payable turnover period	(0.000.0.017.1.468)	0.012083
31	Ratio of net Earning to sale	(0.000.0.016.1.394)	0.011442
32	Return on Equity (ROE)	(0.000.0.015.1.365)	0.011191
33	Ratio of gross Earning to sale	(0.000.0.015.1.362)	0.011174
34	Return on Asset (ROA)	(0.000.0.015.1.342)	0.011008
35	Ratio of operating Earning to sale	(0.000.0.015.1.341)	0.010993
36	Ratio of gross Earning to total assets	(0.000.0.015.1.331)	0.010918
37	Return on fixed asset	(0.000.0.014.1.314)	0.010778
38	Return on current asset	(0.000.0.014.1.289)	0.010567
39	Earning before interest and tax to equity	(0.000.0.013.1.209)	0.009901

CONCLUSION

Based on findings of this research, Cost and liquidity ratios are the most important and effective ratios, and this is in accordance with results of Dater, Naik. and Radcliffe (1998), Jun, Marathe, and Shawky (2002), Olsen and Charles (2003), Edirisinghe and Zhang (2008), Nagy and Obenberger (1994), Babic and Plazibat (1998), Namazi and Zare (2004). we can infer that if a company couldn't cover its needs from current assets or in order to fulfill company's goals, it couldn't accomplish its short term commitments, or it's asset's liquidity face problems, these problems will hinder company's long term activity, and will lower companies credibility due to not accomplishing short term commitments, and this will increase cost of financing for the company, and this deceases companies profit and this cycle will decease shares value and rank of the company.

Next group of ratios that are after ratios of costs and liquidity, are related to capital structure that these results are in accordance with results of Keim and Stambaugh (1986), Campbell (1987), Fama and French (1988; 1989), Hodrick (1992), Xing (2002), Edirisinghe et al. (2008), Babic and Plazibat (1998), Lewellen (2003), Nagy and Obenberger (1994), Namazi and Zare' (2004), Hamedian (2000), Delbari (2001), Ahmadpour (2009), Amiri, Shariatpanahi, and Banakar (2010). This means that ratio of capital structure is among the most important and effective ratios in finance. Financial leverage can be considered as one of the most important and effective ratios in stock selection. Investors consider these ratios very important because these ratios justify financing costs, business risk rate, and financial risk of the company.

Next ratios are related to activity ratios. This result is in line with results of Edirisinghe and Zhang (2008), Johnson and Soenen (2003), Babic and Plazibat (1998), Hodrick (1992), Xing (2002), Gholizade (2004), Momeni and Najafimoghadam (2010). It can be inferred that companies that their activity ratios are distant from industry, cannot be suitable companies for investment. Because in these companies most of company's resources are left useless, or its assets are not proportional with production goals, or its collection policy and/or sales policy is not effective. The next reason can be existence of monopolistic market of material suppliers. Another reason can be abundance of manufacturers in that industry, that shows existence of competitive markets that reduce these ratios.

REFERENCES

Abdel-Kader, M. G., Dugdale, D. & Taylor, P. (1998). *Investment decisions in advanced manufacturing technology*: *A fuzzy set theory approach*. Aldershot, UK: Ashgate Publishing.

Abdullah, L., & Jamal, J. (2011). Weight determination of health related quality of life indicators: A fuzzy decision making method. *Applied Research in Quality of Life*, *6*, 349-361.

Abdullah, L., Jaafar, J., & Taib, I. (2009). A new analytic hierarchy process in multi-attribute group decision making. *International Journal of Soft Computing*, *4*, 208-214.

Abdullah, L., & Jamal, J. (2010). Centroid-point of ranking fuzzy numbers and its application to health related quality of life indicators. *International Journal on Computer Science and Engineering*, *2*, 2773-2777.

Ahmadpour, A., Akbarpoorshirazi, M., & Amiri, R. Z. (2009). Using multi indicator decision making models for stock selection. *Quarterly Journal of Securities Exchange*, *5*, 5-38.

Amid, A., Ghodsypour, S. H., & O'Brien, C. (2006). Fuzzy multi-objective linear model for supplier selection in a supply chain. *International Journal of Production Economics*, *104*, 394-407.

Amiri, M., Shariatpanahi, M., & Banakar, M. H. (2010). Efficient stock portfolio selection, using multi-criteria decision-making. *Quarterly Journal of Securities Exchange*, (11), 5-24.

Babic, P., & Plazibat, L. (1998). Ranking of enterprises based on multicriteria analysis. *International Journal of Production Economics*, *56*, 29-35.

Bellman, R. G., & Zadeh, L. A. (1970). Decision making a fuzzy environment. *Management Sciences*, *17*, B141-B164.

Benachenhou, D. (1996). *Smart trading with FRET*, *trading on the edge*. New York, NY: Wiley.

Bojadziev, G., & Bojadziev, M. (1997). Fuzzy logic for business, finance, and management. Singapore: World Scientific Publishing Co.

