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Inter-criteria Comparison of Bulgarian Construction Companies Using Fuzzy Relations

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***Abstract*—Financial analysis is a prerequisite for effective operating activities and successful long-term company's management. Various financial ratios are used for assessing the financial performance of a company and its ability to adapt to changes in its environment. The problem of the financial state comparison of construction companies can be solved by multiple-criteria decision making (MCDM) with fuzzy relations between important financial ratios. The inter-criteria ranking method called ARAKRI is in the basis of the proposed solution for comparing the competitiveness of nine leading Bulgarian construction companies.The described procedure can improve compliance with the principles of transparency, equal treatment and non-discrimination in Bulgarian public procurement and serve as an objective method of impartial winner determination.**

Index Terms— **Financial performance parameters, Fuzzy multi-attribute decision making methods, soft computing.**

I. INTRODUCTION

The performance of the construction sector has a significant role on the development of the overall national economy. Construction generates animportant part of Bulgarian GDP and provides thousands jobs which are mainly in SMEs. The competitiveness of Bulgarian construction companies is essential not only for growth and employment in general but also for ensuring the sector's sustainability. But the sector has been one of the hardest hit by the economic crisis with a 58% drop between 2008 and the end of 2012 in building and infrastructure works carried out in the country [1]-[2].

In order for recover the construction sector and a sustainable competitiveness to be achieved, some specific issues in construction management need to be resolved, concerning planning, organizing, monitoring and controlling of construction companies. Managerial problems found in the sector, related to objective and transparent assessment of different project proposals measured against predefined criteria, can be successfully solved by the analytical hierarchy process (AHP) [3] and multiple-criteria decision making (MCDM).

As data describing alternatives can be impossible to present precisely and unambiguously, in practice fuzzy logic is used. Fuzzy logic is a mechanism of presenting vague and undetermined variables. It is close to the way people make decisions due to the fact that it uses a method of approximate reasoning and, consequently, enables working with unclear and insufficient information. There are a lot of studies demonstrating that applying fuzzy AHP methods can solve different multiple-criteria managerial problems in construction [4]-[10].

Based on a comprehensive literature review on the applications of fuzzy sets and hybrid fuzzy techniques in construction management research, a trend of increasing application of these techniques is observed [4]. In the paper by Zavadskas et al., a complex overview of contemporary decision-making methods in economics is presented, starting from background approaches until relatively recently published methods [5]. As decision-making methodology develops, their applications become more advanced. New developments of MCDM methods as well as their applications in construction economics are presented by Kaplinski and Tupenaite [6]. In [7] fuzzy decision framework for housing projects selection with fuzzy numbers is presented. The next group of papers discusses integration of old classic methods and fuzzy techniques. Taylan et al. and Kaya and Kahmaran integrate AHP with TOPSIS (Technique for the Order Preference by Similarity to Ideal Solution) for construction projects and intelligent building selection respectively [8]-[9]. Nieto-Morole and Ruz-Vila used the AHP-TOPSIS combination to find a solution to the problem of adequate selection of suitable contractors during prequalification process [10].

The problem of comparing financial performance among companies is a typical problem solved by MCDM to which fuzzy logic can be successfully applied. Esbouei and Ghadikolaei used fuzzy AHP (FAHP) for determining the weights of criteria and three fuzzy methods – VIKOR (from Multi-criteria Optimization and Compromise

Solution in Serbian), ARAS (Additive Ratio Assessment) and COPRAS (COmplexPRoportionalASsessment) to rank the companies [11]. Shaverdi et al. also defined a fuzzy-based evaluation model for assessing Iranian Petrochemical Sector performance [12]. Ilieva propose fuzzy decision-making implementation in agent based e-auctions modelling for the most suitable bidding strategy selection under given market conditions [13]. FAHP is applied to determine the weight coefficients then companies are ranked according to their financial performance via ARAS method [14].

In this paper, we apply a fuzzy AHP method for financial performance evaluation of leading Bulgarian construction companies based on an inter-criteria ranking. First, we generate a hierarchical set of financial indicators (ratios), which represent the competitiveness of each of the compared companies. Fuzzy relation between their weights coefficients (importance) are calculated using AHP. The ranking of compared companies has been performed by ARAKRI – a fuzzy algorithm of alternatives ranking via fuzzy relations [15]-[17].

