

# A New Fuzzy Decision Support Method for Analysis of Economic Factors of Turkey's Construction Industry

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**Abstract**—Imperfect knowledge cannot be avoided all the time. Imperfections may have several forms; uncertainties, imprecision and incompleteness.

When we look to classification of methods for the management of imperfect knowledge we see fuzzy set-based techniques. The choice of a method to process data is linked to the choice of knowledge representation, which can be numerical, symbolic, logical or semantic and it depends on the nature of the problem to be solved for example decision support, which will be mentioned in our study.

Fuzzy Logic is used for its ability to manage imprecise knowledge, but it can take advantage of the ability of neural networks to learn coefficients or functions. Such an association of methods is typical of so-called soft computing.

In this study a new method was used for the management of imprecision for collected knowledge which related to economic analysis of construction industry in Turkey. Because of sudden changes occurring in economic factors decrease competition strength of construction companies. The better evaluation of these changes in economical factors in view of construction industry will made positive influence on company's decisions which are dealing construction.

**Keywords**—Fuzzy Logic, Decision Support Systems, Construction Industry.

## I. INTRODUCTION

THE Republic of Turkey is a major force in the international construction market [1].

Construction industry is a crucial field of activity for the economy of a country [2]. The sector is a major employer. The percentage of population in total civil employment working in construction sector including construction material production varies between 6 % and 10% with respect to years. Construction industry is directly linked to other industrial sectors and it is a leading industry in developing countries [3]-[4].

Construction companies are usually functioning under the following categories;

### 1. Contractors

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### 2. Subcontractors

### 3. Consultant companies

There are some uncertainties about the future of the sector, as the future directly depends on the economical growth rate as well as the level of public expenditures. As a result of privatization, the share of public sector in construction sector will decrease [5]-[6].

When compared for sectors, construction sector has been complex because of including many experting areas, dealing with various sectors more than 200 and attracting the attention of international contracting activities. Due to the existence of many factors influencing economic conditions, it is essential to analyze these factors in several ways and determine the relationships between these factors. Defining with fuzzy expression of importance degree of those factors, which vary from company to company, makes, it is impossible to analyze with deterministic approach.

## II. ECONOMIC SITUATION ANALYSIS FOR CONSTRUCTION INDUSTRY

The Turkish construction industry began to develop after the end of the Second World War in 1945. Until 1979, the country faced serious economic troubles with an increasing high rate of inflation, decreasing natural resources, declining exports, growing imports, and the accumulation of numerous unpaid debts to other countries. Consequently, like many other sectors, the construction industry suffered a crisis during this period. There were many bankruptcies, unfinished jobs, legal claims, and unemployed workers in the domestic market during that time [7].

The 1980's marked a turning point in economy, because economic, political and social unrest necessitated radical economic and structural reforms these years signaled the birth of a liberal era for the country [8].

The most important factor affecting directly on developing of construction sector is changes in economic situations. Causing of economic uncertainties to long-term crisis, resulted from nation management, makes it difficult to decide about strategic issues which is relevant to economic conditions for companies [9]-[10].

One of the most important indicators showing importance and position of a sector in economy is its proportion in Gross National Product (GNP) [11]. According to GNP calculations

made by State Institute of Statistics (SIS), in 1990s' economy and construction sectors have decreased %6.4 and %12.7, respectively, in 1999, when most economic reducing is occurred [12]. This awful reducing in the sector especially resulted from restriction in state sector. Other causes of reducing are the high interests in reel economy, high tax ratios and diminishing of demand for house and private sector. In addition to these negative conditions, dimensions of economic decreasing have become more severe due to earthquake disaster occurred in 1999 and proportion of the sector in GNP decreased to 5.1% [13].

Unfortunately, improving in economy in 2000 has not affected construction sector and while economy increased 4.2% in the first quarter of 2000 year, construction sector decreased 2.5%.

Employment in Turkey for 1999 has been announced as 22 billion by SIS. 1.2 billion of this employment corresponded to 5.4% of total employment are working in construction sector. Thus, construction sector, which is a very important employment area for the workers who are generally assumed as unqualified worker, is being affected by economical changes while it affects economic improvements. Ratio of the construction sector in the employment has risen for the last three years but decreased a result of reducing occurred in the sector in 1999. Fluctuations in employment proved that economic factors have negative effects on the construction sector [14].

There is a very close relationship between construction sector and state investments in Turkey. In 1998, economical crisis, especially affecting the Far East countries and the Independent States Community, kept its effect in following year and state spending and investments has been reduced because of uncertainties caused by central and local elections, tax judgments and constancy precautions. The importance of state investments for construction sector seems more clearly when considering that 33% of construction spending is made by state. In this case, it can be said that state investments must be accelerated so as to develop the construction sector. But in practice, the situation is not in this way. While the ratio of state spending given from national budget was 4.8% in 1999, this ratio was determined as 4.9% in 2000 [15].

