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Research Article

Innovative Solutions for Forecasting the Sustainable Growth of the Russian Confectionery Industry Based on the Cognitive Model

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Abstract: In modern conditions, ensuring companies' sustainable development is of great importance. The financial stability of partner enterprises largely determines the sustainable development of the company. Despite the large number of scientific works in this area, gaps exist that require additional scientific research to eliminate. The relevance of the study is that in modern conditions, AI techniques are used to ensure companies' sustainability. The scientific novelty lies in the fact that the study proposes and proves the hypothesis that a company's profit forecast can be obtained using an AI system, and then a strategic partner company in the confectionery industry can be selected using the fuzzy model. The purpose of this study is to form a deep learning model "Random Forest" (DF) based on data collected by a parser from company websites, add parameters calculated using the VaR, Z-Altman, and Hurwitz models to the dataset, and form a fuzzy classifier model for decision-making. The study is based on the following methods: a cognitive model that includes modules that calculate the VaR, Z-Altman, and Hurwitz parameters, as well as the DF deep learning model and the fuzzy model. The authors proposed a methodology based on the fuzzy classifier model for assessing the reliability of a partner. The Fuzzy model uses the following parameters: return on equity (ROE) and return on sales (ROS). Both indicators are calculated using the predicted value of net profit returned by the DL model.

Keywords: AI-model; Banking system; Cognitive model; Deep learning model; Random forest

1. Introduction

Practice shows that economic development stability as a whole is largely determined by the stability development of individual enterprises as components of the economy, as a system. Therefore, in a turbulent economy, the development of which is not calm, the study of the problem

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of ensuring stability is the focus of attention of many modern scientists under the influence of many factors. The scientific novelty lies in the hypothesis that an artificial intelligence system could be used to forecast a company's profit, and further use of the forecast would allow for the selection of a strategic partner company.

Agencies and experts often use profit forecasting for confectionery industry enterprises when preparing analytical reviews. State statistical agencies operate only with actual values. The exact amount of net profit for confectionery industry enterprises in Russia in 2023 is not yet known because the results of the past year have not yet been summed up. However, according to expert estimates, the net profit will be about 2.00-2.50 billion dollars.

The confectionery market volume in Russia is expected to grow by 5-7% in 2023 compared to 2022. Some of Russia's largest confectionery companies, such as United Confectioners, KDV Group, and Rot Front, reported profit growth in the first half of 2023. This trend is expected to continue in the second half of the year. Concurrently, the amount of profit of confectionery companies can be affected by various factors, such as changing consumer preferences, raw material price fluctuations, and economic instability.

Many modern scientists have devoted their research to studying the sustainability of enterprises in a turbulent economy. Thus, Silvestre argued that sustainable companies play an even more important role in managing increasing uncertainty, stimulating supply chain learning, promoting innovation, and improving sustainable development indicators due to the highly complex and uncertain business environment in a turbulent economy (Silvestre, 2015).

Giovanni Francesco Massari and Ilaria Giannoccaro used an integrated adaptive systems approach to conceptualize horizontal collaboration in supply chains and developed a new agent-based model to model its impact on sustainability under different environmental conditions (Massari and Giannoccaro, 2021). Addressing this gap, Oscar Rodrıguez-Espindola -Espindola and co-authors analyzed the impact of external factors on the adoption of circular economy and technology and their impact on sustainable innovation. The study concluded that a circular economy, which promotes innovation focused on sustainable development, has a positive impact on financial and social performance (Rodriguez-Espindola et al., 2022).

The cognitive model developed by the authors in this study makes it possible to combine and harmonize business research processes, starting with the collection of the required information that reflects the results of the work of companies in the confectionery industry for 10 years, ending with the formation of forecast values of net profit based on the deep learning model DL-model "Random forest". In addition, the fuzzy algorithm was used in the cognitive model, which made it possible to make a decision on choosing a partner in market uncertainty.