Buckley, J. J., Eslami, E., & Feuring, T. (2002). *Fuzzy mathematics in economics and engineering*. Heidelberg, Germany: Physica-Verlag.

Campbell, J. Y. (1987). Stock returns and the term structure. *Journal of Financial Economics*, *18*, 373-399.

Colson, G., & Bruyn, C. D. (1989). Models and methods in multiple objectives decision making. *Mathematical Computer Modelling*, *14*, 1201-1211.

Dater, V., Naik, N., & Radcliffe, R. (1998). Liquidity and stock returns: An alternative test. *Journal of Financial Market*, *1*, 203-219.

Deboeck, G. J. (1996). *Trading on the edge*. New York, NY: Wiley.

Delbari, M. (2001). *Examining effective criteria on stock selection in Tehran Stock Exchange based on hierarchical analysis process model* (Master's thesis). Faculty of Economics and Administrative Sciences, University of Esfahan, Iran.

Dourra, H., & Siy, P. (2002). Investment using technical analysis and fuzzy logic. *Fuzzy Sets and Systems*, *127*, 221-240.

Dulmin, R., & Mininno, V. (2003). Supplier selection using a multi-criteria decision aid method. *Journal of Purchasing and Supply Management*, *9*, 177-187.

Edirisinghe, N. C. P., & Zhang, X. (2008). Portfolio selection under DEA-based relative financial strength indicators: Case of US industries. *Journal of the Operational Research Society*, *59*, 842-856.

Elton, E. J., Gruber, M. J., Agrawal, D., & Mann, C. (2001). Explaining the rate spread on corporate bonds, *Journal of Finance*, *59*, 247-277.

Eugene, F., & French, K. R. (1989). Business conditions and expected returns on stocks and bounds. *Journal of Financial Economics*, *25*, 23-49.

Fama, E., & French, K. R. (1988). Dividend yields and expected stock returns. *Journal of Financial Economics*, *22*, 3-8.

Francis, J. C. (1993). *Management of investment* (3rd ed.). New York, NY: McGraw-Hill Inc.

Gholizadeh, M. H. (2004). *Designing model of ranking Tehran Stock Exchange companies*, *using data envelopment analysis* (Doctoral dissertation). Faculty of Management, Uninersity of Tehran, Iran.

Gogus, O., & Boucher, T. O. (1998). Strong transitivity, rationality and weak monotonicity in fuzzy pairwise comparisons. *Fuzzy Sets and Systems*, *94*, 133-144.

Götze, U., Northcott, D., & Schuster, P. (2007). *Investment appraisal*: *Methods and models*. Berlin, Germany: Heidelberg Springer-Verlag.

Hodrick, R. J. (1992). Dividend yield and expected stock returns: Alternative procedures for inference and measurement. *The Review of Financial Studies*, *5*, 357-386.

Ishii, H., Lee, Y. L., & Yeh, K. Y. (2007). Fuzzy facility location problem with preference of candidate sites. *Fuzzy Sets and Systems*, *158*, 1922-1930.

Johnson, R., & Soenen, L. (2003). Indicators of successful companies. *European Management Journal*, *21*, 364-369.

Jun, S. G., Marathe, A., & Shawky, H. A. (2002). Liquidity and stock returns in emerging equity markets. *Emerging Markets Review*, *4*, 1-24.

Kamdem, J. S., & Moussa, M. A., Terraza, M. (2012). Fuzzy risk adjusted performance measures: Application to hedge funds. *Insurance*: *Mathematics and Economics*, *51*, 702-712.

Karanovica, G. B. G. (2012). Application of fuzzy logic in determining cost of capital for the capital budgeting process. *Procedia Economics and Finance*, *3*, 78-83.

Keim, D. B., & Stambaugh, R. F. (1986). Predicting returns in the stock and bond market. *Journal of Financial Economics*, *17*, 357-390.

King, R. T. F. A., Radha, B., & Rughooputh, H. C. S. (2004). *A fuzzy logic controlled genetic algorithm for optimal electrical distribution network reconfiguration* (pp. 577-582). Paper presented at Proceedings of 2004 IEEE international conference on networking, sensing and control, Taipei, Taiwan.

Kosko, B. (1993). *Fuzzy thinking*: *The new science of fuzzy logic*. New York, NY: Hyperion.

Lam, K. P., Chiu, K. C., & Chan, W. G. (1996). *Neural network in financial engineering*: *An embedded fuzzy knowledge base for technical analysis of stocks*. Singapore: World Scientific Publishing Co.

Lewellen, J. (2003). Predicting return with financial ratios. *Journal of Financial Economics*, *74*(2), 209-235.

Li, Y. P., Huang, G. H., Yang, Z. F., & Nie, S. L. (2008). IFMP: Interval-fuzzy multistage programming for water resources management under uncertainty. *Resources*, *Conservation and Recycling*, *52*, 800-812.

Liu, C. S., & Lai, M. Y. (2009). The vehicle routing problem with uncertain demand at nodes. *Transportation Research Part E*: *Logistics and Transportation Review*, *5*, 517-524.