II. RESEARCH OBJECTIVES AND HYPOTHESES

Based on a review of current literature surrounding fuzzy financial performance evaluation and its use in companies' ordering, the following objectives were identified:

I. Select an appropriate set of financial ratios for construction companies'evaluation that will address the following parameters influencing sustainable development:
- (1) High profitability;
- (2) Adequate liquidity;
- (3) Financial leverage (multiplying gains);
- (4) Efficiency in using various resources;
- (5) Quick inventory turnover minimizing inventory requirements;
- (6) Lowcosts to ensure lower expenses and higher profitability.

II. Compute the weight of each ratio to determine its impacton the company's overall financial performance.
III. Calculate the fuzzy relation between companies for each of assessment's ratios.
IV. Rank the selected construction companies using inter-criteria ARAKRI method.

III. RESEARCH METHODOLOGY

Construction is a sector that develops faster in comparison with all other sectors. Volatility is inherent to it: in a short period, a project that has been going well can start deteriorating, and this phenomenon is rare observed in other sectors. Because of volatility, it is crucial for construction companies to timely collect the financial information needed in order to effectively control expenses.
For the purposes of analyzing the current financial state of leading construction companies, eighteen financial ratios, grouped in six categories (A-F), have been studied:

A. *Profitability*

A.1. Net profit margin

Net income after taxes ÷ Total revenue

This ratio is paramount for assessing a company. It shows the profitability of a company's income while taking into consideration interest and taxes. The higher this ratio is the higher profit per unit of revenue the company generates. This ratio varies among industries and sectors and is about 5% in construction.

A.2. EBIT (EBIT margin)

Earnings before interest and taxes ÷ Total revenue

It measures a company's profitability without considering interest and taxes.

B. *Liquidity*

These ratios demonstrate a company's ability to finance new contracts and meet current obligations. The contracting party relies heavily on these calculations to determine the number and size of construction projects a subcontractor can handle.

B.1. Current ratio (CR)

Current assets ÷ Current liabilities

It shows the extent to which a company can meet its short-term obligations by its current assets, i.e. describes the ability of a company to withstand market's short-term fluctuations. Interpreting this ratios is related to that the company should not use sources of short-term financing to acquire long-term asset. Therefore, the recommended value of CR is greater than 1.

B.2. Quick ratio

(Cash + Short term marketable investments + Receivables) ÷ Current liabilities

This ratio shows to what extent a company can meet its short-term liabilities with cash or assets that are easily convertible to cash. Unlike the current ratio, this one does not presume that inventory can be used to cover liabilities, as inventories are relatively illiquid (hard to turn into cash).

Here, the denominator does not include all short-term liabilities, but only those that are liquid. Shares traded on the market are added in the nominator. The greater this ratio is, the more stable a company is. On the other hand, an excessive value can imply that the company has a resource surplus which is inefficiently employed.

B.3. Cash ratio

Cash + Short-term marketable investments) ÷ Current liabilities

Indicates what part of short-term liabilities can be covered by cash, cash-equivalents and highly liquid assets.

C. Financial Leverage

These ratios are related to those measuring liquidity and describe the degree of financial independence of a company from its creditors, i.e. the degree to which newly-acquired capital is used. In a balance sheet, liabilities to creditors are listed as long-term and short-term, and they encompass obligations to suppliers (accounts payable), to bank creditors, to customers who have made advance payments, to employees, to local and state budgets for deferred taxes, to insurance funds for accrued social and health insurance payments, revenue for future periods, etc. Such ratios are:

C.1. Equity-to-Debt ratio

Equity ÷ Total debt

This ratio takes into account total debt, including accounts payable, accrued expenses, etc.

C.2. Debt-to-Equity ratio

Total debt (liabilities) ÷ Shareholders' equity

The debt-to-equity coefficient sheds light on the degree of a company's dependence on its creditors and for paying off liabilities. This ratio is usually below one and shows the amount of liabilities per unit of shareholder's equity a company has. A higher ratio generally indicates greater risk.

D. Efficiency

These are measures of the relationship between revenue and expenses.