Increasingly, AI systems are used to forecast profits and assess the financial stability of partner enterprises, determining the relevance of scientific research and its practical significance. The scientific novelty is that it was hypothesized that when using a cognitive model based on the DL-model "Random Forest" and the fuzzy algorithm, a forecast of the net profit of industry enterprises can be obtained, as well as an assessment of their financial stability as strategic partners. In this study, when forming a dataset of the DL-model "Random Forest," the following models were used: VaR, Z-Altman, and Hurwitz matrix. The calculated linear regression coefficients, reflecting the dynamics of the net profit of industry enterprises over time, were included in the Hurwitz model to determine each enterprise's stability as a system.

The use of the fuzzy algorithm in conditions of market uncertainty made it possible to provide support for making a managerial decision on choosing a partner based on the forecast parameters of ROE and ROS, obtained using the net profit value returned by the algorithm from the RF DL model, which is important in modern conditions. ROE, which is the measure of operational efficiency, shows the measure of operational efficiency. Calculated as the net profit quotient divided by equity. ROS: Return on sales, reflecting business efficiency. Calculated by dividing net profit by the revenue of the company.

The practical significance lies in the fact that the results obtained in this study can be used in the practical activities of companies. The developed methodology supports management decisions regarding the choice of a business partner. Practice shows that fuzzy algorithms based on the use of "soft" computing are widely used in modern conditions. In a number of early scientific studies, authors used them in their works (Lomakin and Spirova, 2014; Lomakin, 2013). Zadeh (Zadeh, 2012) developed the foundations of fuzzy logic. Fuzzy algorithms have a wide range of applications (Kang et al., 2023), from fuzzy Petri net reasoning to state assessment of Markov chain models (Dimirovski, 2005).

The most important elements of the new technological redistribution are cognitive models, smart manufacturing, the Internet of things, big data, and many others. Models, methods, and modeling technologies that use deep learning (DL) are widely used, for example, to predict bankruptcy (Lomakin et al., 2023a) and to assess the financial stability of the economy.

2. Methods

The formed cognitive model ensured the flow of the process chain. 1) At the information collection stage, the Parser collected the necessary data on the work of confectionery enterprises and placed them in the database. 2) The deep learning model "Random Forest" DL was formed based on the collected data, as well as data from other modules that were placed in the DATASET. As a result, the dataset included nine parameters: (1) revenue, million dollars, 2023 year; (2) assets, million dollars; (3) market share, %; (4) ROE, %; and (5) ROS, %; 6. Z-Altman; 7. Intangible assets, %; VaR, %; 8. 9. The Hurwitz determinant and net profit forecast. Thus, during the process chain operation, the results of the following modules were included in the DL "Random Forest" dataset: 3) VAR model for risk assessment and profit forecast calculation, 4) Altman Z-model (two-factor) for bankruptcy probability assessment, and 5) Hurwitz matrix for company sustainability assessment. The flow of the process used, which is based on the proposed methodology, is illustrated in Figure 1.

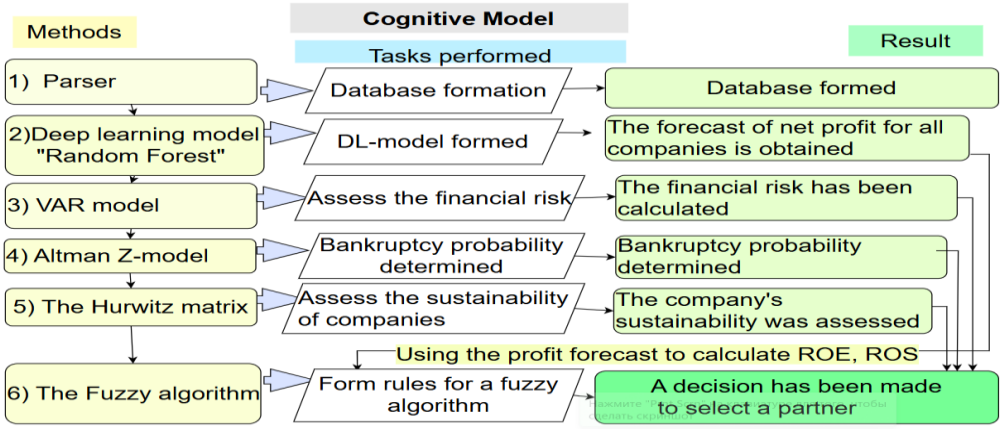

Figure 1 Algorithm scheme for selecting a strategic partner

The DL random forest model was successfully generated. The net profit forecast for the next year was obtained.

