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FUZZY MODELING OF THE CREDITWORTHINESS ASSESSMENTS OF BANK'S POTENTIAL BORROWERS IN UKRAINE

The work is aimed at defining the directions of credit activity intensification of the economic entities through critical analysis of banks as a powerful leverage of raising additional resources and ensuring sufficient conditions for the development of entrepreneurship. The system of management of quality credit portfolio has considered as the basis for increasing the capacity of the banking system and development the credit relations in a country. It is proved that the issue of complex automation of processing indicators in the face of rising systemic risk, forecasting the results based on the analysis of their dynamics is an increasingly urgent task for the modern banking system. Authors have proposed modern analytical tools to provide the necessary quality of credit activity of the structural units of banks by grounded assessment of the creditworthiness of potential borrowers. The paper presents the model of assessing the creditworthiness of potential borrowers of the bank based on fuzzy logic regarding selected qualitative and quantitative indicators that are fully characterizing the client.
JEL: G21; C61; C45

1. Introduction

In conditions of transformations of the world economy, one of the main tasks of the banking system is the creation of favorable conditions for the stable reproduction process and entrepreneurial activity development because the prospects for further growth of economic entities largely depend on the ability of banks to meet their needs by necessary financial resources. Research the directions of activation of economic entities credit activity and bank's activity as a powerful lever of influence and ensuring the development of

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entrepreneurship are actualized in terms of lack of own funds to finance the production. In its turn, the complex system of management of credit portfolio on the basis of grounded analysis and assessment of its quality is essential for increasing the capacity of the banking system and development the credit relations.

Today banks as one of the main parts of the economic system of the state are often faced with borrowers who cannot repay the loan. And a lot of bad loans in the total bank assets is the cause of the banking system losses.

The credit activity of banks is complicated by the absence of grounded methods of assessing the creditworthiness of the borrower, lack of information base for a full analysis of the financial standing of customers. Also, the modern economic conditions require the use of new information technologies and computerized tools for collecting, processing and providing information. Therefore, solving the problem of assessing the creditworthiness of customers is one of priority for the bank. That is why it is reasonable to determine the ways of improving the assessment of the creditworthiness of borrowers by the justification the appropriate methodical approach and forming the model of assessment of the creditworthiness of potential borrowers of the bank.

2. Analysis of recent research and publications

It should be noted that in the scientific literature researchers pay much attention to the investigation of the mechanism of bank's participation in the monetary relations both at the macro level (Levine, 2003; Huerta-de-Soto, 2009; Herrmann & Jochem, 2003; Mersch, 2015; Draghi, 2013; Barth, Caprio & Levine, 2013; Blundell-Wignall & Atkinson, 2010; Claessens & Horen, 2014; Pacces & Heremans, 2012; Severe, 2016; Rad, 2016) and micro level (Danila, 2007; Eremia & Stancu, 2006; Thompson & Strickland, 2009; Cucinelli, 2016; Mukherjee, 2014).

However, the analysis of existing viewpoints showed that depending on economic conditions and goals of research, approaches to management of the bank credit portfolio quality based on the assessment of the creditworthiness of potential borrowers are formulated by scientists controversial. The assessing the creditworthiness of potential borrowers of the bank is the subject of many scientists' research. Despite the significant contribution of scientists to study the ways of effective formation and evaluation of the credit portfolio this issue is still important today and needs further study in both theoretical and in practical terms.

It should be noted that most scientific works devoted to the research of separate aspects of credit activity of banks. Thus, according to the work of Severe (2016) the impact of the monetary policy of banks is essential to the development of production, is especially noticeable with changes in interest rates on loans, which reduction increases the industrial growth in the country.

Ali-Shawtari, Ariff, and Abdul-Razak (2015) assessed the viability of the banking sector and proposed policy concerning the restructuring the industry in order to increase its

effectiveness. In other words, there were identified common directions of intensification of bank's work.

Carvajal (2015) investigated the impact of the credit restriction on macroeconomic instability and emphasized the importance of credit facilities for business entities. Rad (2016) studied the link between risk management and system of management in banks, in particular, studied the management intent underlying the forming of bank's activity control system.

Mertzanis (2015) emphasized the importance of developing a risk management system and grounded analysis in the process of regulating the bank's activity. Osei-Assibey and Asenso (2014) presented the results of modeling interconnection between indicators of bank's activity, industrial and macroeconomic changes, examined in detail the regulatory capital and its impact on credit expansion, the role of credit and credit debt impact on the efficiency of the bank. Gaillard (2014) investigated the lack of clear and reliable information about potential borrowers and the impact of limited information on the activity of banks.

Hsu-Che, Ya-Han, and Yen-Hao (2014) analyzed credit ratings for assessing credit risk. Ordinary credit rating approaches mainly focus on two classes classification (good or bad credit), which leads to a lack of adequate accuracy for the assessment of credit risk in practice. Scientists had proved that most previous studies focused on the use of different methods of data analysis, but the issue of selection and data processing are still remained scarcely explored.

Acknowledging the importance and practical significance of these results, we emphasize that the overall there is a lack of deep theoretical research and practical recommendations for solving the problem of improving and managing exactly the process of assessing the creditworthiness of the borrowers based on advanced information technologies.

3. Formulation of the purpose of the article

The purpose of this article is the examining of existing approaches to determine the creditworthiness of the borrower, analyzing characteristics of such approaches and justification the methodology of evaluating the creditworthiness of the borrower – individual, that let's decide most effectively in the specific conditions of activity of banks.

4. Approaches for assessing the borrower creditworthiness

Each bank uses its own procedures and criteria for assessing the creditworthiness and financial position of the borrower based on the analysis of financial statements, following the recommendations of the central bank. For this purpose, there are used advanced applications of express-analysis of the financial standing of companies and dynamic of cash flow. However, there is a lack of recommendations for determining the validity and

normative values of some parameters. In the absence of powerful analytical tools in most banks, this problem remains unresolved or solved subjectively in practice.

The main problem of assessing the creditworthiness of borrowers, both individuals and legal entities in banks, there is a great complexity of this work. The process of assessing the creditworthiness are mostly not automated, so there are plenty of busy workers. In addition to the above, search for the required information about the client and its documents is often difficult, because several departments and workers are engaged simultaneously in the assessment of the creditworthiness of the borrower. The main problem with the bank credit process is the inherent uncertainty of it. Not having full information about potential borrowers and changes in the environment, banks have to deal with credit risk almost every day. The development of information technology and information systems allows solving almost no limited number of tasks related to decision-making under uncertainty.

Most frequently to assess the creditworthiness of the borrower used: statistical methods; decision tree; genetic algorithms; neural networks.

Statistical methods based on discriminant analysis are used in solving problems of classification. Thus, the famous Altman model using for analyzing the creditworthiness of entities is based on multiple discriminant analysis. Linear or logistic regression is used to analyze the creditworthiness of individuals. All regression methods are sensitive to the correlation between characteristics, so there should not be strongly correlated characteristics of the borrower in the model.