Lotfi, A. A., & Kashani, F. H. (2004). *Bandwidth optimization of the E-shaped microstrip antenna using the genetic algorithm based on fuzzy decision making* (pp. 2333-2336). Paper presented at 2004 IEEE Antennas and Propagation Society International Symposium, Monterey, California.

Magni, C. A., Malagoli, S. & Mastroleo, G. (2006). An alternative approach to firms' evaluation: Expert systems and fuzzy logic. *International Journal of Information Technology*, *5*, 195-225.

Merna, T., & Al-Thani, F. F. (2005). *Corporate risk management*: *An organizational perspective*. New York, NY: John Wiley & Sons Ltd.

Merton, R. C. (1974). On the pricing of corporate debt: The risk structure of interest rates, *Journal of Finance*, *29*, 449-470.

Momeni, M., & Najafimoghadam, A. (2010). Assessing economic performance of companies listed in Tehran Stock Exchange using TOPSIS model. *Quarterly Journal of Quantitative Economics* (*Quarterly Journal of Economics Review*), (3), 55-75.

Nagy, R. A., & Obenberger, R. W. (1994). Factors influencing individual investor behavior. *Financial Analysis Journal*, (50), 63-68.

Namazi, M., & Zare, B. (2004). Information theory application in determining systematic risk, case study: Companies listed in Tehran Stock Exchange. *Journal of Accounting and auditing Review*, (39), 79-100.

Namazi, M., & Khajavi, S. (2004). Profitability of accounting variables in predicting systematic risk of companies listed in Tehran Stock Exchange. *Journal of Accounting and auditing Review*, (4), 93-119.

Namazi, M., & Rostami, N. (2006). Examining the relation between financial ratios and stock return rate of companies listed in Tehran Stock Exchange. *Journal of Accounting and auditing Review*, (44), 105-127.

Olsen, D., & Charles, M. (2003). Neural network forecast of Canadian stock returns. *International Journal of Forecasting*, *19*, 453-465.

Saaty, T. L. (1998). Ranking by eigenvector versus other methods in the analytic hierarchy process. *Appl*. *Math*. *Lett*, *11*, 121-125.

Simutis, R. (2000). *Fuzzy logic based stock trading system* (pp. 19-21). Paper presented at Proceedings of the IEEE/IAFE 2000 Conference on Computational Intelligence for Financial Engineering, New York.

Singh, S., & Fieldsend, J. (2000). *Financial time series using fuzzy and long memory pattern recognition systems* (pp. 166-169). Paper presented at Proceedings of the IEEE/IAFE 2000 Conference on Computational Intelligence for Financial Engineering, New York.

Sugeno, M. (1985). *Industrial application of fuzzy control*. New York, NY: North-Holland.

Ta, C. C., Chung, T. T., & Yeou, R. S. (1996). *Application of fuzzy multiple attributes decision making on company analysis for stock selection* (pp. 509-514). Paper presented at Asian Fuzzy Systems Symposium, Proceedings of IEEE Conference, New York.

Tanaka, K. (1997). *An introduction to fuzzy logic for practical applications*. New York, NY: Springer-Verlag.

Vinat, D., Naik, N., & Radcliffe, R. (1998). Liquidity and stock returns: An alternative test. *Journal of Financial Market*, *1*, 203-219.

Von Altrock, C. (1997). *Fuzzy logic and neuro fuzzy applications in businness and finance*. Englewood Cliffs, NJ: Prentice-Hall.

Wen, M., & Iwamura, K. (2008). Fuzzy facility location allocation problem under the Hurwicz criterion. *European Journal Operational Research*, *184*, 627-635.

O'Neil, W. J. (1995). *How to make money in stocks* (2nd ed.). New York, NY: McGraw-Hill Inc.

Xing, Y. H. (2002). *Firm investment and expected equity returns business*. Retrieved from http://www.ruf.rice.edu/~yxing/versionVAR2.pdf

Yager, R. R., Goldstein, L. S. & Mendels, E. (1994). An approach to aggregating market research data based on fuzzy reasoning. *Fuzzy Sets and Systems*, *68*, 1-11.

Yang, L. X., Ji, X. Y., Gao, Z. Y., & Li, K. P. (2007). Logistics distribution centers location problem and algorithm under fuzzy environment. *Journal of Computational and Applied Mathematics*, *208*, 303-315.

Zebda, A. (1989). Fuzzy set theory and accounting. *Journal of Accounting Literature*, *8*, 76-105.

Zebda, A. (1991). The problem of ambiguity and vagueness in accounting. *Behavioral Research in Accounting*, *3*, 117-45.

Zhou, C. (2001). The term structure of credit spreads with jump risk. *Journal of Banking and Finance*, *25*, 2015-2040.

Zimmermann, H. J. (1978). Fuzzy programming and linear programming with several objective functions. *Fuzzy Sets and Systems*, *1*, 45-55.

Zimmermann, H. J. (1995). *Fuzzy set theory and its applications* (3rd ed.). Dordrecht, Netherlands: Kluwer Academic Publishers.