6) The fuzzy algorithm was generated based on the ROE and ROS indicators. At this step, the authors used their own technique, which allowed them to identify the forecast returns on sales and equity of the analyzed companies. To do this, when calculating the forecast ROE, they found the quotient of the profit forecast and equity, and when calculating ROS, they found the quotient of the profit forecast and sales.

The fuzzy model ensured a decision on choosing a particular company as a strategic partner. In a turbulent economy, classical methods of forecasting a company's profit (e.g., correlation, expert, and extrapolation methods) usually do not work or are unreliable. Therefore, it is advisable to use

the fuzzy method to make a decision on choosing a particular company in the confectionery industry, which provides support for decision-making in conditions of market uncertainty and risk. A fuzzy rule is a classical rule of the type "IF ... THEN ...", where fuzzy statements are used as conditions and conclusions. Such rules are written in the following form (conditionally), for example: IF (earnings are stable) AND (there is real estate), THEN (a loan can be issued).

In previous studies, the author processed various statistical data using the fuzzy algorithm (Lomakin and Starikova, 2014; Lomakin, 2013).

3. Results and Discussion

3.1. Cognitive model of confectionery market research

A cognitive model for confectionery market research is shown below (Figure 2).

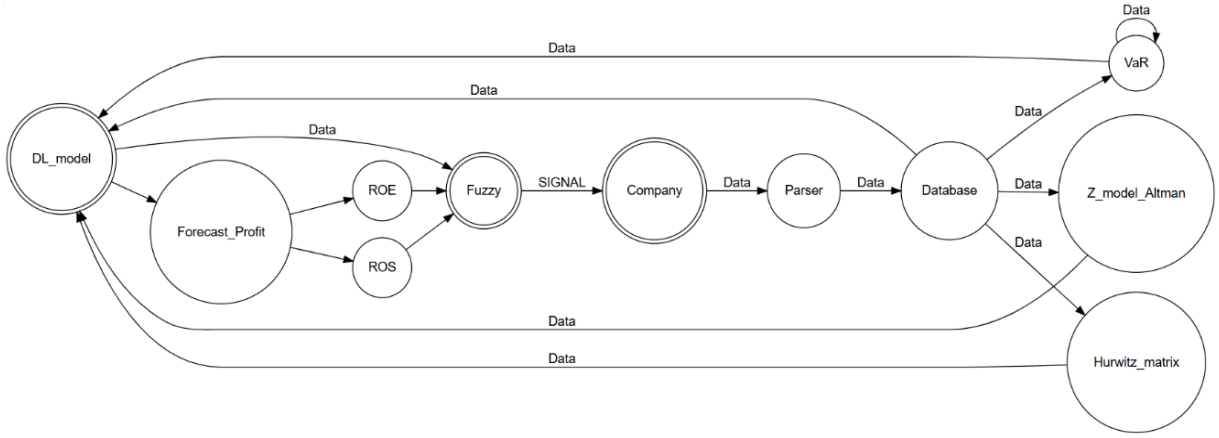

Figure 2 The cognitive model for confectionery market research

The cognitive model includes: 1) the Parser, 2) the DL-model "Random Forest", 3) the VAR model, 4) the Altman's two-factor Z-model, 5) the Hurwitz stability assessment matrix and 6) The Fuzzy algorithm. This study is important because it proposes an original approach to selecting a partner enterprise. The idea is to use existing algorithms to form a dataset of a deep learning model that makes a profit forecast.

