Journal of Theoretical and Applied Information Technology
31st March 2020. Vol.98. No 06

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

FUZZY LOGIC OF ZADEH AND DECISION-MAKING IN THE FIELD OF LOAN

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ABSTRACT

In the article, the features of lending to small (medium) businesses are considered. A method for assessing the creditworthiness of small businesses based on the application of the mathematical apparatus of the theory of fuzzy sets is proposed. There are analyzed 22 parameters, such as: industry development dynamics, market demand for products, current solvency and liquidity ratios, receivables and payables turnover ratios, etc. In general, it is assumed that any parameter takes values on a certain interval of real numbers. Further, the values of the initial indicators are mapping on the interval [0,1]. This process is called data unification. The rules on the basis of which decisions are made are formulated in the form of logical formulas containing parameters. Some parameters are obtained as a result of the analysis of the enterprise, other parameters are predicted. A software system is currently being implemented to support the lending process.

Keywords: *Creditworthiness, Lending to small and medium-sized businesses, Data unification, Fuzzy logic, Linguistic variable, Logical rules, Decision making*

1. INTRODUCTION

Lending of small and medium-sized businesses is currently a dynamically developing area of banking. In general, the credit rating system for small enterprises consists of four stages:

1) monitoring the work of small businesses;
2) an expert interview with the owner of a small enterprise;
3) assessment of the personal financial situation of the owner of the enterprise;
4) analysis of the financial situation of a small enterprise based on primary documents.

Traditional credit rating methods are not suitable for small businesses. This is due to the high level of errors in the financial statements of small enterprises, the use of various tax avoidance schemes, etc. In this regard, the formation of tools for assessing the creditworthiness of small businesses is very relevant. Today, the management of a small enterprise proceeds in conditions of uncertainty regarding the future financial condition of the enterprise itself and its economic functioning environment, since this sector of the economy is most susceptible to the global financial crisis. From this point of view, the analysis of the appropriateness of lending to small businesses should be considered as a problem to be solved under conditions of a high degree of uncertainty [1], [2], [3].

Currently, there are methods for extracting new knowledge that use various algebraic structures to eliminate uncertainty [4], [5], [6].

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

To solve this problem, alternative methods for assessing the creditworthiness of small enterprises are used, based on the fuzzy logic of L. Zadeh. As you know, he replaced the classical Cantor concept of a set, assuming that the characteristic membership function of an element can take values in the interval [0, 1] of real numbers, and not just the values 0 or 1, as usual. Such sets were called by him fuzzy. Further he introduced the concept of a linguistic variable and assumed that its values are fuzzy sets. It can be stated that L. Zadeh created a mathematical apparatus for describing the processes of intellectual activity, including the fuzziness and uncertainty of concepts and mathematical expressions [7].

The decision-making procedure in a generalized form includes: the formulation and comparison of alternatives, the selection of alternatives, the building and adjustment of the action program. The formalization of the assessing process of creditworthiness of a small enterprise can be represented as follows [8].

Suppose that the borrower has a certain set of characteristics (indicators) that are subject to assessment while making decisions on lending, presented in the form $X = \{x_i : i = \overline{1,N}\}$. Assessment of characteristics is based on a set of criteria $C = \{c_j : j = \overline{1,M}\}$.

Next, a set of possible outcomes (alternatives) is determined $A = \{a_t : t = \overline{1,T}\}$.

At the next stage, a set of fuzzy inference rules of the form "If ..., then ..." $P = \{p_l, l = \overline{1,L}\}$ is built.

Then, the convolution of the left part of the rules according to the schemes is performed, which will be described in detail below.

The choice of one or another alternative is also a fuzzy measure that determines such characteristics of the loan, such as: maximum loan amount; interest rate; loan period [9].

The determination of a set of indicators and logical rules in the result is the choice of a lending scheme $S = \{s_k, k : \overline{1,K}\}$.

Further we consider 22 parameters, such as: industry development dynamics, market demand for products, current solvency and liquidity ratios, receivables and payables turnover ratios, etc. In general, it is assumed that any parameter takes values on a certain interval of real numbers. The values of the initial indicators are mapping on the interval [0,1]. This process is called data unification.

2. INDICATORS FOR ASSESSING THE CREDITWORTHINESS OF A SMALL (MEDIUM-SIZED) BUSINESS

Initial indicators are displayed on the interval [0,1]. That is a set of parameters is represented as a set of linguistic variables. In general, the issue of how exactly to display this requires serious research. More useful information is contained in the literature [10], [11].

