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Credit Risk Assessment of Bank Customers using DEMATEL and Fuzzy Expert System

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***Abstract*—Credit risk remains one of the major threats that financial institutions especially banks face, and it is essential to model the credit risk of these institutes and banks. The purpose of this research is credit risk assessment of bank customers. In this paper, the DEMATEL method has been used to select the proper financial ratios which are effective on the decision making process of the experts and based on these financial ratios and the acquired rules via bank experts, a Mamdani's Fuzzy Expert system has been developed which predicts the Customers' Credit Risks. This system is able to help the banking systems to identify the level of credit risks for their customers according to their financial status which is a critical issue for the banks. Finally, the presented steps have been studied in an Iranian Bank as empirical study.**

Keywords-Credit Risk, Financial Ratios, DEMATEL, Fuzzy Expert system.

I. INTRODUCTION

Commercial banks provide financial products and services to clients while managing a set of multi-dimensional risks associated with liquidity, capital adequacy, credit, interest and foreign exchange rates, operating and sovereign risks, etc. Banks take risks, and transform or embed such risks to provide products and services. Banks are also ‘‘profit-seeking’’ organizations basically formed to make money for shareholders. Management of risk and profitability are very closely related. Therefore, banks may not live without managing these risks. Among the different banking risks, credit risk has a potential ‘‘social’’ impact because of the number and diversity of stakeholders affected. A potential client’s credit risk level is often evaluated by the bank’s internal credit scoring models. Some studies have used Data Envelopment Analysis(DEA) for predicting Credit Risk [1].In the area of DEMATEL , there are previous studies around this matter including paper [2] which Combined DEMATEL technique with a MCDM model to explore portfolio selection and paper [3] which suggests a hybrid MCDM model combined with DEMATEL and ANP and paper [4] uses DEMATEL for selecting optimal management systems and paper[5] for selecting Supply chain management(SCM) suppliers and paper [6] for producing effective evaluation of e-learning programs and paper [7] for a job-seeking service .Regarding the studies about Credit Risk , Recent studies have considered new non-parametric methods such as mathematical programming, classification trees, neural networks[8,9,10,11] and support vector machines. As [12] is suggesting that highly complex or non-linear models are not expected to have a considerable predicting ability compared to simpler models. Paper [13] explores the performance of credit scoring using ANN and multivariate adaptive regression splines (MARS). Paper [14] neural network to evaluate credit risk.

Credit scoring has both financial and non-financial aspects. The scope of the current paper, however, is limited to the evaluation of a bank client’s financial performance. In this paper, a Fuzzy Expert system has been used to evaluate the credit risk of Bank Legal customers. Studying the financial cases of companies as the bank customers, is noticeable for bank experts as the proper solution to identify the credit risk level. Here, the aim is analyzing the customers' credit risks based on the experts' analysis obtained from the financial ratios which has been extracted from financial Balance sheets .So the knowledge which helps the bank experts to make connection between the customers' credit risk level and financial situations can be obtained in the form of rules. In this study, a Fuzzy Expert system has been designed in which the case of customers' financial ratios will be considered as the Input and the level of predicted credit risk as the output. Regarding to this fact that all financial ratios for companies are not enough important for decision making of experts, the financial ratios which are more effective on the determination of the credit risk of companies, have been filtered and these financial filtered ratios have been considered in decision making. The rest of this paper is structured as follows: In the next section, an overview of the

Credit Scoring is presented. In section III an explanation of DEMATEL method and Fuzzy expert system are given. Section IV will focus on the proposed model and its use in the case of Saman Iranian Bank. In the final section, some conclusions are drawn from the study.