The dataset for the DL random forest model was formed not only on the basis of statistical data collected by the parser from company websites but also using the results calculated using the VaR, Z-Altman, and Hurwitz models. The improvement is that the obtained forecast value of the candidate company's net profit is used to calculate the ROS and ROE of sales and assets, which, when included in the fuzzy model, provide an output—a decision: to work with the candidate company (1) or not (0). A fragment of the cognitive model script is presented in Figure 3.

```
Digraph CB {
 fontname="Helvetica,Arial,sans-serif"
 node [fontname="Helvetica,Arial,sans-serif"]
 edge [fontname="Helvetica,Arial,sans-serif"]
 n0 [label= "Federal \n regulation"];
 n1 [label="Innovation \n Industry 4.0", URL="h", tooltip="P"];
 ##n2 [label=" Sustainable \n development ", URL="h",tooltip=""];
 n3 [label="Production \n Industry", URL="h", tooltip="P"];
 n4 [label="Altman's \n Z_model",  tooltip="P"];
n5 [label="Investors \n", tooltip="Package regexp implements regular expression sear."];
 n0 -> n1;
```

Figure 3 The fragment of the cognitive model script

The central link of the cognitive model is the DL-model of DL "Random Forest Regression," which functionally interacts with "Parser," a program designed to collect data from the websites of companies in the industry under study, a database (BD) for storing and processing data.

The second important element is the fuzzy model, which is designed to make a "Yes/No" management decision to select a company in the confectionery industry as a strategic partner. Forming a deep learning model "Random Forest" is necessary to forecast and assess the sustainability of the development of companies in the confectionery market. Research shows that the main trends in the development of digital technologies in the manufacturing sector are the emergence of business processes based on the use of cyber-physical systems, production ecosystems, artificial intelligence, big data, parallel computing, fuzzy algorithms, and others.

The following were used to generate the Random Forest DL model dataset: 1) VaR model for assessing financial risks, 2) Altman's two-factor Z-model, and 3) Hurwitz stability assessment matrix. The data obtained from the models were used to create a dataset and obtain a forecast for net profit based on the RF DL model. Using the fuzzy algorithm based on the forecasted values of ROE and ROS, the financial stability of the company in the industry was assessed using fresh forecast values of net profit.

3.2. Calculating the VaR with the VaR model

In practice, the value at risk (VaR) is widely used to assess financial risk. This is an estimate, expressed in monetary units, of the amount that expected financial losses will not exceed with a given probability over a given period of time. The model uses three parameters: time horizon, confidence level, and base currency. As a rule, the time horizon depends on the situation's specifics. According to the Basel methodology, it is 10 days, and according to RiskMetrics, it is 1 day. The confidence level is the level of acceptable risk: according to Basel requirements, 99% is used, and 95% is used in RiskMetrics. The base currency is the currency used to measure this indicator.

The use of statistical approaches embedded in the model allows us to obtain an accurate assessment of the probability and size of financial losses. VaR is a method that allows you to realistically estimate possible future losses with a given probability for a certain period. The VaR method determined the value of probable losses based on the quantile, a given probability level, mathematical expectation, and standard deviation in the sample.

Having calculated VaR, we can say that there is confidence with a probability of X/100 that losses will not exceed Y dollars over the next N days, and the value of Y is VaR. Risk assessment of the dynamics of industry enterprises' net profit was carried out over a period of 10 years: 2013-2023. The VaR model used delta-normal modelling of the loss probability and size. Using the variation series of profit dynamics, we calculated the possible financial losses for each company. The following formula was used to calculate the company's annual changes in net income (Equation 1).

$$\Delta = LN \frac{P_{t+1}}{P_t}, \quad (1)$$

where Pt+1 is the amount of net profit at time t+1;

Pt is the net profit at time t;

Pt + 1 is the net profit in the next period t with a given quantile level.

Having the range of variation of the studied characteristic from the maximum value of 8.958 to the minimum value of -7.894, we obtain a range of variation of 16.852. The quotient divided by the number of observations (years) 11 is the group interval.

The number of groups K = 4.213 (~4) for grouping the studied characteristic—the growth rate of net profit—was calculated using the Sergess method.

The VAR model is formed using net profit data for the period from 2013 to 2023 for each of the enterprises in the industry included in the DL model. Based on the grouping of enterprises by asset size, a pattern was identified that the Z-Hurwitz parameter, which will be calculated below, indicates a decrease in the stability of the enterprise as a system as the size of the enterprise decreases. For example, the forecast for the net profit of the Confil company, obtained using the RF

model, amounted to 2.41177 million dollars, and according to the VaR model, 2.65912 million dollars, or 10.3% more than that of the RF model. Confil's Z-Hurwitz was -0.017, which indicates that "the system is not stable." For clarity and to use the international standard currency, all rubles were converted to US dollars at a rate of 100 rubles to 1 US dollar on November 20, 2024.