In the general case, we assume that any parameter takes values on a certain interval of real numbers. The simplest case is when each parameter is associated with one linguistic one, which can be called the "degree of favorableness of the indicator". In explicit form, it is necessary to specify the mapping of the interval of real numbers that this parameter can take to the interval [0,1]. This process is called the process of standardizing indicators.

Taking the composition of the "degree of auspiciousness" with the functions presented below, we obtain accordingly new linguistic variables: "the value of the parameter is low" (L); "Average parameter value" (M); "high parameter value" (H). Note that this kind of linguistic variables are often used in technical systems. Often consider even a greater number of gradations: below average, above average, close to zero, etc. [12], [13].

Each linguistic variable has its own membership function. One of the possible ways to define membership functions was proposed in work [14]. It examines the management of a technical system, namely, a steam boiler. In principle, in our case, the situation is very similar.

In the result, the choice of the type of membership functions, both of the alternatives themselves and of the evaluated criteria, is determined based on expert preferences [15].

It is obvious that the expert's uncertainty in the assessment grows with an increase in the deviation of the value of the estimated parameter from the optimal value. Moreover, in most cases, this uncertainty does not grow linearly. However, the use of nonlinear membership functions entails a significant complication of mathematical calculations and graphical constructions [16], [17], [18], [19].

Journal of Theoretical and Applied Information Technology
31st March 2020. Vol.98. No 06

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

For these reasons, in this paper, triangular and trapezoidal membership functions are used as the initial membership functions, which is primarily due to the simplicity of the subsequent calculations and graphical constructions. We can say that member ship function sarepiece wiselinear.

Determining the degree of compliance of the selected set of assessed criteria with one or another alternative is a key factor in the subsequent selection of the most suitable lending scheme that has an optimally selected set of conditions for subsequent lending. The set of estimated parameters was determined earlier in [20], and it is given below (Table 1).

Table 1. Financial and general economic indicators

№	Initial indicators
1	Dynamics of development of the industry
2	Prospects for the development of the industry
3	The need of the market (industry) for such products (work, services)
4	The dynamics of the development of the economy of the region
5	Prospects for the development of the economy of the region
6	The need of the market (region) for such products (work, services)
7	Current Liquidity Ratio
8	Ratio of financial independence
9	The working capital financed by equity to total assets ratio
10	Debt Service Coverage Ratio
11	Accounts Receivable Turnover Ratio
12	Accounts Payable Turnover Ratio
13	Inventory turnover ratio
14	Debt-to-equity ratio
15	Profit Margin Ratio
16	Evaluation of the professional level of staff
17	Evaluation of the moral and psychological atmosphere in the enterprise
18	Sufficiency of the period of stay of the enterprise in the market
19	Economic policy of the enterprise
20	Technical policy of the enterprise
21	Personnel policy of the enterprise
22	Credit history of the borrower (if not absent)

3. THE INDICATORS UNIFICATION PROCESS

This section describes in detail how the given indicators are mapped onto the interval [0,1], i.e. how are indicators unified? The case is considered when one linguistic variable "degree of favorableness of a given indicator" is associated with each parameter (indicator).

1. K_1 – Dynamics of development of the industry.

The average profit growth over a certain period is analyzed on the basis of industry data and/or data (regional, provincial) departments and services.

Let us denote the $i-$current year, $N-$length of the analyzed period, p_j – profit earned in the industry in the $j-$year.

$$K_1 = K_1(i) = \frac{\sum_{j=i-N+1}^{i} g(j)}{N},$$

where $g(i) = \frac{p_j - p_{j-1}}{p_{j-1}} * 100\%.$

We assume

$$\mu_1 = \begin{cases} \frac{x}{2}, & if \quad x \le \alpha, \\ 1, & if \quad x \ge \alpha. \end{cases}$$

We consider it as positive if the average profit growth $\ge \alpha$. The α value is determined by the expert.