Statistical methods are based on averaging indicators, but during the study of real difficult phenomena of life, these characteristics may be inapplicable. Assessment of creditworthiness of the borrower through these methods requires a lot of data about the credit history, that is not always possible. Also typical is the problem of lack of examples of borrowers that were unable to repay their debts. A significant drawback of statistical methods is the requirements for special training of the user.

The method of decision trees is high-speed processing and training while maintaining the properties of fuzzy inference. When using the method of decision trees for classification of loan applications a set of rules is used that formed in the construction of the tree based on the training set. The tree includes interrelated initial (root), intermediate and end nodes. Each node meets the condition (rule) of the classification of objects. To build a tree at each internal node you need to find a condition that would break the set associated with this node in the subset.

With selected characteristic, the set is divided. As a result, the obtained subset is consisted of objects belonging to the same class, or are as close as possible to this. The number of objects from other classes in each of these sets should be as less as possible.

But the method of decision trees has significant drawbacks. It is not suitable for tasks with a large number of possible links and when the condition (rule) can be formulated only in terms of "more / less". That hinders its application to tasks where the class is determined by a complex combination of variables.

Genetic algorithms are based on a stochastic search of a global optimum objective function. The idea of genetic algorithms is borrowed from nature and means an organization the process of evolution, the ultimate objective of which is the optimal solution. Such algorithms have a lot of drawbacks. The criterion of selection the indicators does not guarantee finding the "best" solution. You must also have available a fairly large amount of input data to complete the procedure.

Neural networks are the computational structures that model simple biological processes commonly associated with processes in the human brain. According to Michie et al. (1994), neural networks are a set of elements (artificial neurons) connected by synoptic links. The disadvantage of using neural networks is that they are a "black box". It means that they work on the principle of transferring information from one level of neurons to others, certain input signal corresponds to a certain output and the mechanism of such work is still unknown. Knowledge recorded as the weight of several hundred interneuronal relationships and it is difficult for a person to analyze and interpret them. Also, there is a lack of hard rules of the choice of network speed training for solving specific problems.

There are many architectures of neural networks. For example, to classify clients of German and Australian banks use the following networks: network of Kohonen, Back Propagation network, radial basis network, cascading network.

General disadvantages for practical application of the above methods are requirements to the volume of input and stringent requirements for characteristics and selection criteria for the borrower. In real life borrower's environment is constantly changing, as a result his marital and financial status is changing too. This brings uncertainty to the information about the client. Incorrect assessment of the borrower in these conditions can increase the risk of bank or loss potentially reliable customers.

Turtle, Bector and Gill (1994), Friedlob and Schleifer (1999), Allen, Bhattacharya and Smarandache (2003), Chi-Man-Hui, Muk-Fai-Lau and Kak-Keung-Lo (2009), Kahraman (2011) and others show that the most effective methods are the combined methods of intelligence that combines the benefits of natural and artificial intelligence (for example, methods of fuzzy sets theory).

Based on this theory, methods of building information models significantly expand the traditional areas of application computer and create an independent direction of scientific and applied research. Recently, fuzzy modeling is one of the most active and perspective directions of modeling in management and decision-making. In the management of technical facilities, fuzzy modeling allows obtaining more adequate results, compared with the results based on the use of traditional analytical models and control algorithms.

Fuzzy modeling process can be represented in the form of interconnected stages, at each stage, there are carried out specific actions directed to building and further using of information and logical models of systems. In addition, each stage is performed in order to build and use the fuzzy model system to solve the initial problem.

Separate stages of the process fuzzy modeling are: analysis of the problem situation; structuring of the subject area and building a fuzzy model; execution of computing

experiments with the fuzzy model; application of the results of computational experiments; correction or completion fuzzy model.

Thus, a fuzzy model of the original or a fuzzy system is first of all characterized by uncertainties type of ambiguity (fuzziness) of the system's limits and its individual states, input and output impacts.

The task of assessing the creditworthiness can be formulated as follows. Every credit application is given by the vector, another word by formalized in a certain way data from the borrower's questionnaire and chosen loan parameters. Then according to the chosen vector, it is necessary to make a decision on the loan, the borrower should be classified as "reliable" or as "not reliable."

In world practice, still there is no single standardized system of assessing the creditworthiness of borrowers, that's why banks use different methods that are complemented each other. At present sector of loans to individuals is the most sensitive to changes in the socio-economic sphere, and many existing methods for assessing the creditworthiness of clients has appeared inefficient. Because of growing competition in the market of credit services and unsatisfied demand for different banking products, credit institutions have to look for ways to attract credit-worthy customers with saving the possibility of control losses. So there is a need for better selection of borrowers.

Assessment of the creditworthiness of the borrower – individual based on the ratio of the requested loan and its personal income, overall assessment of the financial situation of the borrower and the cost of its property, on the results of studying personal characteristics and credit history. Lending to borrowers – individuals allows banks, on the one hand, to increase their income in a short period of time, and on the other hand, it is always associated with the risk of late payment or no repayment of the loan in full. Accurate assessment of the ability of borrowers to meet their loan obligations allows reducing possible losses. Therefore, a competent organization of assessing the creditworthiness of borrowers very is important.

Permanent improvement of the lending system in the face of rising interbank competition is a necessary condition for the bank for forming its public image as a universal credit institution and serves as an additional source of income of credit operations with individuals. Despite intense development in recent years this area of banking business still has huge reserves of growth. Assessment of the creditworthiness of a potential borrower is carried out to determine its class of reliability and financial ability to timely and fully implement repayment in terms and conditions established by the credit agreement.

The periodicity of assessment of the financial condition of the individual borrowers is defined by the bank based on the state of debt servicing and maturity of the loan. If the credit debt service is characterized by delay or prolongation, then an assessment of the financial condition of the individual borrowers should be constant for a period of delayed repayment of debt, except when it is related to valid reasons. The world banking practice distinguishes a number of components that together allow determining the level of creditworthiness of the borrower. In order to create an effective methodology of the complex system of assessment the creditworthiness of borrowers in indicators of

creditworthiness should be included not only the value that is relatively easily calculated using quantitative data but also those that may be described by the evaluative judgments.

Yue Jiao, Yu-Ru Syau, and E. Stanley Lee (2007) in their work presented a model for assessing the credit rating of small financial enterprises based on the fuzzy adaptive network. There are deep mathematical calculations and a lot of specification of the neural network. The authors use a set of specific indicators taking into account the object of their research.

Based on the research work of scientists there were generalized main qualitative and quantitative characteristics of the borrower, that should be taken into account in assessing the creditworthiness of the borrower – individual. Particular attention is paid on considering the quality indicators of the creditworthiness of borrowers in the regulation of credit activity of the banks. This question was so emphasized by Tammi (2013) in his works. Also, questions of security of credit were investigated by Ghosh (2016) by the example of specialized banks.