D.1. Efficiency Ratio – Expenses

Revenue ÷ Expenses

Efficiency ratio – expenses provides information on how much revenue from its activities a company gets per unit of expenses. It is considered as beneficial if this coefficient of a company grows.

D.2. Efficiency Ratio – Revenue

Expenses ÷ Revenue

This coefficient is reciprocal to the previous ones. It shows expenses per unit of revenue. A good tendency is when the efficiency coefficient diminishes.

E. Turnover

E1. Inventory turnover ratio

Cost of goods sold ÷ Average inventory

Reflects the speed of inventory realization. The higher this ratio is, the more efficiently a company uses its resources. High turnover of goodsrelies heavily on a stable supplychain.

E2. Inventory turnover in days - Days of inventory on hand

Number of days in period ÷ Inventory turnover ratio

This coefficient provides information on the average time in days it takes a company to sell its inventory. A company should strive to decrease this ratio.

E3. Inventory turnover ratio

Average inventory ÷Cost of goods sold

The ratio reveals how many"times" the whole inventory was sold during a certain time period (e.g. year). The lower this ratio is, the slower the company is taking to clear (realize) its inventory.

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F. Expenses per 100 units of revenue

F.1. Expenses per 100 units of revenue ratio

Expenses ÷ Cost of goods sold

F.2. Materials expense ratio

Materials expense ÷ Gross income

Material expenses encompass all costs incurred for materials needed in core business and ancillary activities.

F.3. External services ratio

External services ratio ÷ Gross income

F.4. Depreciation expense ratio

Depreciation ÷ Gross income

Depreciationexpense Ratio is measured as a percentage, the lower the percentage,the stronger the ratio. This ratiodenotes the amount of income that is required to maintain the capital being used by the company. The lower the percentages the better, a company should be no higher than 5% to be considered strong. Any percentage higher than 15% means that the firm may be wearing out its capital to quickly.

F.5. Payroll expense ratio

Payroll expense ÷ Gross income

A company can use the payroll ratio to determine how much of each dollar of sales goes to paying employee salaries.

F.6. Social security expense ratio

Social security expense ÷ Gross income

A company can use the social security ratio to determine how much of each dollar of sales goes to paying employee social securities.

After basic financial ratios have beenstudied, we identifiedthe framework for financial assessment of a construction company. The proposed model has a hierarchical structure, which comprises the describedratios into the six categories discussed (Fig. 1).

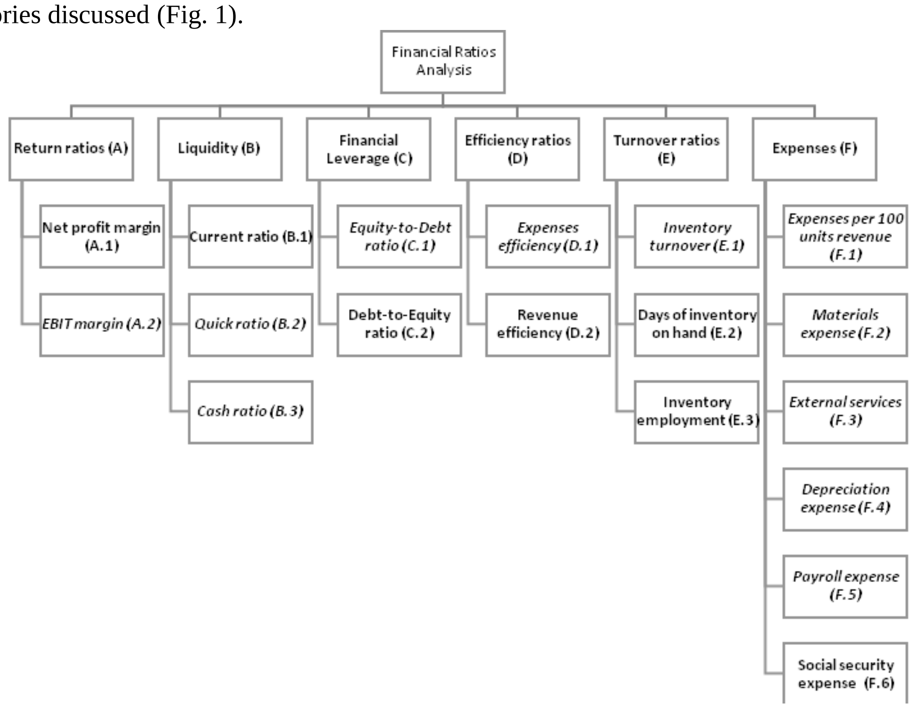

Fig 1. Framework of the model for financial assessment of construction companies

Because of possible dependencies between some of the financial coefficients, after performing a correlation analysis, we limit the factors in the model to eleven. The final set of coefficients is labeled in Italic style (Fig. 1).