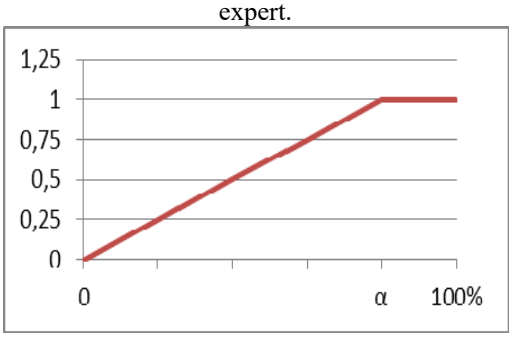

Figure 1: Dynamics of development of the industry

2. K_2 – Prospects for the development of the industry.

K_2 is calculated by the same way, only the predicted data for *M* years are taken

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31st March 2020. Vol.98. No 06

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

$$K_2 = K_2(i) = \frac{\sum_{j=i+1}^{j=i+M} h(j)}{M},$$

where

$$h(j) = \frac{v_j - v_{j-1}}{v_{j-1}} * 100\%,$$

v_j – projected profit in j-th year. Similarly, we assume

$$\mu_2 = \begin{cases} \frac{x}{\beta}, & if \quad x \le \beta, \\ 1, & if \quad x \ge \beta. \end{cases}$$

We consider it positive if the average projected profit growth is $\ge \beta$. In general case, $\alpha \ne \beta$.

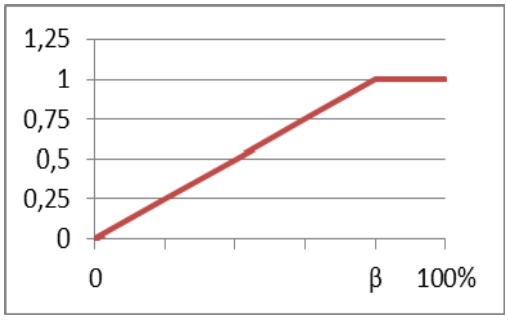

Figure 2: Prospects for the development of the industry

3. К3 – The need of the market (industry) for such products (work, services).

The range, demand and supply of products in the industry are analyzed with the help of an assessment: fulfilling the assortment plan; level of average realized prices in the industry; indicators of the impact of product quality on its average price.

It may be taken into account such factors as: the proportion of new products in the total output; the proportion of certified products in the total output; the proportion of products that meet international standards in the total output.

4. К4 – The dynamics of the development of the economy of the region.

5. К5 – Prospects for the development of the economy of the region.

6. К6 – The need of the market (region) for such products (work, services).

The indicators of the second group (K_4, K_5, K_6) are assessed similarly, but on a regional scale, based on statistical information from regional departments, regional statistical services and data from Bank of Russia reports.

7. К7 – Current Liquidity Ratio:

$$K_7 = \frac{CA}{CL},$$

$$\mu_7(x) = \begin{cases} 1, & if \quad x \ge 2, \\ \frac{x}{2}, & if \quad x < 2. \end{cases}$$

Where CA – value of current assets; CL – current liabilities. Recommended Value ≥ 2.

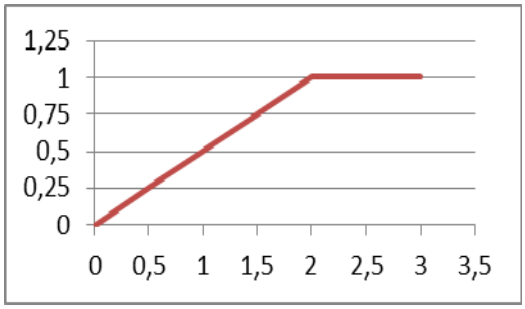

Figure 3: Current Liquidity Ratio

The current liquidity ratio characterizes the security of short-term liabilities of the enterprise with all its current assets.

The current liquidity ratio gives an overall assessment of the liquidity of assets, showing how many rubles of current assets are accounted for the ruble of current liabilities. The logic of calculating this indicator is that the company repays short-term liabilities mainly due to current assets; therefore, if current assets exceed current liabilities, an enterprise can be considered as successfully functioning (at least theoretically).The value of the indicator can vary by industry and type of activity, and its reasonable growth in dynamics is usually regarded as a favorable trend.

Figures should be labeled with "Figure" and tables with "Table" and should be numbered sequentially, for example, Figure 1, Figure 2 and so on (refer to table 1 and figure 1). The figure numbers and titles should be placed below the figures, and the table numbers and titles should be placed on top of the tables. The title should be placed in the middle of the page between the left and right margins. Tables, illustrations and the corresponding text should be placed on the same page as far as possible if too large they can be placed in singly column format after text. Otherwise they may be placed on the immediate following page. If its size should be smaller than

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8. К8 – Ratio of financial independence.

$$K_8 = \frac{E}{B} * 100\%,$$

$$\mu_8(x) = \frac{K_8}{100}$$

$$\mu_8(x) = \begin{cases} 1, & if \quad x \geq 50\%, \\ \dfrac{x}{50\%}, & if \quad x < 50\%. \end{cases}$$

where B – total balance and E – equity capital. Recommended value $\geq 50\%$.