II. CREDIT SCORING

Credit scoring is a technique that helps some organizations, such as commercial banks and credit card companies; determine whether or not to grant credit to consumers, on the basis of a set of predefined criteria [15]. Credit scoring tasks can be divided into two distinct types: The first type is application scoring, where the task is to classify credit applicants into ‘‘good’’ and ‘‘bad’’ risk groups. The data used for modeling generally consists of financial information and demographic information about the loan applicant. In contrast, the second type of tasks deals with existing customers and along with other information, payment history information is also used here. This is distinguished from the first type because this takes into account the customer’s payment pattern on the loan and the task is called behavioral scoring. Recently, under BASEL II committee recommendations [13], it is increasingly becoming almost a regulatory requirement for the banks to use sophisticated credit scoring models for enhancing the efficiency of capital allocation. Usually, a credit score is a number that quantifies the creditworthiness of a person, based on a quantitative analysis of credit history and other criteria; it describes the extent to which the borrower is likely to pay his or her bills/debt. A credit score is primarily based on credit reports and information received from some major credit reporting agencies. Using credit scores, banks and credit card companies evaluate the potential risk involved in lending money, in order to minimize bad debts. Lenders can also use credit scores to determine who qualifies for what amount loan and at what interest rate. The generic approach of credit scoring is to apply a quantitative method on some data of previous customers – both faithful and delinquent customers – in order to find a relationship between the credit scores and a set of evaluation criteria. One important ingredient to accomplish this goal is to seek a good model so as to evaluate new applicants or existing customers as good or bad. In credit scoring, a generic process consists of two procedures: (1) applying a quantitative technique on similar data of previous customers – both faithful and delinquent customers – to uncover a relationship between the credit scores and a set of criteria; (2) utilizing the discovered relationship and new applicants’ credit data to score new applicants and to evaluate new applicants as good or bad applicants [16].

III. DEMATEL METHOD & FUZZY EXPERT SYSTEM

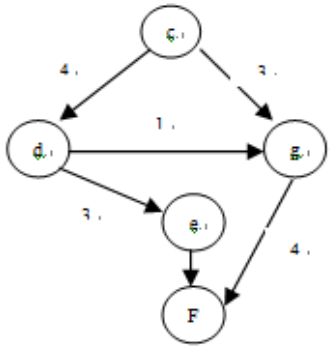
A. DEMATEL METHOD

The DEMATEL method is based upon graph theory, enabling us to plan and solve problems visually, so that we may divide multiple criteria into a cause-and-effect group, to better understand causal relationships to plot a network relationship map. Directed graphs (also called digraphs) will demonstrate the directed relationships of sub-systems The DEMATEL method can be summarized in the following steps: Step 1: Find the average matrix. Suppose we have H experts and n criteria to consider. Each expert is asked to indicate the degree which represents he or she believes a criterion i affects criterion j. These pairwise comparisons are denoted by a_{ij} and are given an integer score ranging from 0, 1, 2, 3, and 4, representing ‘No influence (0),’ ‘Low influence (1),’ ‘Medium influence (2),’ ‘High influence (3),’ and ‘Very high influence (4),’ respectively. We can then compute the n×n average matrix A for all expert opinions by averaging the H experts’ scores as follows:

$$[a_{ij}]_{n\times n}=1/H \ \ \sum_{k=1}^{H}[x_{ij}^{k}]_{n\times n} \quad (1)$$

The average matrix $A = [a_{ij}]_{n\times n}$ is also called the initial direct relation matrix. A shows the initial direct effects that a criterion exerts on and receives from other criteria. Fig. 1 below is an example of such a network influence map. Each letter represents a criterion in the system. An arrow from c to d shows the effect that c has on d, and the strength of its effect is 4. DEMATEL can convert the structural relations among the criteria of a system into an intelligible map of the system.

Figure 1. .Example of an influence map



Step 2: Calculate the normalized initial direct-relation matrix. The normalized initial direct-relation matrix D is obtained by normalizing the average matrix A in the following way:

$$\text{Let } s=\max\left(\max_{1\le i\le n}\sum_{j=1} a_{ij}\ ,\ \max_{1\le j\le n}\sum_{i=1} a_{ij}\right) \quad (2)$$

$$\text{Then } D=\frac{A}{S} \quad (3)$$

Since the sum of each row i of matrix A represents the total direct effects that criterion i gives to the other criteria, represents the total direct effects of the criterion with the most direct effects on others. Likewise, since the sum of each column j of matrix A represents the total direct effects received to other criteria by criterion i, represents the total direct effects that the criterion j receives the most direct effects from other criteria. Step 3: Compute the total relation matrix. The total relation matrix T is an n × n matrix and is defined as follow:

$$\max_{1 \le i \le n} \ \sum_{j-1}^{n} a_{ij}$$

$$T=[t_{ij}], \quad i,j=1,2,\ldots, n \quad (4)$$

Where
$T=D+D^2+D^m=D(1+D+D^2+\ldots+D^{m-1})=D|(1+D+D^2+\ldots+D^{m-1})(1-D)|(1-D)^{-1}=D(1-D)^{-1}$, as $m\to\infty$ and $(1+D+D^2+\ldots+D^{m-1})(1-D)|=1-D^m$