3.3. Bankruptcy Risk Assessment Using the Altman Z-Model

Altman's Z-model was developed to assess the risk of bankruptcy of public companies. The Altman model is a function of indicators that reflect an enterprise's economic potential and the results of its work over the past year. The index, which was proposed by Altman, allows one to assess the degree of an enterprise's risk of bankruptcy, the level of its financial stability, the company's margin of safety, management activities, and compare it with other enterprises (see equation 2).

$$Z = -0.3877 - 1.0736 * X1 + 0.0578 * X2, \quad (2)$$

The study revealed a pattern that as the Z-Altman values for companies in the industry decrease in the variation series, as the risk of bankruptcy increases, companies increasingly experience "outliers" in return on equity (ROE) values.

ROE, the return on equity, shows the measure of operational efficiency. Calculated as the net profit quotient divided by equity. This is observed in companies with an abnormally high share of borrowed capital, which is a signal for partners not to take risks and not to work with such a partner.

The parameters of Altman's two-factor model indicate the following. If the value of Z becomes less than 0, then the probability that the company will go bankrupt is less than 50%, and the probability decreases as Z decreases. If Z = 0, the probability of bankruptcy is 50%. However, if Z begins to increase and its values become greater than 0, then the probability of bankruptcy will be higher than 50% and will continue to increase as Z increases. Assessing the sustainability of industry companies based on the Hurwitz matrix is advisable.

3.4. Model for assessing companies' sustainability based on the Hurwitz matrix

The Hurwitz criterion works with a closed-loop system's characteristic polynomial. The transfer function for the open-loop system can be written as the following formula (see equation 3):

$$W = W_p * W_y, \quad (3)$$

where: W_p – transfer function of the control system (regulator).
W_y – transfer function.

The method uses the coefficients of the company's characteristic equation as a system (Equation 4):

$$W(s) = \frac{Y(s)}{U(s)}, \quad (4)$$

where $W(s)$ - is the system's transfer function;
$U(s)$ = 0-system parameter.

The Hurwitz determinant is calculated based on the coefficients of the characteristic equation. In this case, it is constructed using the following algorithm:

- the coefficients of the characteristic equation are located along the main diagonal and from left to right from a1 to an;
- Then, from each element of the filled diagonal, the columns of the matrix are added up and down, so that the values of the indices used are located in descending order from top to bottom;
- Coefficients with indices whose values are less than zero or greater than n are replaced by zeros.

The dimension of the Hurwitz matrix is determined by the maximum power at s in the characteristic equation (n) (see equation 5):

$$(a_1\ a_3\ \ a_5\ 0\ \cdots\ 0\ a_0\ a_2\ \ a_4\ 0\ \cdots\ 0\ 0\ a_1\ \ a_3\ 0\ \cdots\ 0\ \ \ 0\ a_0\ \ a_2\ \ \ a_4\ \cdots\ 0\ \vdots\ \ \ \ddots\ \vdots \\ \ldots\ \cdots\ a_n\ ), \quad (5)$$

According to the Hurwitz criterion, for the stability of a dynamical system, it is necessary and sufficient that all n main diagonal minors of the Hurwitz determinant are positive when the condition a 0 is greater than 0. The resulting minors are called the Hurwitz determinants. To calculate the Hurwitz determinant, a special program was written in Python.

The given code allows the experiment to be repeated and complex calculations to be reproduced automatically to obtain the required parameter—the Gurvits determinant. The determinant is a "digitized" parameter of enterprise stability as a system.

The specific method for finding the determinant and the solution method are selected based on the order of the matrix. Our models used 2 coefficients. The values of the calculated values of the determinant of the Hurwitz matrix regarding the sustainability of companies are as follows: Babaevsky concern Z-Hurwitz = 1193, which means "the system is stable"; Krupskaya factory Z-Hurvits = 0.002, which means "the system is stable"; and enterprise Confil Z-Hurvitsa = -0.017 – "the system is not stable."