For the proposed model of the creditworthiness assessments of bank's potential borrowers (individuals) on the basis of fuzzy logic the input indicators were selected taking into account the recommendations of the central bank, internal instructions of Ukrainian banks, the experience of using the system of indicators in domestic banking practice by an expert survey of employees of the largest banks in Ukraine.

5. Description of the proposed model

The authors constructed a model assessing the creditworthiness of the borrower based on fuzzy logic taking into account selected indicators with further the possibility of expanding the list of assessment criteria. According to these indicators, we make a linguistic score for generalizing indicator of creditworthiness.

General indicator (R) is a three-level convolution where partial indicators (a_1, a_2, a_3, b_1, b_2, b_3, c_1, c_2, c_3, d_1, d_2, d_3) combined in the components of evaluation (A, B, C, D), and the components in their turn – in the resulting indicator. Model of assessment of the creditworthiness of the individual borrower is based on predefined parameters and the chosen method (Figure 1).

Thus, input and output options were identified and each of them is characterized by a set of linguistic terms of linear (triangular and trapezoidal) membership function.

Figure 1

The structure of the model of assessing the creditworthiness of potential borrower-individual (realization in FuzzyTech program tool)
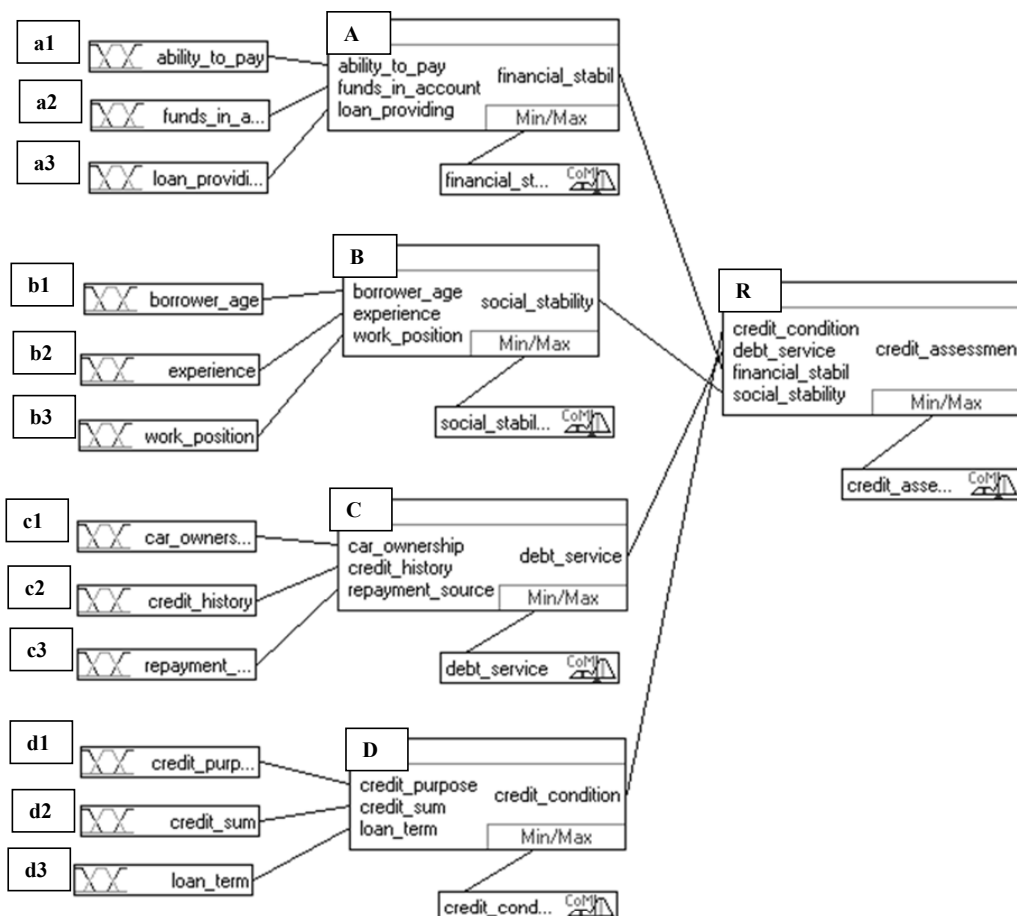
Intervals of changes of such components as the financial stability of the borrower, debt service of the borrower, credit conditions are based on the "golden ratio" or Fibonacci numbers as the basis of harmonious division.

On the upper level, the input parameters are the borrower's financial stability, social stability, debt service, credit conditions. They are also output parameters of the lower level. For each input parameter has constructed membership function depending on the deviation from the schedule of passing control points (Table. 1).

Table 1

The components (characteristics of membership functions) for assessing creditworthiness of borrower (R)

Symbol	Name	Symbol	Linguistic assessment	The trapezoidal numbers for the values of linguistic variable				Interval
A	Financial stability of the borrower	A1	weak	0.000	0.118	0.382		0.000-0.382
		A2	enough	0.375	0.499	0.558	0.618	0.382-0.618
		A3	strong	0.600	0.735	0.853	1.000	0.618-1.000
B	Social stability of the borrower	B1	weak	0.000	0.120	0.250		0.000-0.250
		B2	enough	0.200	0.350	0.500	0.750	0.250-0.750
		B3	strong	0.650	0.850	0.950	1.000	0.750-1.000
C	Debt service	C1	satisfactory	0.000	0.236	0.382		0.000-0.382
		C2	good	0.370	0.499	0.618		0.382-0.618
		C3	excellent	0.550	0.735	1.000		0.618-1.000
D	Credit conditions	D1	low risky	0.000	0.127	0.254	0.382	0.000-0.382
		D2	risky	0.375	0.508	0.618		0.382-0.618
		D3	very risky	0.500	0.744	1.000		0.618-1.000

As already noted, general indicator of assessment of the creditworthiness of the borrower – individual (R), consists of four components, which have three terms in accordance with the range of variation: financial stability of the borrower, social stability of the borrower, debt service and credit conditions.

In Table 2 terms and intervals of an overall assessment of the creditworthiness of the borrower for the model are given. Intervals of changes in the assessment of the creditworthiness of the borrower and its linguistic assessment are based on Harrington's Desirability Function (Harrington, 1965).

Table 2

Overall assessment of creditworthiness of the borrower for the model

Indicator	Intervals	Linguistic assessment
R1	0.00-0.37	Low
R2	0.30-0.65	Satisfactory
R3	0.55-0.80	Good
R4	0.70-1.00	very good

Each of the components of an overall assessment of the creditworthiness of the borrower combines a number of partial indicators. In annex 1-4 the structure of each component in the context of the partial indicators is given. The intervals of changing of the indicator of the current ability to pay are selected in accordance with the generally accepted practice of its use in the bank's work, as well as the intervals for the indicator of ensuring the credit, the loan term, lending amount.