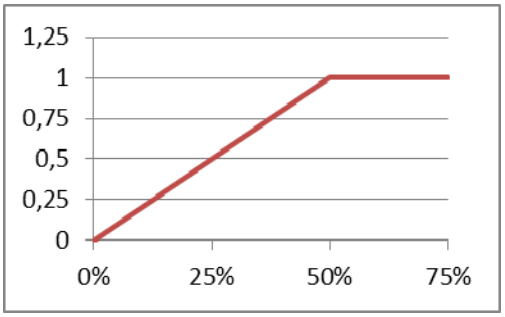

Figure 4: Ratio of financial independence

9. К9 – The working capital financed by equity to total assets ratio:

$$K_9 = \frac{AWCF}{I} * 100\%,$$

$$\mu_9(x) = \begin{cases} 1, & if \quad x \geq \beta, \\ \dfrac{x}{\beta}, & if \quad x < \beta. \end{cases}$$

$\beta \approx 60 - 80\%$ is determined by expert.

$AWCF$ – Army Working Capital Fund, I – Inventories.

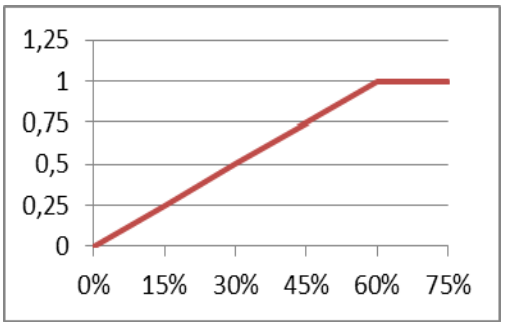

Figure 5: The working capital financed by equity to total assets ratio

This indicator shows (evaluates) the financial potential of own sources of financing and the ability to settle obligations. Its negative value indicates the lack of equity in the turnover of the enterprise and the financing of non-current part of assets from borrowed funds.

The coefficient shows the extent to which stocks are formed at the expense of own funds.

10. К10 – Debt Service Coverage Ratio.

$$K_{10} = \frac{NOI}{TDS},$$

$$\mu_{10}(x) = \begin{cases} 1, & if \quad 1{,}5 \leq x \leq 2, \\ \dfrac{x}{2}, & if \quad x < 1{,}5. \end{cases}$$

NOI – net operating income, TDS – total debt service.

Debt Service Coverage Ratio is the ratio of the net cash flow generated during the payment period (once a month, once a quarter, etc.) by the company implementing the innovative project (net profit before interest is paid out depreciation ± change in the need for net working capital), which, in accordance with the forecast, can be used to pay off the main debt and interest to the planned amount of debt servicing for a given period under all loan agreements of the enterprise.

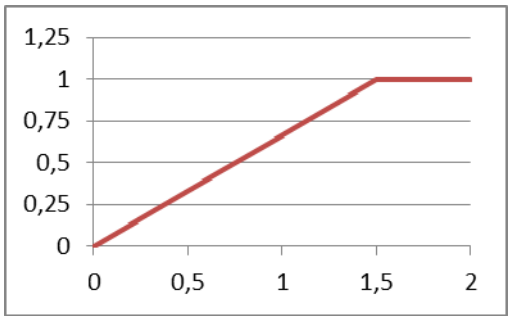

Figure 6: Debt Service Coverage Ratio

11. К11 – Accounts Receivable Turnover Ratio.

$$K_{11} = \frac{R}{\overline{AAR}},$$

$$\mu_{11}(x) = \begin{cases} x, & if \quad 0 \leq AR \leq 1, \\ 0, & if \quad AR > 1. \end{cases}$$

Where $\overline{AAR}$ – he average accounts receivables calculated according to the arithmetic mean formula; R – revenue.

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This ratio shows the number of revolutions made by receivables for the period;

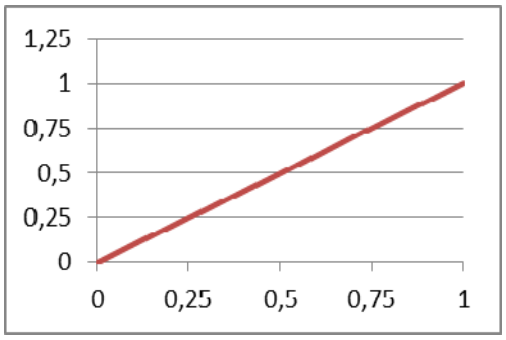

Figure 7: Accounts Receivable Turnover Ratio

The share of receivables in current assets shows the proportion of receivables in current assets of the organization. An increase in the value of this indicator, as a rule, is regarded as a negative phenomenon, since it indicates that an increasing share of current assets is temporarily diverted from circulation and is not involved in the organization's current activities. However, an extremely low value of the indicator may be a sign of a rather tight credit policy, leading to a decrease in sales.