We also define r and c as n×1 vectors representing the sum of rows and sum of columns of the total relation matrix T as follows:

$$r=[r_i]_{n\times1}=\left(\sum_{j=1}^{n} t_{ij}\right)_{n\times1} \quad (5)$$

$$c=[c_j]'_{n\times1}=\left(\sum_{i=1}^{n} t_{ij}\right)'_{1\times n} \quad (6)$$

Where superscript 0 denotes transpose. Thus when j = i, the sum ($r_i + c_i$) gives us an index representing the total effects both given and received by criterion i. In other words, ($r_i + c_i$) shows the degree of importance (total sum of effects given and received) that criterion i plays in the system. In addition, the difference ($r_i - c_i$) shows the net effect that criterion I contributes to the system. When ($r_i - c_i$) is positive, criterion i is a net causer, and when ($r_i - c_i$) is negative, criterion i is a net receiver. Step 4: Set a threshold value and obtain the network relationship map (NRM). In order to explain the structural relation among the criteria and keep the complexity of the system to a manageable level at the same time, it is necessary to set a threshold value p to filter out some negligible effects in matrix T. Only some criteria, whose effect in matrix T is greater than the threshold value, should be chosen and shown in a network relationship map (NRM) for influence. After the threshold value is decided, the final influence result of criteria can be shown in a NRM. [17].

B. FUZZY EXPERT SYSTEM

A Fuzzy Expert System is simply an expert system that uses a collection of fuzzy membership functions and rules, instead of Boolean logic, to reason about data. Fuzzy Inference System (FIS) incorporates fuzzy inference and rule-based expert systems. There are different types of fuzzy systems are introduced. Mamdani fuzzy systems and TSK fuzzy systems are two types of fuzzy systems commonly used in literature that has different ways of knowledge representation.TSK (Takagi-Sugeno-Kang) fuzzy system was proposed in an effort to develop a systematic approach to generate fuzzy rules from a given input–output data set. Rules in this fuzzy system are like:

If x1 is A1 AND/OR x2 is A2 Then y = f(x1,x2) (7)

Where A1 and A2 are fuzzy sets and y is a (usually linear) function of crisp variables. In order to perform inference operations, the output of each rule have to be weighted. For example regarding the jth rule

w_j=AND *method*($\mu_{Aj}(x_1)$, $\mu_{Bj}(X_2)$)

Rj: If x1 is Aj AND x2 is Bj Then yj = fj(x1,x2)

$\mu_{Aj}(.)$ and $\mu_{Bj}(.)$ (8)

The weight wj is computed as where are membership functions of Aj and Bj, respectively, and the ANDmethod is the operation defined by the AND operator which is usually the ‘‘min’’ operation. Then the final output of the system will be obtained by final output (4)

$$\text{Final output} = \sum_j w_j y_j \Big/ \sum_j w_j \quad (9)$$

Mamdani fuzzy system was proposed as the first attempt to control a steam engine and boiler combination by a set of linguistic control rules obtained from experienced human operators. Rules in Mamdani fuzzy systems are like these:

If x1 is A1 AND/OR x2 is A2 Then y is B1 (10)

Where A1, A2 and B1 are fuzzy sets. The fuzzy set acquired from aggregation of rules’ results will be defuzzified using defuzzification methods like centroid (center of gravity), max membership, mean-max, and weighted average. The centroid method is very popular, in which the ‘‘center of mass’’ of the result provides the crisp value. In this method, the defuzzified value of fuzzy set A, d (A), is calculated by the formula (5)

$$d(A)= \int_A x.\mu_A(X)dx \Big/ \int_A \mu_A(X)dx \quad (11)$$

where is the membership function of fuzzy set A .Regarding our problem in which various possible conditions of parameters are stated in form of fuzzy sets, the Mamdani fuzzy systems will be utilized due to the fact that the fuzzy rules representing the expert knowledge in Mamdani fuzzy systems, take advantage of fuzzy sets in their consequences, while in TSK fuzzy systems, the consequences are expressed in form of a crisp function [18].