For indicators funds on accounts in banks, sources of debt repayment and purpose of lending intervals are based on the results of a survey of experts of the banking sector. The

"age of the borrower" and "work experience" are broken at intervals, taking into account the logic and objective trends of the labor market in Ukraine.

Intervals for the indicator "place of work (position)" correspond to the logic of construction of the Unified Tariff Grid in Ukraine. The intervals of the indicator "Automobile ownership" (the cost of cars) are due to the general tendency of prices in the car market and the purchasing power of Ukrainian citizens.

Depending on the input variables and possible options of its combination (rules for assessing the creditworthiness of the borrower) we received general characteristics R (Table 3). The full set of rules is given in annex 5-9.

Table 3

Rules for assessing the creditworthiness of the borrower (fragment)

Rule	Financial stability	Social stability	Debt service	Credit conditions	Overall assessment of creditworthiness
1	weak	weak	Satisfactory	low risk	low
2	weak	weak	Satisfactory	risk	low
.....					
15	enough	enough	Satisfactory	risk	satisfactory
16	enough	weak	Satisfactory	risk	low
.....					
81	enough	strong	Excellent	low risk	very good

Computer representation of membership functions for input components (A, B, C, D) of the general indicator of the creditworthiness of the borrower (R) is shown on Figure 2. Computer representation of membership functions for input variables of the structural components (A, B, C, D) is given in annex 10.

For effective practical use of the model following steps should be done on the stage of implementation of the model: accumulating a sufficient base for each of the input parameters; conducting adaptation; clarification and correction the model (look and membership functions parameters, decision-making rules). Based on data about individuals an approbation of the model of the assessing the creditworthiness of borrowers has been conducted.

Figure. 2

Computer representation of membership functions for input components (A, B, C, D) of the general indicator of the creditworthiness of the borrower (R)
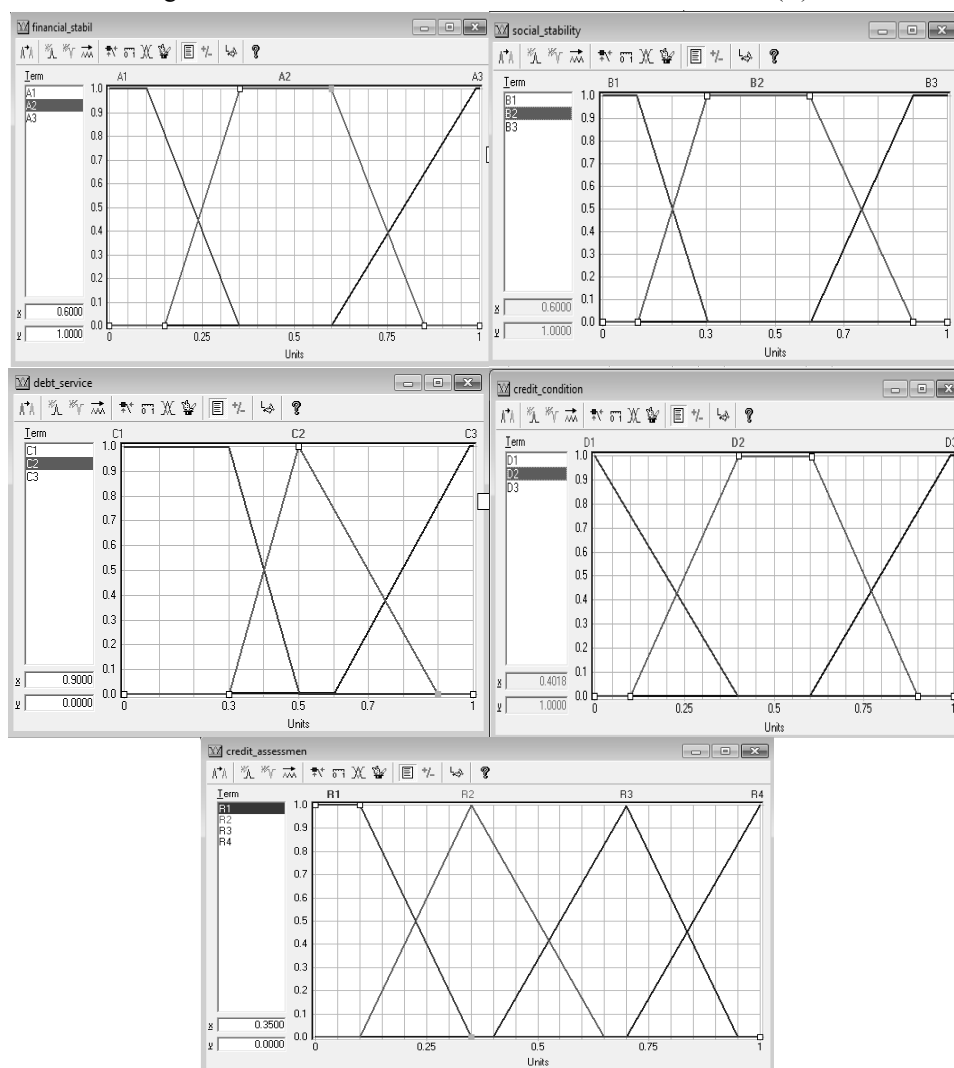
6. Numerical example of calculations

The results of assessing the creditworthiness of borrowers are given on Figure 3, for all potential clients we have received a summary assessment of creditworthiness.

On the left side of each interactive window while working in the program user enters a numerical value (assessment) of input parameters, and on the right side, the program displays the results of calculations for all output parameters (interim and final).