As a result of constancy precautions taken in 1999, diminishing in state investments and the uncertainty caused by taken precautions led to stop private sector investments or cancel for an indefinite time, and the construction sector entered to a reducing process. In addition, high credit interests and dull economy promoted reducing in private sector investments.

Consequently, present situation has been forming a chaos case for construction sector and economical uncertainties with political unsteadiness are dragging the construction companies to some insurmountable problems.

### III. FUZZY LOGIC AND FUZZY SET THEORY

Fuzzy set theory was introduced by Zadeh in the mid-1960's [16]. The basic concept is that propositions are not

necessarily true or false but rather have a degree to which they are true, represented by a number between 0 and 1, inclusive. Traditional propositional binary logic is replaced by new mathematical concepts that permit conjunctions, disjunctions, and implications in terms of these partial truth values. A component of fuzzy logic, fuzzy set theory allows partial set membership, a concept that is useful in classification problems.

Since the introduction of fuzzy logic, the field has expanded enormously in terms of both theoretical developments and application. For an overview of the theory behind fuzzy systems, see Kaufmann [17] and the journal Fuzzy Sets and Systems, which contains both theory and applications. Economic factors can be defined as fuzzy sets, along with membership functions that indicate the degree to which an item belongs to a fuzzy set.

## IV. PROPAGATION OF RESULTS

### A. Max-Min Networks

Saito and Mukaidono [18] propose a max-min algorithm to replace the traditional sum-product algorithm that is used traditionally in neural network learning algorithms. A number of self-consistent fuzzy systems can be designed using  $t$ -norms and  $t$ -co-norms [19]. Thus the traditional sum-product paradigm for weight combination is replaced by one of these constructs. The minimum and maximum of membership functions are often used in place of AND and OR operations, respectively. A max-min network generally consists of a number of nodes that use either the min or the max operation to combine weights. The max-product networks are similar to the max-min networks except that the product is used in place of the min.

### B. Possibility Theory

A possibility distribution can be defined by assigning to every element  $x$  in  $U_x$  a degree of possibility [20];

$$\Pi_x(x) = f_A(x) \quad (1)$$

Let  $r(x,y)$  represent the strength of the implication. There are a number of possibilities for the definition of  $r(x,y)$ , which are described in Bouchon-Meunier [21]. An example is the Mamdani implication;

$$r(x,y) = \min(f_A(x), f_b(y)) \quad (2)$$

As an example, consider the rule;

IF (inflation is big-threat) THEN (economic factors is threat),

$f_A(x)$  and  $f_b(y)$  must be defined. The respective universes of discourse are the range of all possible values,  $U_x=(0,100)$ ,  $U_y=(0,1)$ , where 0 indicates big-opportunity and 1 indicates big-threat.

In order to implement a reasoning process, these rules must be combined with data to produce conclusions. In ordinary binary logic, *modus ponens* is used for this purpose. Again, several possibilities have been proposed for a fuzzy *modus ponens*. Assume the actual data for the above rule is

$$X \text{ is } A \quad (3)$$

Define an operation  $T$  such that,

$$g_B(y) = \max(t(g_A(x), r(x,y))) \quad (4)$$

Where  $g_A(x)$  and  $g_B(y)$  are membership functions. Usually,  $T$  is a  $t$ -norm [22], which is a function satisfying the following properties;

$$\begin{aligned} T(x,1) &= x && \text{(Boundary)} \\ T(x,y) &= T(y,x) && \text{(symmetry)} \\ T(x,z) &\leq T(y,z) \text{ if } x \leq y && \text{(Monotonicity)} \\ T(x,T(y,z)) &= T(T(x,y),z) && \text{(Associativity)} \end{aligned} \quad (5)$$

The most common choice for a  $t$ -norm is the minimum.  $T$  must be chosen in conjunction with  $r(x,y)$  to preserve the conclusion when the observation is identical with the premise.

Usually, production rules have multiple antecedents and take the form;

IF ( $V_1$  is  $A_1$ ) and ( $V_2$  is  $A_2$ )..... and ( $V_n$  is  $A_n$ ), THEN  $U$  is  $B$  [22].