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G. Decision making method with fuzzy relations between alternatives and inter-criteria weights (ARAKRI)

Let $A = \{a_1,..., a_i,..., a_n\}$ is a set of alternatives (construction companies, project proposals, etc.), evaluated by a set of criteria (financial ratios) $K = \{k_1,..., k_j..., k_m\}$. Let the weights of criteria are $w = \{w_1,..., w_j,..., w_m\}$.

The set *R*define fuzzy relations of preference $R_1, R_2,..., R_m$ between alternatives. The relations are represented by matrices $R_k = \|r_{ij}^k\|$ with dimensions $n \times n$, where $r_{ij}^k = \mu_k(a_i, a_j), i, j = 1,...,n, k = 1,...,m$. Here $\mu_k : A \times A \to [0,1]$ is the membership function of relation R_k , and r_{ij}^k is the degree of preference of the alternative a_i to a_j according to the criterion k_k. If $r_{ij}^k = 0.5$, then a_i *and* a_j are equally preferred. If $r_{ij}^k = 1$, then a_i is absolutely preferred to a_j. The case $r_{ij}^k > 0.5$ shows that a_i is preferred to a_j according to k^{th} criterion. The matrices $R_k, k = 1,..., m$ are additive reciprocal, i.e. rule is in effect:

$$r_{ij}^k + r_{ji}^k = 1, i, j = 1,...,n. \quad (1)$$

Let is given also a fuzzy relation of preference *W* between the weights of the criteria, i.e. criteria are pairwise compared based of their importance and degree of preference for each pair of criteria is determined. Let $W = \|w(k_i, k_j)\| = \|w_{ij}\|, i, j = 1,...,m,$ where $w(k_i, k_j)$ is the preference's degree of the criterion k_i according to criterion k_j :

$$w_{ij} = \begin{cases} 1 & \text{if } i = j \\ 0.5 + \dfrac{w_i - w_j}{2(\max\{w\} - \min\{w\}} & \text{if } i \neq j \end{cases} \quad (2)$$

To obtain a relation of preference between alternatives combining relations set on any criteria, taking into account the fuzzy relation between the weights of thecriteria, the ARAKRI method is proposed, based on *composition* operation between two fuzzy relations [15]-[17].

The composition $X \circ Y$ between relations X and Y with *t*-norm *T* is a fuzzy relation in $A \times A$ with a membership function:

$$\mu(a_i, a_j) = \mu_{X \circ Y}(a_i, a_j) = \max_k\{T(\mu_X(a_i, a_k), \mu_Y(a_k, a_j))\}, \ i, j, k = 1,...,n. \quad (3)$$

When t-norm *T* = min, then the composition is max-min. When *T* = *xy*, then it is a max-product composition $X \circ Y$ and can be obtained by multiplication of the two matrices X и Y . It should be noted that $X \circ Y \neq Y \circ X$.

For the calculation of a new aggregate relation between X and Y, $X \neq Y$ with a degree of membership for the couple $a_i, a_j \in A$ we calculate:

$$r_{ij} = \begin{cases} 0.5 & \text{if } a_i = a_j \\ S(T(w^1, z_{ij}^1), T(w^2, z_{ij}^2)) & \text{if } a_i \neq a_j \end{cases}, \quad (4)$$

where $Z^1 = \|z_{ij}^1\| = X \circ Y$ and $Z^2 = \|z_{ij}^2\| = Y \circ X$ are the compositions from (3), $w^1 = w(k_X, k_Y), \ w^2 = w(k_Y, k_X)$ are the preference's degree of the criterion, setting the preference relation of *X* to *Y* and *Y* to *X*, respectively, *T* is a t-norm and *S* is its corresponding t-conorm.