Figure 3

Computer representation of the results of assessing the creditworthiness of borrowers
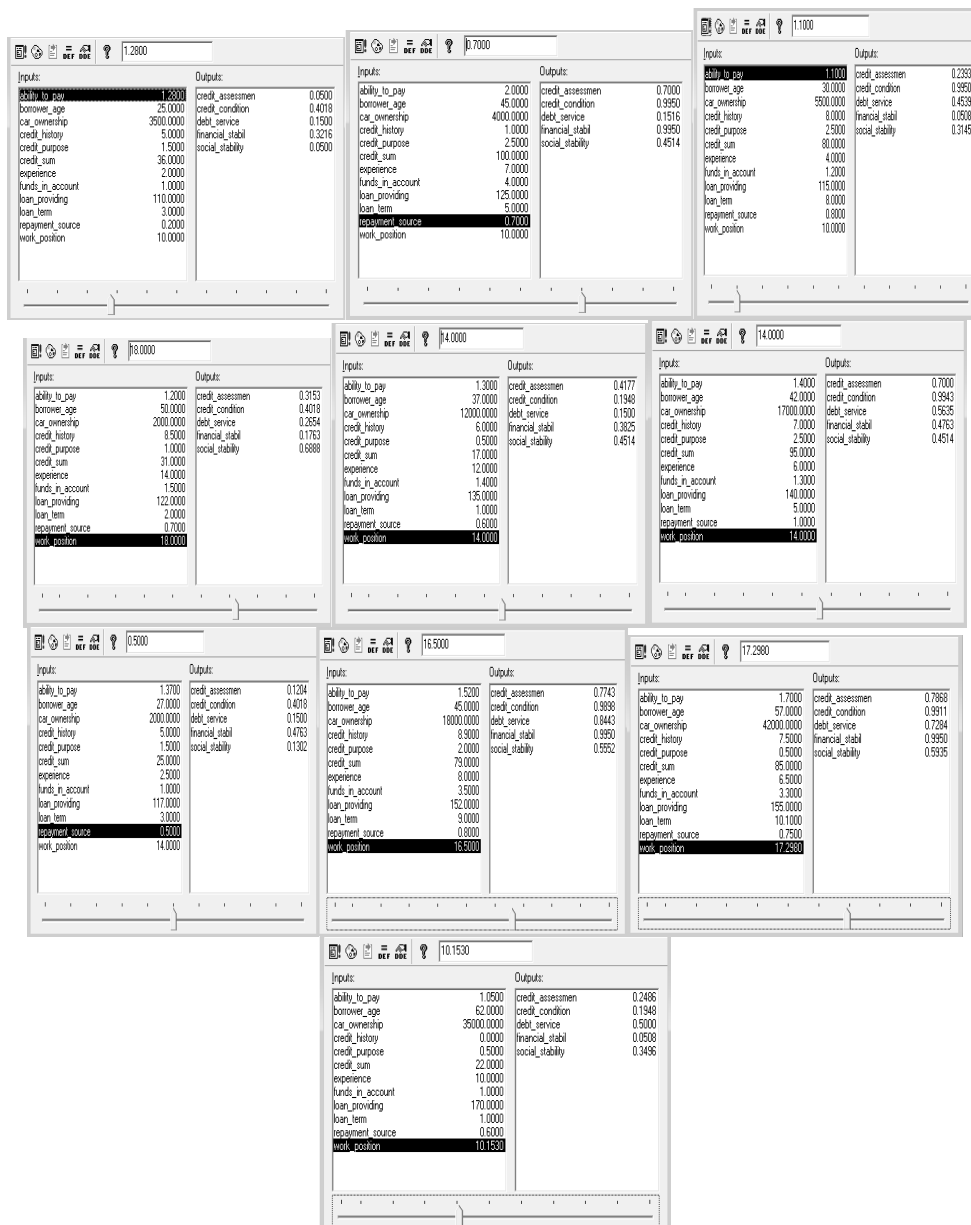
There are input variables of the model and the results of assessing the creditworthiness of borrowers in Table 4.

Table 4

Input numerical data for each client and the results of assessing the creditworthiness of borrowers

| Client | Creditworthiness of the borrower | | | | | | | | | | | | Creditworthiness assessment R |
| | Financial stability (A) | | | Social stability (B) | | | Debt service (C) | | | Credit conditions (D) | | | |
	ability to pay	funds in account	loan providing	experience	borrower age	work position	repayment sources	credit history	car ownership	credit purpose	loan term	credit sum	
1	1.28	1	110	2	25	0.5	0.2	5	3500	1.5	3	36000	0.05
2	2	4	125	7	45	1	0.7	1	4000	2.5	5	100000	0.7
3	1.1	1.2	115	4	30	0.5	0.8	8	5500	2.5	8	80000	0.239
4	1.2	1.5	122	14	50	2	0.7	8.5	2000	1	2	31000	0.315
5	1.3	1.4	135	12	37	3	0.6	6	12000	0.5	1	17000	0.418
6	1.4	1.3	140	6	42	1.5	1	7	17000	2.5	5	95000	0.7
7	1.37	1	117	3	27	1.5	0.5	5	2000	1.5	3	25000	0.12
8	1.52	3.5	152	8	45	2	0.8	8.9	18000	2	9	79000	0.774
9	1.7	3.3	155	7	57	2.7	0.8	7.5	42000	2	12	85000	0.787
10	1.05	1	170	10	62	1	0.6	0	35000	0.5	1	22000	0.249

There are grouped assess of the creditworthiness of clients and their linguistic assessment in Table. 5. Of course, these recommendations are not exhaustive; they are carefully developed by employees of the bank, approved by the credit committee, and then provided to the credit manager for further work. Also, a more detailed analysis of direct numerical modeling of our model is the subject of further research.

Table 5

Summary results of the assessment creditworthiness of clients

Linguistic assessment of the creditworthiness of client: «low»	Recommended actions by the bank	Linguistic assessment of the creditworthiness of client: «satisfactory»	Recommended actions by the bank
client 1 client 3 client 4 client 7 client 10	Refuse to provide credit	client 5	Refuse to provide credit, but provide recommendations for correct deficiencies and improve indicators
Linguistic assessment of the creditworthiness of client: «good»	Recommended actions by the bank	Linguistic assessment of the creditworthiness of client: «very good»	Recommended actions by the bank
client 2 client 6	Satisfy an application for credit, but on a lower amount	client 8 client 9	Satisfy an application for credit

We assume, in particular, consider such questions as construction of membership functions based on statistical analysis of expert interviews; the use of more complex forms of membership functions, including non-standard; opportunities for learning and adjustments constructed system fuzzy inference using the neural network; increasing the number of initial model parameters; determine the weights of parameters; development model using different values of weighting coefficients for different initial, intermediate parameters and appropriate decision-making; creation the modules by adding models in the programming language C.

7. Conclusions

The main problem in the analysis of the creditworthiness of borrower – individual is the inaccuracy of data, lack of a base of knowledge of customers' past and the necessity to work with linguistic characteristics that are difficult to mathematical processing. In specific terms of banks functioning methods based on fuzzy logic, including methods based on fuzzy neural network and Mamdani controller give good results. They allow getting grounded decision considering the fuzzy evaluation, fuzzy information about the object, initial settings, that are characterized by fuzzy criteria.

Thus, the work provided practical recommendations for improving the approach to evaluating the quality of the credit portfolio of the bank and ensure its quality on the basis of the model of assessment creditworthiness of borrower – individual. Implementation of advanced methical tools of modeling the analysis of the creditworthiness of borrower based on fuzzy logic allows the bank's management to implement grounded decisions at the stage of customer service more effectively.

Because complex automation of processing parameters, calculations of results based on these parameters is becoming increasingly important for modern banking systems, the model for evaluating the creditworthiness of borrowers – individuals based on fuzzy logic was developed based on specified parameters and offered to practical use. It is timely to ensure the quality of banks' activity.