IV. EMPIRICAL STUDY

The major steps followed in the practical study of this research, have been implemented in Saman bank. The evaluation of credit risk for bank customers is based on the financial analysis. As the first step, the financial variables which are important for bank experts to assess the level of legal customers' risk have been selected. The followings are the extracted financial ratios from the balance sheet being reviewed by the bank experts, for evaluating the loan applicants: Current Ratio(C1), Quick Ratio (C2), Asset Turnover(C3), Working Capital Turnover(C4), Average Collection Period(C5), Debt Coverage Ratio(C6), Debt Ratio(C7), Current Debt to Net worth(C8), Gross Profit Ratio(C9), Payout Ratio(C10), Return On Sales(C11), Return on Assets(C12). Then the main variables that are most effective in decision making process and the experts' judgement about determining customers' credit risk, have been chosen and have been prioritized via DEMATEL technique. To evaluate the importance degree for each of these 12 financial ratios with the use of experts' opinions, the DEMATEL steps have been run .Table 1 shows the factor scores and related values for cause and effect groups as the sum of given and received influences on criteria.

TABLE1. THE SUM OF INFLUENCES GIVEN AND RECEIVED ON CRITERIA

Criteria	R	J	R+J	R-J
C1	3.1372	1.9415	5.0787	1.1957
C2	3.3106	2.1526	5.4632	1.158
C3	1.9003	3.064	4.9643	-1.1637
C4	2.2439	2.8586	5.1025	-0.6147

C5	2.7273	2.1389	4.8662	0.5884
C6	2.4636	2.9979	5.4615	-0.5343
C7	2.7695	1.7077	4.4772	1.0618
C8	2.1161	2.689	4.8051	-0.5729
C9	2.2176	2.4201	4.6377	-0.2025
C10	2.3669	2.495	4.8619	-0.1281
C11	2.4525	1.6464	4.0989	0.8061
C12	1.6539	2.9217	4.5756	-1.2678

According to this table, the criteria situation in the final hierarchy has been specified as Fig 2.Since the criteria C1, C2, C5, C7, and C11 are in the highest level, these five financial ratios have been selected as the most effective financial variables.

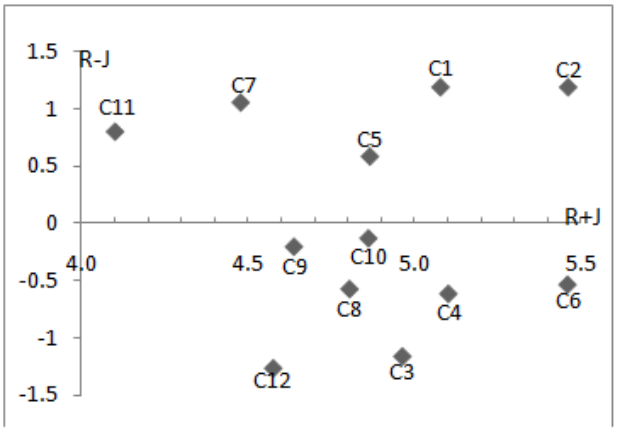


Figure 2. The causal diagram

In the next step ,the filtered financial ratios from the previous step, have been considered as the most important criteria in decision making of bank experts to identify the credit risk of customers. According to these financial ratios, the experts opinions in the form of rules have been obtained (Table 2).Then, a Mamdani's Fuzzy Expert system has been designed with the financial ratios as the system Inputs and customers' credit risk degree as the output.

TABLE 2.THE RULES FOR DESIGNING FUZZY EXPERT SYSTEM

	Current Ratio	Debit Ratio	Return On Sales	Average Collection Period	Quick Ratio	Credit Risk Degree of Customer
1	High	Medium	Medium	High	Low	High
2	Medium	High	High	Low	Medium	Low
3	High	Low	Medium	High	High	Medium
4	Medium	High	High	Medium	Medium	Medium
5	Low	High	Medium	Low	Medium	High
6	Low	Low	High	High	Low	Medium
7	High	Medium	Low	Medium	Medium	Medium
8	Medium	Low	High	Low	High	Low
9	High	High	Low	Medium	Medium	Medium
10	Medium	High	Medium	High	Low	High

With the use of MATLAB software, according to experts, for each of Input and output variables, the suitable membership function has been defined(Fig 3-8) and with regarding to obtained rules from the experts' bank ,the Fuzzy Expert system has been designed.