12. K_{12} – Accounts Payable Turnover Ratio.

$$K_{12} = \frac{R}{\overline{AAP}},$$

$$\mu_{12}(x) = \begin{cases} x, & if \quad x \le 1, \\ 1, & if \quad x \ge 1. \end{cases}$$

Where, $\overline{AAP}$ – is the average accounts payable, calculated according to the arithmetic mean formula.

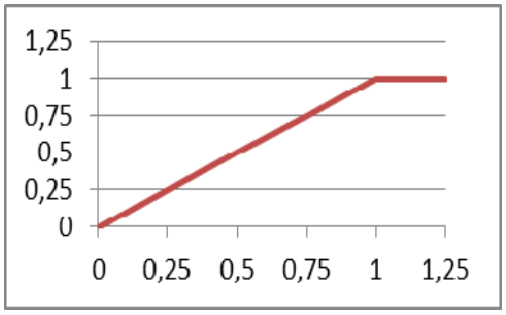

Figure 8: Accounts Payable Turnover Ratio

This ratio shows the number of turns made by accounts payable for the period;

The share of accounts payable in current liabilities shows the share of accounts payable in current liabilities. Its increase, as a rule, indicates a certain decrease in the financial stability of the organization.

13. K_{13} - Inventory turnover ratio

Inventory turnover ratio shows how many times during the analyzed period the organization used the average available inventory balance. This indicator characterizes the quality of reserves and the effectiveness of their management. It allows us to identify the remains of unused, obsolete or substandard reserves. The importance of the indicator is due to the fact that profit arises with each "turnover" of stocks (i.e., use in production, the operating cycle). Please note that in this case stocks are also understood as inventory (stocks of finished products) and production stocks (stocks of raw materials).

Stock turnover can be calculated as a ratio: the cost of sales to the average inventory.

$$K_{13} = \frac{CS}{AI},$$

$$\mu_{13}(x) = \begin{cases} 1, & if \quad x \ge \alpha, \\ \frac{x}{\alpha}, & if \quad x < \alpha. \end{cases}$$

CS–cost of sales, *AI*– average inventory.

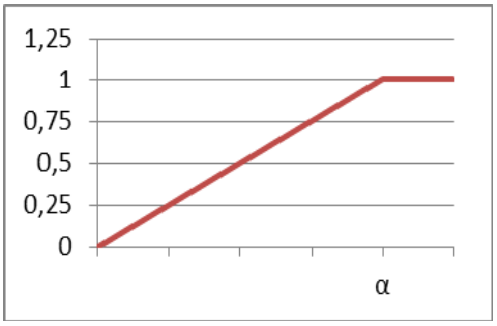

Figure 9: Inventory turnover ratio

Along with the turnover ratio, the turnover ratio in days (trade) is often calculated. In this case, this means how many days the company has enough stocks.In this case, this means how many days the company has enough stocks**.**

$$K_{13} = \frac{AI}{CS} * 365.$$

There are no generally accepted standards for the turnover indicators; they should be analyzed within the framework of one industry and, even better, in the dynamics for a particular enterprise. The decrease in inventory turnover ratio may reflect the

Journal of Theoretical and Applied Information Technology
31st March 2020. Vol.98. No 06

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

accumulation of excess reserves, inefficient warehouse management, and the accumulation of unusable materials. But high turnover is not always a positive indicator, because it can talk about the depletion of stocks, which can lead to interruptions in the production process.

For organizations with high profitability of sales, a lower turnover is characteristic than for companies with a low rate of return.

14. K_{14} – Debt-to-equity ratio.

$$K_{14} = \frac{TL}{TE},$$

$$\mu_{14}(x) = \frac{K_{14}}{100},$$

$$\mu_{14}(x) = \begin{cases} 1, & if \quad x \le \lambda \\ 1-\lambda & if \quad x \ge \lambda \end{cases}$$

TL – total liabilities, TE – total equity.