The results of research can be used in practical activities of banks to assess the financial status of bank's client according to the established criteria and make a decision by bank's managers concerning expediency granting credit in each case. Formulated theoretical-methodological and practical arrangements may be used for further research in evaluating the quality of the credit portfolio and credit risk management.

Of course, there is a certain subjectivity about building a model. It manifests itself at the initial stage, when on the basis of expert assessments (groups or even one specialist) sets of membership functions, numerical characteristics and the form of sets of terms of linguistic variables.

Therefore, the example given in the article only shows the possibility of developing and using such models on the basis of fuzzy sets theory and fuzzy modeling. Therefore, in practical use, a preliminary adjustment, adaptation of the model, based on specific loan conditions and other features, is required, which can only be identified and accounted for in the practical application of the model.

Considering the interaction of the proposed approach with other existing ones, two main points should be noted.

The first is that in practice it is advisable to simultaneously use several different approaches to solve this problem. And if the results obtained by different methods are the same or almost the same, the decision to lend the borrower can be considered correct. That is, the results confirm each other. Otherwise, additional calculations or use of other methods of developing and making decisions, including, possibly, correcting the calculation models themselves are necessary.

The second point to be noted is that the proposed fuzzy modeling approach requires good statistical preparation at the stage of initial model development. This concerns the definition of a set of evaluation parameters, the numerical values of their individual levels, the nature (kind) of membership functions and linguistic variables. At this stage it is necessary to make maximum use of methods of expert evaluation and statistical processing of their data.

The practical value of the results investigation confirmed the real trends and existing needs of the banking system of Ukraine. Proposed analytical tools can be used by banks in practice. The competitive advantages of it include the flexibility to expand the base of input parameters and the ability to adapt according to the requirements that can permanently change.

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APPENDIX

Annex 1

Indicators (characteristics of membership functions) for assessing of the borrower financial stability (A)

Symbol	Name	Symbol	Linguistic assessment	Triangular and trapezoidal numbers for the value of linguistic variable				Interval
a1	The current ability to pay (CAP)	a11	low	1	1.25			1< CAP <1.25
		a12	middle	1.20	1.3	1.40	1.5	1,25< CAP <1.5
		a13	high	1.45	2			CAP >1.5
a2	Funds on accounts in banks	a21	absent	0	1			No funds on accounts in banks (1 point)
		a22	insufficient	0.75	1.5	2		Funds on accounts in the amount less than the loan amount (2 points)
		a23	sufficient	1.7	3	4		Funds on accounts that exceed the amount of the loan (4 points)
a3	Ensuring the credit (EC)	a31	sufficient	100	110	125		The collateral value of the property less than 25% higher than the amount of credit debt 100%< EC <125%
		a32	middle	120	130	140	150	The collateral value of the property at least 25% higher than the amount of credit debt 125%< EC <150%
		a33	high	145	200	250		The collateral value of the property at least 50% higher than the amount of credit debt EC >150%

Annex 2

Indicators (characteristics of membership functions) for assessing of the borrower social stability (B)

Symbol	Name	Symbol	Linguistic assessment	Triangular and trapezoidal numbers for the value of linguistic variable				Interval
b1	Work experience	b11	low	0	1	3		To 3 years
		b12	middle	2.5	3.5	7	10	From 3 to 10 years
		b13	high	8.5	15			More than 10 years
b2	Age borrower	b21	young	20	25	35		20-35 years
		b22	adult	30	35	45	55	35-55 years
		b23	old	50	65	70		55-70 years
b3	Place of work (position)	b31	low	0.5	1			The worker or employee (0.5 or 1 point)
		b32	middle	0.75	1.5	2		Specialist, top manager of the company (2 points)
		b33	high	1.75	2.5	3		Own business or the head (3 points)

Annex 3

Indicators (characteristics of membership functions) for assessing of the borrower social stability (C)

Symbol	Name	Symbol	Linguistic assessment	Triangular and trapezoidal numbers for the value of linguistic variable				Interval
c1	Sources of debt repayment	c11	unstable	0	0,1	0,2		Unstable additional income (0.2 points)
		c12	stable	0,15	0,4	0,6		Stable additional income (0.6 points)
		c13	stable and reliable	0,50	0,7	0,8	1	The official salary and other confirmed income (1 point)
c2	Credit history	c21	sufficient	0	5			There is a breach of contract (0 points) Not used (5 points);
		c22	good	4	6	8		Systematic delay payments over 7 days (4 points) Systematic delay payments to 7 days (6 points) Delay payments not systematically to 7 days (8 points)
		c23	excellent	7	10			Individual cases of overdue payments (7.5 points) Debt service is good without violations (9 points)
c3	Automobile ownership	c31	cheap	300	1000	2000	3000	Cost up to USD 3,000
		c32	budget	2500	5000	7000	10000	Cost from 3 000 to 10 000 USD.
		c33	medium	9000	15000	25000	30000	Cost from 10 000 to 30 000 USD
		c34	expensive	27000	50000	75000	100000	Cost from 30 000 USD.

Annex 4

Indicators (characteristics of membership functions) for credit conditions (D)

Symbol	Name	Symbol	Linguistic assessment	Triangular and trapezoidal numbers for the value of linguistic variable				Interval
d1	The purpose of lending	d11	Consumer lending	0	0,5			Purchases of consumer goods (0.5 points)
		d12	Auto Loans	0,4	1	1,5	2	Purchase of cars (1 point-domestic, 2 points-import)
		d13	Mortgage Lending	1,75	2	2,5		Purchase of house (2 points - secondary market, construction - 2.5 points)
d2	Loan term	d21	Short	0,1	1			To 1 year
		d22	Medium	0,75	2	3	5	From 1 to 5
		d23	Long	4	10	15		From 5 to 15
d3	Lending amount	d31	Small	1000	5000	10000	20000	To 20 000 UAH
		d32	Medium	18000	25000	35000	50000	From 20 000 to 50 000 UAH
		d33	Big	48000	70000	100000		Over 50 000 UAH

Annex 5

The rules for forming assess of the financial stability of the borrower (A) (A1 weak; A2 sufficient; A3 strong)

The combination of components			Financial stability A	The combination of components			Financial stability A
a11	a21	a31	A1	a12	a23	a33	A3
a11	a22	a31	A1	a12	a22	a33	A3
a11	a23	a31	A2	a12	a21	a33	A2
a11	a22	a32	A1	a12	a23	a32	A3
a11	a21	a32	A1	a13	a21	a31	A2
a11	a23	a33	A2	a13	a22	a31	A2
a11	a22	a33	A1	a13	a23	a31	A3
a11	a21	a33	A1	a13	a22	a32	A2
a11	a23	a32	A2	a13	a21	a32	A2
a12	a21	a31	A2	a13	a23	a33	A3
a12	a22	a31	A2	a13	a22	a33	A3
a12	a23	a31	A3	a13	a21	a33	A2
a12	a22	a32	A2	a13	a23	a32	A3
a12	a21	a32	A2				