To orderthe given alternatives using inter-criteria dependencies from the best to the worst one, we execute the following steps:

Step 1. The compositions of relations' couples are calculated, using (4), i.e. for the example from the financial ratios model (Fig. 1), these new relations are calculated $Z^{ij} = R_i \circ R_j, i, j = 1,...,m$.

If in (4), a *max-min* compositionis used, i.e. t-norm *T* = min, then Step 2 follows.

If in (4), a *max-product* compositionis used, i.e. t-norm is *T* = *xy*, then Step 3 follows.

Step 2. Calculate *max-min* compositions of relations' pairs from Step 1, i.e. in this case, the t-norm *T* = min, (3) changes to:

$$\mu_{Z_i \circ Z_j}(a_i, a_j) = \max_k\{\min(\mu_X(a_i, a_k), \mu_Y(a_k, a_j))\}, \ i, j, k = 1,...,m$$

Step 3. Calculate *max-product* compositions of relations' pairs from Step 1, i.e. in (3) t-norm is *T* = *xy*:

$$\mu_{Z_i \circ Z_j}(a_i, a_j) = \max_k\{\mu_X(a_i, a_k) * \mu_Y(a_k, a_j)\}, \ i, j, k = 1,...,m$$

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Step 4. Fuzzy relations are calculated, uniting compositions' pairs from Step 2, for example, $Z^1 = \|z_{ij}^1\|$ and $Z^2 = \|z_{ij}^2\|$, using (4) with t-norm $T = \min(x, y)$ and t-conorm $S = \max(x, y)$, considering W, i.e. (4) for $Z^1 = \|z_{ij}^1\|$ and $Z^2 = \|z_{ij}^2\|$ changes to:

$$r_{ij}^1 = \begin{cases} 0.5 & \text{if } a_i = a_j \text{ .} \\ \max\{\min(w^{12}, z_{ij}^1), \min(w^{21}, z_{ij}^2)\} & \text{if } a_i \neq a_j \end{cases} \quad (5)$$

Step 5. Fuzzy relations are calculated, uniting compositions' pairs from Step 3, for example, $Z^1 = \|z_{ij}^1\|$ and $Z^2 = \|z_{ij}^2\|$, using (4) with t-norm $T = xy$ and t-conorm $S = x + y - xy$, taking W into account, i.e. (4) for $Z^1 = \|z_{ij}^1\|$ and $Z^2 = \|z_{ij}^2\|$ changes to:

$$r_{ij}^1 = \begin{cases} 0.5 & \text{if } a_i = a_j \\ w^{12} z_{ij}^1 + w^{21} z_{ij}^2 - w^{12} z_{ij}^1 w^{21} z_{ij}^2 & \text{if } a_i \neq a_j \end{cases} \quad (6)$$

Step 6. For aggregating these new relations R from (5) and (6), the aggregation operator MaxMin is used with membership function:

$$\mu(a_i, a_j) = \alpha \max_k \{\mu_k(a_i, a_j)\} + (1-\alpha) \min_k \{\mu_k(a_i, a_j)\},\ \alpha \in [0,1], i, j = 1,\dots,n,\ k = 1,\dots,m \quad (7)$$

Step 7. R', the asymmetric relation of R is calculated as follows:

$$R(a,b) \geq R(b,a) \rightarrow R'(a,b) = R(a,b) \vee R'(b,a) = 0 .$$

The relation R' is a fuzzy partial ranking and a fuzzy linear ranking, i.e. solutions were obtained for the problem of inter-criterion ranking. The final rankings of alternatives are two - one for each type of composition (max-min и max-product) with a MaxMin aggregating operator used in(7).
Relations $R_1, R_2, \dots, R_m$ are additively transitive and additively reciprocal, and relation W is additively reciprocal. These properties of the relations are sufficient conditions for solving the problem of ranking the n alternatives from the best to the worst one.