The possibility distribution discussed earlier can be generalized to;

$$\Pi_{V_1, V_2, \dots, V_n}^u \text{ on } X_1 \times X_2 \times \dots \times X_n \times Y \quad (6)$$

Such that,

$$\Pi_{V_1, V_2, \dots, V_n}^u = 1 \wedge (1 - A_1(x_1) \wedge A_2(x_2) \wedge \dots \wedge A_n(x_n) + B(y)) \quad (7)$$

Where  $\Pi_{V_1, V_2, \dots, V_n}^u = A_i(x)$  are the individual possibility measure and  $\wedge$  is the min operator.

## V. MATERIAL AND METHODS

In order to determine the influence degree of construction companies from economic factors, large construction companies and belonged to Turkish Constructors Association (TCA) and The Turkish Employers' Association of Construction Industries (TEACI) were selected.

In this study, a 150 company sampling group, consisted of 50 contractors, 50 subcontractors and 50 consultant construction companies, was selected. Companies were equally separated to three different groups from the point of view of service field (contractor, subcontractor and consultant construction companies) so as to determine approach differences to economic factors. Attention has been given to

select great, generally preferred and esteemed companies which were investigated in this research. It is determined that contractor companies are greater from subcontractor companies and consultant companies, not widespread in our country, are less great companies. 60% of the companies are working for state sector and 40% are working for both state and private sector. It is observed that most of the companies working for state sector is specialized about substructure and also make abroad contractor works.

A public survey was arranged to determine influencing degree of selected companies from economic factors. Data obtained from companies was analyzed with SPSS (Statistical Package for the Social Sciences) 7.0 and Minitab 13. Numerical values found with programs above were evaluated with Fuzzy Tech Professional 5.54 software and influencing degree of companies from economic factors was determined by obtained results.

## VI. CASE STUDY

In this study a fuzzy logic control was used to evaluate to economic factors. We used five input variables (inflation, devaluation, interest rate, exchange fluctuation and taxes) to find out economic situation analysis. All of the input membership functions have three linguistic terms (opportunity, non-affect and threat) (see Fig. 1). Output membership function has five linguistic terms (big-opportunity, opportunity, non-affect, threat and big-threat) (see Fig.2). Rule base was prepared by collaboration of economy specialists and civil engineers.

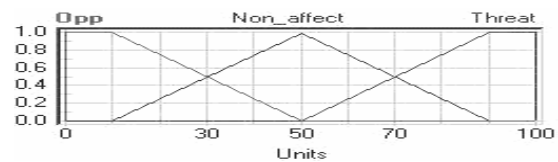


Fig. 1 Inputs membership function

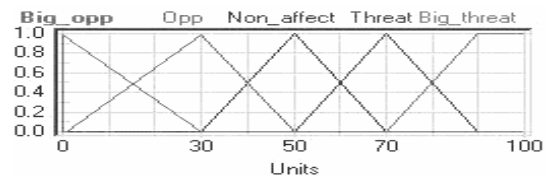


Fig. 2 Output membership function

The computation of fuzzy rules is called fuzzy rule inference. The inference is a calculus consisting of the steps: aggregation, composition and result aggregation. The first step of the fuzzy inference aggregation, determines the degree to which the complete if part of the rule is fulfilled. We used minimum operator for computation of the fuzzy rule.

$$\text{AND: } \mu_{IF} = \min_i(\mu_i) \quad (8)$$

The result produced from the evaluation of fuzzy rules is still fuzzy. Out membership function is used to retranslate the

fuzzy output into a crisp value. This translation is known as defuzzification and can be performed using several methods. To obtain clear analysis of economic situation, Mean of Maximum (MoM) defuzzification method was preferred.

The Mean of Maximum method, computes a system output only for the term with the highest resulting degree of support. If the maximum is not unique the mean of maximizing interval is computed.

The MoM procedure evaluates the most significant of the different terms  $j$  of a linguistic output variable then obtain  $Y$  by using maximum  $Y_j$  of the each term  $j$ .

$$Y = Y_j (\mu_{\text{Result, Term, Max}}) \quad (9)$$

We want to give a solution sample to understand clearly about how the economic situation analysis system works. Table 1. shows random input values and calculated output which are related with these inputs.