Annex 6

The rules for forming assess of the social stability of the borrower (B) (B1 weak; B2 sufficient; B3 strong)

The combination of components			Social stability B	The combination of components			Social stability B
b11	b21	b31	B1	b12	b23	b33	B2
b11	b22	b31	B1	b12	b22	b33	B3
b11	b23	b31	B1	b12	b21	b33	B3
b11	b22	b32	B2	b12	b23	b32	B2
b11	b21	b32	B1	b13	b21	b31	B2
b11	b23	b33	B2	b13	b22	b31	B2
b11	b22	b33	B2	b13	b23	b31	B1
b11	b21	b33	B1	b13	b22	b32	B2
b11	b23	b32	B1	b13	b21	b32	B2
b12	b21	b31	B1	b13	b23	b33	B3
b12	b22	b31	B2	b13	b22	b33	B3
b12	b23	b31	B1	b13	b21	b33	B3
b12	b22	b32	B2	b13	b23	b32	B2
b12	b21	b32	B2				

Annex 7

The rules for forming assess of the debt service of the borrower (C) (C1 satisfactory; C2 good; C3 excellent)

The combination of components			Debt service C	The combination of components			Debt service C
c11	c21	c31	C1	c13	c21	c31	C1
c11	c22	c31	C1	c13	c22	c31	C2
c11	c23	c31	C1	c13	c23	c31	C2
c11	c22	c32	C1	c13	c22	c32	C2
c11	c21	c32	C1	c13	c21	c32	C2
c11	c23	c33	C1	c13	c23	c33	C3
c11	c22	c33	C1	c13	c22	c33	C3
c11	c21	c33	C1	c13	c21	c33	C2
c11	c23	c32	C1	c13	c23	c32	C3
c12	c21	c31	C1	c11	c21	c34	C2
c12	c22	c31	C1	c11	c22	c34	C2
c12	c23	c31	C1	c11	c23	c34	C2
c12	c22	c32	C1	c12	c21	c34	C2
c12	c21	c32	C1	c12	c22	c34	C2
c12	c23	c33	C2	c12	c23	c34	C3
c12	c22	c33	C2	c13	c21	c34	C2
c12	c21	c33	C2	c13	c22	c34	C3
c12	c23	c32	C2	c13	c23	c34	C3

Annex 8

The rules for forming assess the credit conditions (D) (D1 low risky; D2 risky; D3 very risky)

The combination of components			Credit conditions D	The combination of components			Credit conditions D
d11	d21	d31	D1				
d11	d22	d31	D1	d12	d23	d33	D3
d11	d23	d31	D1	d12	d22	d33	D3
d11	d22	d32	D2	d12	d21	d33	D2
d11	d21	d32	D1	d12	d23	d32	D2
d11	d23	d33	D3	d13	d21	d31	D2
d11	d22	d33	D3	d13	d22	d31	D2
d11	d21	d33	D2	d13	d23	d31	D3
d11	d23	d32	D2	d13	d22	d32	D2
d12	d21	d31	D1	d13	d21	d32	D3
d12	d22	d31	D2	d13	d23	d33	D3
d12	d23	d31	D2	d13	d22	d33	D3
d12	d22	d32	D2	d13	d21	d33	D3
d12	d21	d32	D2	d13	d23	d32	D3

Annex 9

The rules for forming assess of the creditworthiness of borrowers (R)
(R1 low; R2 satisfactory; R3 good; R4 very good)

The combination of components				Creditworthiness of borrowers
A1	B1	C1	D1	R1
A1	B1	C1	D2	R1
A1	B2	C1	D2	R1
A1	B2	C1	D3	R1
A2	B2	C1	D2	R2
A2	B1	C1	D2	R1
A2	B2	C1	D3	R2
A3	B1	C1	D1	R2
A1	B2	C1	D1	R1
A1	B3	C1	D1	R2
A1	B1	C1	D3	R1
A1	B3	C1	D3	R1
A2	B1	C1	D1	R2
A2	B2	C1	D1	R3
A2	B3	C1	D1	R3
A2	B1	C1	D3	R2
A2	B3	C1	D3	R2
A2	B3	C1	D2	R2
A3	B3	C1	D3	R3
A3	B1	C1	D3	R2
A3	B2	C1	D1	R3
A3	B2	C1	D3	R3
A3	B3	C1	D2	R3
A1	B2	C2	D2	R2
A1	B1	C2	D1	R1
A1	B1	C2	D3	R1
A1	B2	C2	D3	R2
A1	B3	C3	D1	R2
A1	B2	C3	D1	R2
A2	B3	C3	D1	R4
A1	B3	C1	D2	R2
A3	B3	C1	D1	R3
A3	B1	C1	D2	R2
A3	B2	C1	D2	R3
A1	B2	C2	D1	R2
A1	B1	C2	D2	R1
A1	B3	C2	D1	R2
A1	B3	C2	D2	R2
A1	B3	C2	D3	R2
A2	B2	C2	D2	R3
A2	B1	C2	D2	R3

The combination of components				Creditworthiness of borrowers
A2	B2	C2	D1	R3
A2	B3	C2	D2	R3
A2	B2	C2	D3	R3
A2	B1	C2	D1	R3
A2	B3	C2	D3	R3
A2	B3	C2	D1	R3
A2	B1	C2	D3	R2
A3	B3	C2	D3	R3
A3	B2	C2	D2	R3
A3	B3	C2	D2	R3
A3	B1	C2	D1	R3
A3	B3	C2	D1	R4
A3	B1	C2	D3	R3
A3	B1	C2	D2	R2
A3	B2	C2	D1	R3
A1	B3	C3	D3	R2
A1	B1	C3	D1	R2
A1	B1	C3	D3	R1
A1	B1	C3	D2	R1
A1	B2	C3	D2	R2
A1	B3	C3	D2	R2
A2	B3	C3	D3	R3
A2	B2	C3	D2	R3
A2	B3	C3	D2	R3
A2	B1	C3	D1	R3
A2	B1	C3	D2	R2
A2	B2	C3	D1	R4
A2	B1	C3	D3	R2
A3	B3	C3	D3	R4
A3	B3	C3	D1	R4
A3	B3	C3	D2	R4
A3	B1	C3	D1	R3
A3	B1	C3	D2	R3
A3	B2	C2	D3	R3
A1	B2	C3	D3	R2
A2	B2	C3	D3	R3
A3	B1	C3	D3	R3
A3	B2	C3	D3	R3
A3	B2	C3	D2	R3
A3	B2	C3	D1	R4