H. Algorithm for Inter-criteria Ranking of Construction Companies Using Fuzzy Relations with ARAKRI method

The stages of the process of inter-criteria ranking of construction companies with fuzzy relations are graphically depicted in Fig. 2:

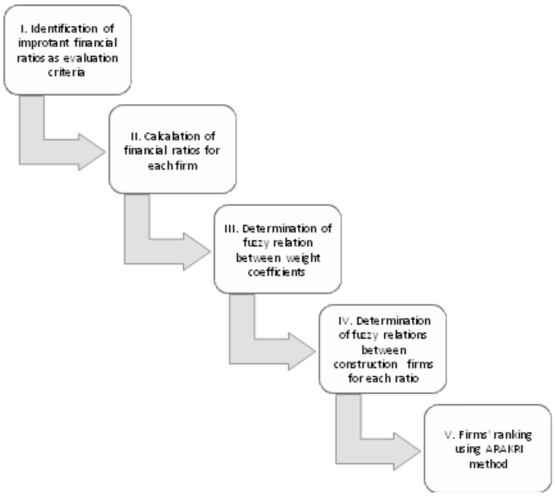

Fig 2. Flowchart of the solution to the problem of inter-criteria ranking

First, in *Stage I*, eleven financial ratios suitable for measuring construction companies' performance has been identified (Subsection A-E.).
Selected financial ratios for nine leading Bulgarian construction companies (Holding GBS, GBS Corporation, Technoexportstroy, Strabag, Enemona, Markan, Balkanstroy, Trace Group Hold, and Holding Roads) were calculated (*Stage II*). Financial statement data as per 2011, the last published on the National Commercial Register's website, has been used in this paper.
In order for the fuzzy relation between weight coefficients from the *Stage III* to be established, first an AHP has been proposed. AHP is based on pair-wise comparison that leads to the creation of an absolute ratio scale for

evaluating criteria by their importance. Eighteen levels of importance are employed to rate intensity and they correspond to the numbers from 1/9 through 9 [3].Results obtained for categories and financial ratios from category F. (Subsection A-E.) were put in Table I and Table II, respectively. Fig. 3 visualizes calculated weight coefficients. Table III shows the fuzzy relationship between financial ratios' weight coefficients, according to (1)-(2).

Table I. The pairwise comparison between categories

	A	B	C	D	E	F
A	1	1/2	1	1	2	1
B	2	1	4	3	3	2
C	1	1/4	1	3	2	1
D	1	1/3	1/3	1	3	2
E	1/2	1/3	1/2	1/3	1	1/5
F	1	1/2	1	1/2	5	1

Consistency ratio CR=8.83%.

Table II. The pairwise comparison of ratios from category F. Expenses

	F1	F2	F3	F4	F5
F1	1	2	3	4	3
F2	1/2	1	2	2	1
F3	1/3	1/2	1	2	1/2
F4	1/4	1/2	1/2	1	2
F5	1/3	1	2	1/2	1

Consistency ratio CR=8.28%.