TABLE I  
 RANDOM INPUT VALUES OF ECONOMIC FACTORS

Economic Factors	Random Input Values
Inflation	75
Devaluation	65
Interest rate	75
Exchange fluctuation	65
Taxes	55

TABLE II  
 VALID RULES FOR SAMPLE SOLUTION

Inflation	Devaluation	Int. Rate	Exc. Fluc.	Taxes	Econ. Fact.
Opp.	Non-affect	Non-affect	Opp.	Opp.	Opp.
Opp.	Non-affect	Non-affect	Non-effect	Opp.	Opp.
Non-affect	Non-affect	Opp.	Non-affect	Opp.	Non-affect
Non-affect	Non-affect	Opp.	Non-affect	Opp.	Non-affect
Opp.	Non-affect	Opp.	Opp.	Non-affect	Opp.
Opp.	Non-affect	Opp.	Opp.	Non-affect	Opp.
Non-affect	Non-affect	Opp.	Non-affect	Non-affect	Non-affect
Non-affect	Non-affect	Opp.	Non-affect	Non-affect	Non-affect

TABLE III  
 DEGREE OF SUPPORT OF ALL THE RUNNING RULES

Inflation	Devaluation	Int. Rate	Exc. Fluc.	Taxes	DoS	Econ. Fact.
Opp. 0.25	Non-affect 0.63	Non-affect 1.0	Opp. 0.25	Opp. 0.63	0.25	Big-Opp.
Opp. 0.25	Non-affect 0.63	Non-affect 1.0	Non-effect 0.75	Opp. 0.63	0.25	Opp.
Non-affect 0.74	Non-affect 0.63	Opp. 0.25	Non-affect 0.75	Opp. 0.63	0.25	Non-affect
Non-affect 0.74	Non-affect 0.63	Opp. 0.25	Non-affect 0.75	Opp. 0.63	0.25	Non-affect
Opp. 0.25	Non-affect 0.63	Opp. 0.25	Opp. 0.25	Non-affect 0.38	0.25	Opp.
Opp. 0.25	Non-affect 0.63	Opp. 0.25	Opp. 0.25	Non-affect 0.38	0.25	Opp.
Non-affect 0.74	Non-affect 0.63	Opp. 0.25	Non-affect 0.75	Non-affect 0.38	0.63	Non-affect
Non-affect 0.74	Non-affect 0.63	Opp. 0.25	Non-affect 0.75	Non-affect 0.38	0.38	Non-affect

The output degree is 70. The output degree was obtained by MoM method. This mean is economic situation is "threat" for construction industry. As we mentioned before, result produced from the evaluation of fuzzy rules and passed defuzzification by using out membership function to retranslate the fuzzy output into a crisp value. Now, the question is what mathematics operations done by this process. To find answer, we should look rule based to see which rules are running under this circumstance. Table 2 and Table 3 show running rules.

## VII. CONCLUSION

Use of techniques from fuzzy logic, approximate reasoning, and evidence aggregation can enhance the performance of decision support systems, especially when dealing with borderline cases in which nuances are important. The advantages of these methods must be balanced against the increased complexity of the reasoning process along with the accompanying higher computational demands. In addition, it may be more difficult to interpret the reasoning process of these approaches.

Due to the existence of many factors influencing economic conditions, it is essential to analyze these factors with fuzzy approach. Defining with fuzzy expression of importance degree of those factors, which vary from company to company, makes, it is impossible to analyze with deterministic approach.

Even though the economical factors makes a threat for these three groups (contractors, subcontractors and consultant companies), the worst affected group by these factors is sub contractors companies. Their limited financial sources are being insufficient in the face of negative economical progress.

If we look the situation for the contractor companies, it is established that national and international activities provide a financial flexibility to these companies. Also we can say the contractor companies group less affected than subcontractor companies group. Consultant companies which are smaller in point of work capacity and financial force are the least affected companies by the economical factors.

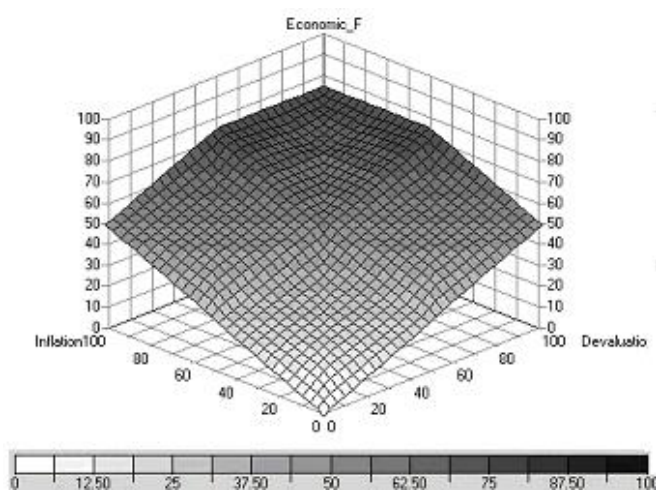


Fig. 3 3D system analysis

Consequently this study point out those economical factors threatens to the constructor companies. The most important threat elements for the companies are inflation and devaluation (Fig. 3) Also exchange fluctuation and taxes are other threat elements for the companies which have international activities.

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