Annex 10

Figure 1. Computer representation of membership functions for input variables
(a1, a2, a3) of the component "financial stability of the borrower" (A)
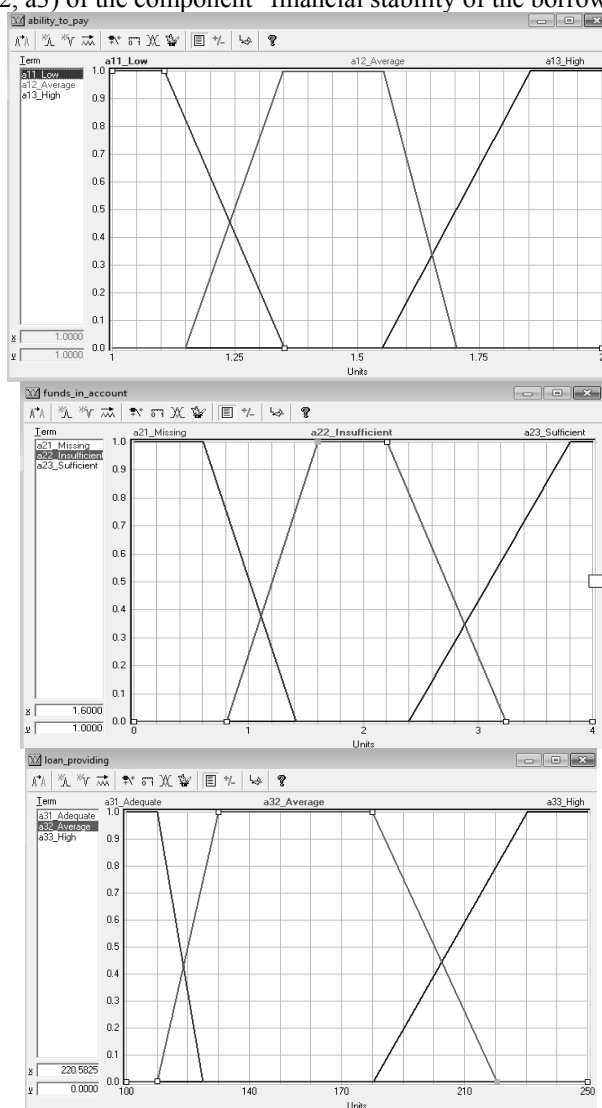
Figure 2. Computer representation of membership functions for input variables
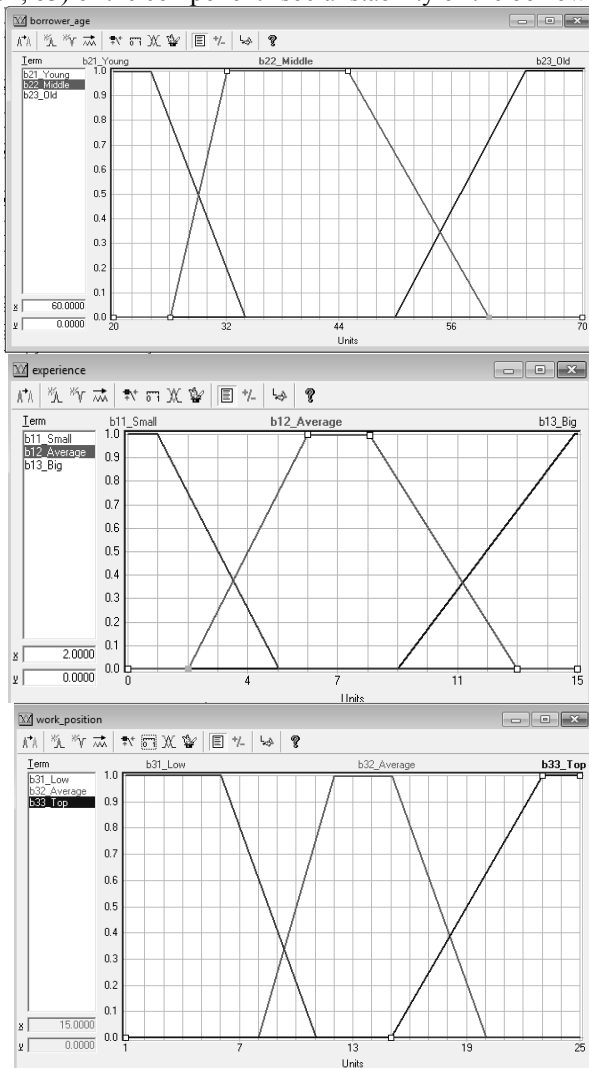(b1, b2, b3) of the component "social stability of the borrower" (B)

Figure 3. Computer representation of membership functions for input variables (c1, c2, c3) of the component "debt service" (C)
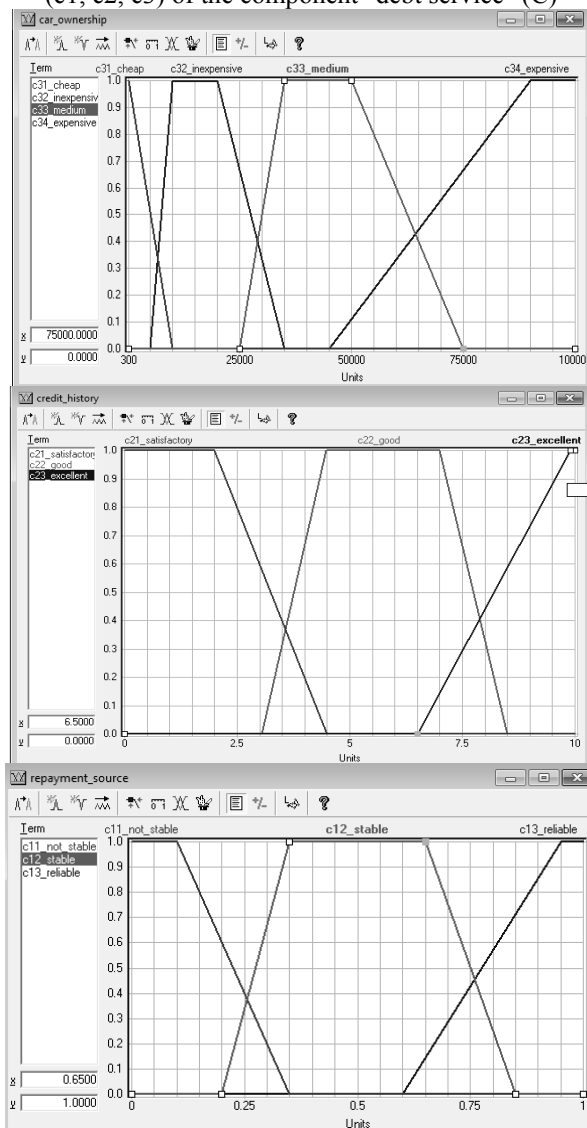
Figure 4. Computer representation of membership functions for input variables
(d1, d2, d3) of the component "credit condition" (D)