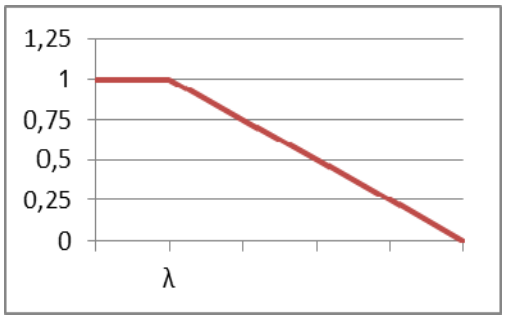

Figure 10: Debt-to-equity ratio

The coefficient shows how many rubles of borrowed funds are accounted for by the ruble of own. Recommended value ≤ 1. It means that the debt ratio shows how many rubles of borrowed funds are in the capital of the enterprise.

15. K_{15} – Profit Margin Ratio.

$$K_{15} = \frac{NP}{R} * 100\%,$$

$$\mu_{15}(x) = \begin{cases} 1, & if \quad x \ge \delta, \\ \dfrac{x}{\delta} & if \quad x \le \delta. \end{cases}$$

Here NP – net profit and R – is revenue.

Return on sales characterizes not only the cost-effectiveness of the production and sale of products (goods, works, services), but also pricing and shows the share of sales profit in revenue.

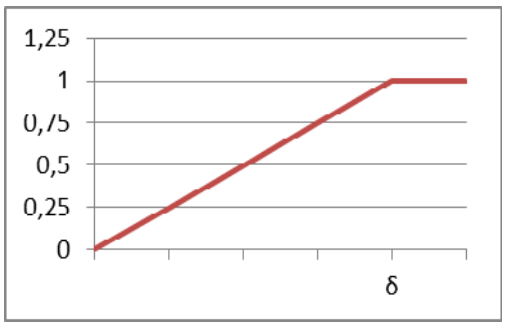

Figure 11: Profit Margin Ratio

16. K_{16} – Evaluation of the professional level of staff

It is assumed that several types of workers are needed at the enterprise. The state with frames can be represented in the form of a table

Table 2. Types of employee

Types of employee	Type 1	Type 2	…	Type k
Number of available employee	n_1	n_2		n_k
Required number of employee	m_1	m_2		m_k

Next we consider the vector $\vec{\delta} =< \delta_1 \dots \delta_k >$, where $\delta_i = n_i - m_i, (1 \le i \le K)$.

The value $K_{16} = E(\vec{\delta}) \in [0,1]$ is determined by experts based on their preference.

17. K_{17} – Evaluation of the moral and psychological atmosphere in the enterprise

We can assume that this value is also evaluated by an expert.

18. K_{18} – Sufficiency of the period of stay of the enterprise in the market

We assume

$$\mu_{18}(x) = \begin{cases} \dfrac{x}{\gamma}, & \text{if} \quad x \le \gamma, \\ 1, & \text{if} \quad x \ge \gamma. \end{cases}$$

There by γ is the minimum period that, in the opinion of the expert, the enterprise should remain on the market.

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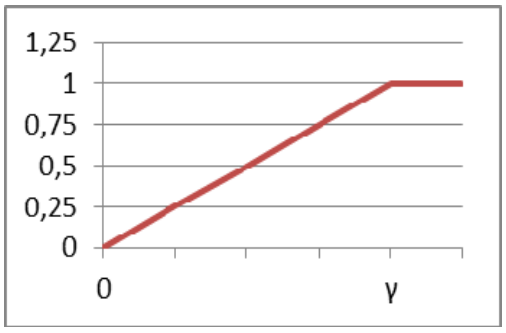

Figure 12: Sufficiency of the period of stay of the enterprise in the market

The following parameters are also usually evaluated by an expert. The second option is when these parameters, or some of them, are not taken into account at all.

19. K_{19} – Economic policy of the enterprise

This parameter characterizes a set of organizational and managerial measures of economic development, developed and approved to achieve goals and objectives at various levels of management, from the enterprise (increasing the competitiveness of production and goods) to the government level (tax and investment policies, etc.).

20. K_{20} – Technical policy of the enterprise

It is a general case, a system of strategic measures carried out by the enterprise's management in the field of strategies to improve product quality, resource conservation, organizational and technical development of production as components of the target subsystem of the management system.

21. K_{21} – Personnel policy of the enterprise

A system of rules and norms (which must be understood and formulated in a certain way) that brings the human resource into line with the firm's strategy (it follows that all HR activities: selection, staffing, certification, training, promotion - are planned in advance and consistent with a common understanding of the goals and objectives of the organization)

22. K_{22} – Credit history of the borrower (if not absent)

Data showing how well the borrower complies with the rules for borrowing and fulfilling obligations arising from the terms of credit transactions.