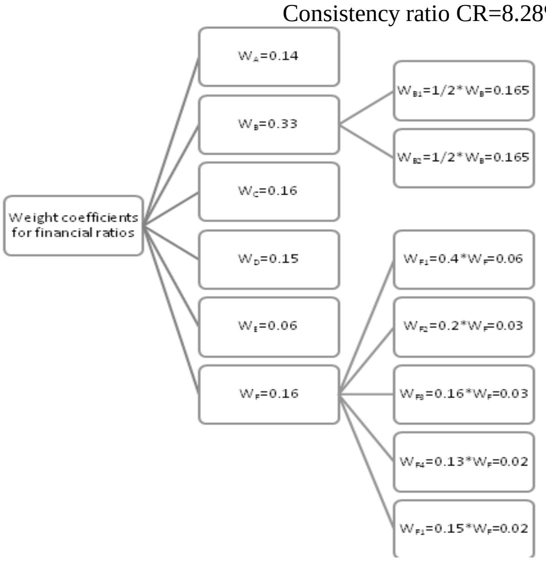

Fig 3. Weights coefficients of selected financial ratios

Table III. Fuzzy relation between weight coefficients

	A2	B2	B3	C1	D1	E1	F1	F2	F3	F4	F5
A2	1	0.414	0.414	0.431	0.466	0.776	0.776	0.879	0.879	0.914	0.914
B2	0.586	1	0.5	0.517	0.552	0.862	0.862	0.966	0.966	1	1
B3	0.586	0.5	1	0.517	0.552	0.862	0.862	0.966	0.966	1	1
C1	0.569	0.483	0.483	1	0.534	0.845	0.845	0.948	0.948	0.983	0.983
D1	0.534	0.448	0.448	0.466	1	0.810	0.810	0.914	0.914	0.948	0.948
E1	0.224	0.138	0.138	0.155	0.190	1	0.5	0.603	0.603	0.638	0.638
F1	0.224	0.138	0.138	0.155	0.190	0.5	1	0.603	0.603	0.638	0.638
F2	0.121	0.034	0.034	0.052	0.086	0.397	0.397	1	0.5	0.534	0.534
F3	0.121	0.034	0.034	0.052	0.086	0.397	0.397	0.5	1	0.534	0.534
F4	0.086	0	0	0.017	0.052	0.362	0.362	0.466	0.466	1	0.5
F5	0.086	0	0	0.017	0.052	0.362	0.362	0.466	0.466	0.5	1

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In *Stage IV*, with experts' input, eleven fuzzy preference relations were constructed, comparing selected construction companies. Fuzzy relations between companies by financial parameters are similar to those in Table III.

In last *Stage V* using the ARAKRI method (Subsection G.) solutions to the problem of inter-criteria ranking have been calculated.

IV. RESULTS AND DISCUSSION

Obtained final rankings and exact values of linear relationships between companies are visualized in Table IV.

Table IV. Ranking of construction companies by their financial performance

t-norm min			t-norm xy		
Rank	**Company Name**	**Value**	**Rank**	**Company Name**	**Value**
1	Strabag		**1**	Strabag	
2	Holding GBS	0.626	**2**	Holding GBS	0.560
3	GBS Corporation	0.667	**3**	GBS Corporation	0.609
4	Markan	0.595	**4**	Technoexportstroy	0.580
5	Technoexportstroy	0.633	**5**	Markan	0.554
6	Balkanstroy	0.632	**6**	Balkanstroy	0.530
7	Trace Group Hold	0.641	**7**	Holding Roads	0.555
8	Holding Roads	0.616	**8**	Trace Group Hold	0.586
9	Enemona	0.605	**9**	Enemona	0.650

Obtained rankings are not identical, but the differences among them are minimal. In the upper part of the table, according to two different t-norms, the first three places are occupied by the same respective companies, and below them, two pairs, 4-5 and 7-8 exchange places. This is not surprising because we performdifferent operationsin the describedcomputational model.

The ordering of construction companies in Table IV. Corresponds to the annual report on the construction companies' state from Bulgarian Construction Chamber for the same period [18]. Compared firms demonstrate a relatively stable financial condition during the period in question.The ranking is unsurprising: the winners, Strabag and GBS, are traditionally among the leaders in annual analysis of construction companies in Bulgaria. During the same period, Markan successfully participated in a large scale enterprising project while developing stably and being financially well. Technoexportstroy and Balkanstroy also have good financial indicators during the period. At the bottom of the chart are Trace Group Hold, Holding Roads, and Enemona due to their limited number of projects and consequent worsening financial standings.

An advantage of the proposed inter-criteria method of ranking construction companies by their financial parameters lies in its working with fuzzy relations instead of with real numbers when data are uncertain, incomplete and/or inexact. A disadvantage of the proposed method is its lack of capability of proving which of the obtained rankings is optimal.

V. CONCLUSION AND FUTURE WORK

The aim of this paper is to propose an approach for inter-criteria firm's rating, which is shown by a real construction companies' data. The discussed method tackles uncertainty in two ways: AHP and fuzzy numbers to express relations between weight coefficients and linguistic evaluations to determine companies' relations based on their financial parameters. During an economic crisis, the bulk of new construction projects is formed by state and municipal procurementfinanced by European funds. Since approximately 80% of construction activities in Bulgaria are public financed, ranking such bids must be transparent and reliable.The proposed method ensures an objective and unbiased multi-criterion ordering of construction companies. Therefore, the discussed ranking method is appropriate for making and supporting decisions concerning the choice of a construction contractor.Although we are focused here on the ARAKRI inter-criteria algorithm, the proposed approach is flexible and can be easily extended to deal with a variety ofdecision-making problems.In future work, we will investigate the results' sensitivities to ARAKRI parameters. We plan also to use the method in our further work which includes implementation of fuzzy logic in selecting the most appropriate firm's strategy using endogenous and exogenous parameters.

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