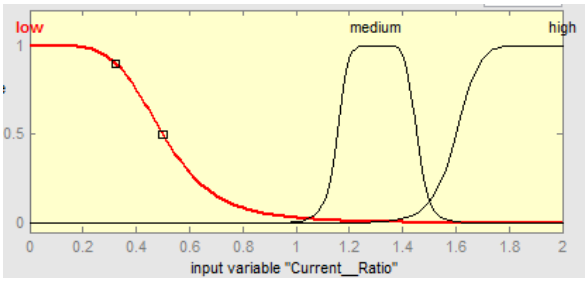


Figure 3. Three Gbell Membership functions for Current Ratio

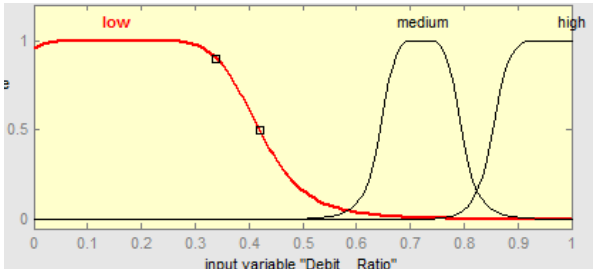


Figure 4. Three Gbell Membership function for Debt Ratio

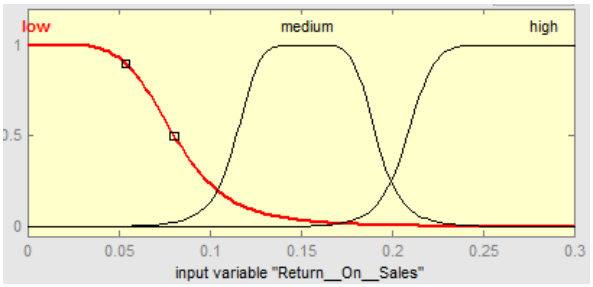


Figure 5. Three Gbell Membership functions for Return On Sales

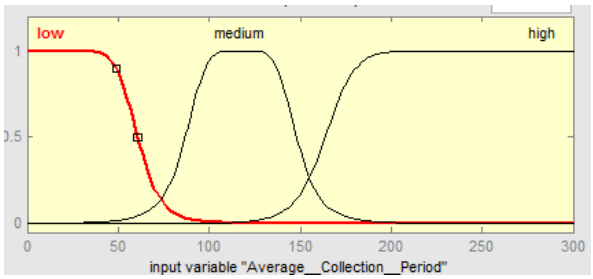


Figure 6. Three Gbell Membership functions for Average Collection Period

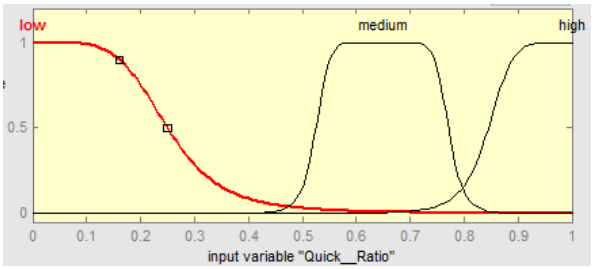


Figure 7. Three Gbell Membership functions for Quick Ratio

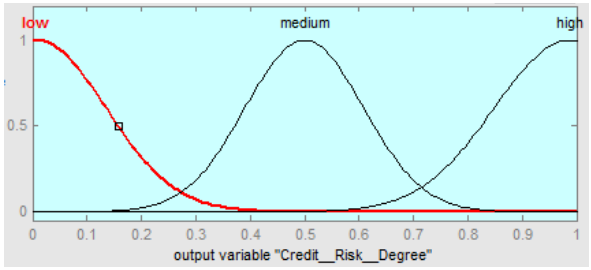


Figure 8. Three Gaussian Membership functions for Credit Risk Degree

This system can predict the level of customers' credit risk with entering the financial ratios values. An instance of the system output is as follows:

Current Ratio =1.31	Debt Ratio =0.42
Return On Sales =0.14	AvCollection Period =161
Quick Ratio =0.23	Credit Risk Degree =0.52

V. CONCLUSION

In this paper, the evaluation of credit risk has been done as one of the most important duties of banking system, with the use of analysis of customers' financial ratios. First , with the use of DEMATEL technique, the most effective financial ratios in experts' decision making have been selected and according to these filtered financial ratios and obtained rules from bank experts ,a Fuzzy Expert system has been designed that is predicting the credit risk of customers. The presented approach in this survey, can demonstrate a good solution to help bank owners and credit institutes to make them able to identify the major variables in decision making and to assess the level of new applicants' risk according to their financial situation .Finally, it can help to make bank policy for giving or not giving loans to their customers.

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