4. FUZZY LOGIC L. ZADEH

Zadeh logic is one of the simple and natural non-classical logics. As mentioned above, the values of the formulas of the logic of Zadeh lie on a segment [0,1]. In the book by H.J. Keisler and Chen Chung Chang "Continuous Model Theory" [21] considered a more general situation, namely, when the values of the formulas lie in a topological space. The main case under study is when the topological space is compact and Hausdorff, and logical connectives and quantifiers are continuous functions. Interestingly, many constructions and theorems of classical logic (more precisely, model theory) are generalized to this case.

From the point of view of the theory of continuous models, the logic of L. Zadeh is a very special case. However, it is interesting in that it has found numerous applications in the technical, natural and humanitarian fields [22], [23].

Let's define the typical logical connectives of logic L. Zadeh:

$x \wedge y = \min(x, y);$

$x \vee y = \max(x, y);$

$\neg x = 1 - x.$

Sometimes consider the following additional ligaments:

$x \overline{\wedge} y = (x + y)/2;$

$x \oplus y = x + y - x \cdot y;$ it is easy to show that if $0 \le x, \quad y \le 1,$ то $0 \le x \oplus y \le 1;$

$x \cdot y -$ cup product;

$con(x) = x^2 -$ concentration operator;

$dil(x) = \sqrt{x} -$ stretching operator.

There are two natural quantifiers:

$\inf(x) -$ analogue of the generality quantifier $\forall$;

$\sup(x) -$ the analogue of quantifier of existence $\exists$.

Some additional quantifiers:

$\mu(x) -$ the measure of the set X, $\mu(x) = \int\limits_{x \in X} dx.$

$c(x), c_\rho(x) -$ centre of gravity of the set X without and with taking into account the density function $c(x) = \dfrac{\int\limits_{x \in X} x dx}{\int\limits_{x \in X} dx}$; $c_\rho(x) = \dfrac{\int\limits_{x \in X} \rho(x) dx}{\int\limits_{x \in X} dx}.$

Journal of Theoretical and Applied Information Technology
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ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

Of course, the last definitions are correct if the set X is measurable, i.e. corresponding integrals must exist.

In the book [21], the concepts of $t-, k-$ and $e-$ sets are introduced. These are "continuous" analogues of negation, conjunction, and the quantifier of existence. More precisely, in a sense, their "substitutes" in the continuous case.

Omitting cumbersome definitions, we note that:

$\{\wedge\}$ is a $k-$set;

$\left\{\begin{matrix}\neg\\ \wedge\end{matrix}\right\}$ is a $k-$set;

$\{\cdot\}$ is a $k-$set;

$\{\sup\}$ is a $e-$set.

No $t-$set, but it can be added.

Let's introduce a family of functions $\{t_x : x \in [0,1]\}$ such that $t_x(x) = 1$, and for any $y \neq x$ performed $t_x(y) \neq 1$. Then they form $t-$set.

The following are examples of this kind of function:

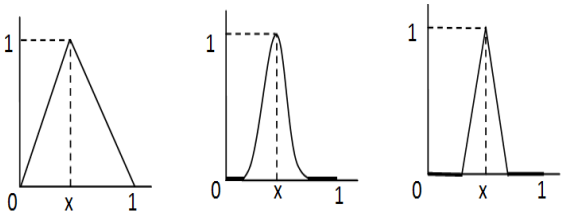

Figure 13: Family of Functions

For classical logic, equivalence $x \to y \equiv \neg x \vee y.$ is known. This is the so-called "material" implication. This formula allows us to introduce the implication for the logic of L. Zadeh. However, for L. Zadeh's logic, the situation turned out to be more interesting. For example, in [14], more than 15 types of various implications are considered.

Some examples of implications for the logic of L. Zadeh:

1) $x \to y = \begin{cases} 1, & if \quad x \le y \\ 0, & if \quad x > y \end{cases};$

2) $x \underset{g}{\to} y = \begin{cases} 1, & if \quad x \le y \\ y, & if \quad x > y \end{cases};$

3) $x \underset{ss}{\to} y = \left(x \underset{s}{\to} y\right) \wedge \left((1-x) \underset{s}{\to} (1-y)\right);$

4) $x \underset{sg}{\to} y = \left(x \underset{s}{\to} y\right) \wedge \left((1-x) \underset{g}{\to} (1-y)\right);$

5) $x \underset{gs}{\to} y = \left(x \underset{g}{\to} y\right) \wedge \left((1-x) \underset{s}{\to} (1-y)\right);$

6) $x \underset{gg}{\to} y = \left(x \underset{g}{\to} y\right) \wedge \left((1-x) \underset{g}{\to} (1-y)\right).$

4. DECISION MAKING PROCESS

It was noted above that parameters (indicators) take rather arbitrary values. More precisely, each parameter varies in a certain inherent interval. Further, we assume that the parameters are unified, i.e. the corresponding intervals are mapped to the interval [0,1].

Each $i-$th indicator can be associated with one "universal" predicate $P^i(x)$ or three single-place predicates $P^i_L(x)$, $P^i_M(x)$, $P^i_H(x)$, which naturally arise through composition with the functions below.

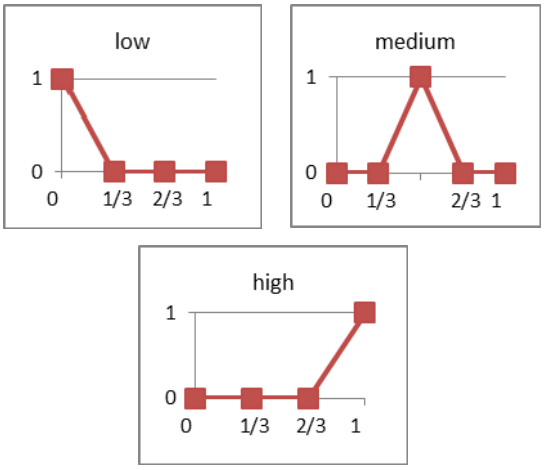

Figure 14: Membership Function

For simplicity, formula definable predicates are also usually introduced:

$$P^i_{LM}(x) = P^i_L(x) \vee P^i_M(x),$$

$$P^i_{HM}(x) = P^i_M(x) \vee P^i_H(x).$$

Similarly with each financial indicator, i.e. characteristic of the loan, we associate the predicate Q^i_D, $D \in \{L, M, H, LM, HM\}$.

The rules on the basis of which decisions are made have the form $\varphi(x_1, ..., x_n) \to \psi(y_1, ..., y_m)$.

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Table 3. Characteristics of the loan

№	Resulting indicators
1	Lending volume
2	Interest rate
3	Loan terms

Usually $\varphi(x_1,...,x_n)=\bigwedge_{j=1}^{n} Q_j(x_j)$, i.e. we have a conjunction of unary predicates of the above signature. Moreover, each Q_j has the form P_D^i, $D\in\{L,M,H,LM,HM\}$.

As a result, we obtain a rule of the following form:

$$P_{LM}^1(x_1)\wedge P_{LM}^2(x_2)\wedge P_M^3(x_3)\wedge P_M^4(x_4)\wedge$$
$$P_{HM}^5(x_5)\wedge P_M^6(x_6)\wedge P_{LM}^7(x_7)\wedge P_M^8(x_8)\wedge$$
$$P_L^9(x_9)\wedge P_L^{10}(x_{10})\wedge P_H^{11}(x_{11})\wedge P_M^{12}(x_{12})\wedge$$
$$P_L^{13}(x_{13})\wedge P_{LM}^{14}(x_{14})\wedge P_L^{15}(x_{15})\wedge P_{LM}^{16}(x_{16})\wedge$$
$$P_M^{17}(x_{17})\wedge P_{HM}^{18}(x_{18})\wedge P_M^{19}(x_{19})\wedge P_{LM}^{20}(x_{20})\wedge$$
$$P_{LM}^{21}(x_{21})\wedge P_L^{22}(x_{22})\to Q_M^1(y_1).$$

Several rules may be used

$$R_i:\varphi_i(x_1..x_n)\to\psi_i(y_1..y_n), i=1,..N.$$

For brevity we write $R_i=R_i(x_1..x_n,y_1..y_m)$.

In most cases, it is natural to consider their disjunction

$$R=\vee_i R_i.$$

Parameters $x_1..x_n$ are obtained as a result of the analysis of the enterprise. These are the indicators mentioned in section 1. Parameters $y_1..y_m$ are predicted. These are indicators such as: loan amount, interest rate, loan duration. In its most general form, one parameter is predicted called the credit index, varying from 0 to 1 and having a natural interpretation. Preference is given to enterprises with a higher credit rating.

Currently, research and development are carried out in the following areas:

1) the formulation of new lending rules;

2) development of rules that take into account legislation;

3) the development of new rules for the unification of heterogeneous data;

4) testing of algorithms in Matlab, Maple, Statistica, Excel;

5) system design, focused on future implementation by means of Phyton, VisualC ++, MySQL.

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