This conclusion serves as an additional argument for the positive conclusion that companies with a positive value of the Z-Hurwitz determinant can be used as a reliable business partner because the enterprise is a stable system. The fuzzy algorithm plays an important role in assessing the financial stability of a company.

3.5. Deep Learning Model "Random Forest"

A histogram of confectionery companies in Russia by sales volume in 2023 is presented below (Figure 4).

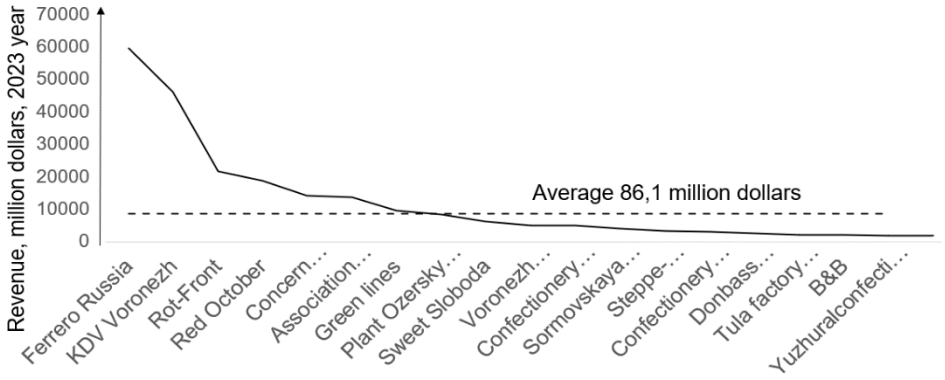

Figure 4 Histogram of Russian confectionery companies by sales volume

Confectionery sector companies may prove to be attractive strategic partners for investors and entrepreneurs. The input data for the DL model are presented in Table 1.

The matrix of paired correlation coefficients, which reflects the strength and direction of the relationship between the factorial and result features, indicates that the factors included in the specification were correctly selected.

However, the model can be improved in the future. The following values of paired coefficients were obtained: Revenue, million dollars 2023 is 0.910, Assets, million dollars is 0.864, Market share, % is 0.910, ROE, % is 0.123, ROS, % is 0.441, Z-Altman is 0.106, Intangible assets, % is -0.186, Var, % is 0.109, and Hurwitz determinant is 0.086. Google Drive presents a set of data reflecting the performance results of enterprises in the Russian confectionery industry in 2023 (Top 30).

The model dataset can be found here. The Random Forest DL model was created using Google Drive. The visualization of the best tree DL-model "RF" (fragment) is presented in Figure 5.

Table 1 Dataset for the deep learning model "Random Forest" (fragment)

	Revenue, million dollars, 2023 year	Assets, million dollars	Market share, %	ROE, %	ROS, %	Z-Alt-man	Intan-gible assets, %	VaR, %	Hur-witz dete-rmi-nant	Net profit forecast, thousand dollars
Ferrero Russia	595.0	407.3	24.7	28.3	14.0	11.0	0.00	14.6	-0.001	83395.5
KDV Voronezh	460.6	373.4	19.1	214.3	6.5	-0.2	0.13	-348.6	-0.002	29730.6
Rot-Front	216.2	134.8	9.0	16.3	3.4	4.5	0.43	-102.7	-0.005	7316.9
Red October	188.3	164.1	7.8	57.7	5.5	8.7	0.24	-5.7	-0.007	10390.3
Concern Babaev	142.2	144.0	5.9	48.7	6.2	3.1	0.67	-149.3	1193	8770.6
Association Slavyanka	135.8	83.3	5.6	216.7	8.1	5.6	0.00	-325.9	-0.246	11043.1
Green lines	95.4	94.9	4.0	2.8	1.1	4.6	0.09	5.6	-0.002	1008.1
Ozersky souvenir	82.6	17.0	3.4	20.0	6.2	6.7	2.68	-532.8	-0.017	5123.2
Sweet Sloboda	62.1	47.4	2.6	223.3	17.7	13.1	0.00	-252.5	-0.002	10974.4
Voronezh factory	51.0	37.6	2.1	25.8	6.0	8.7	0.08	-263.5	-0.004	3045.9

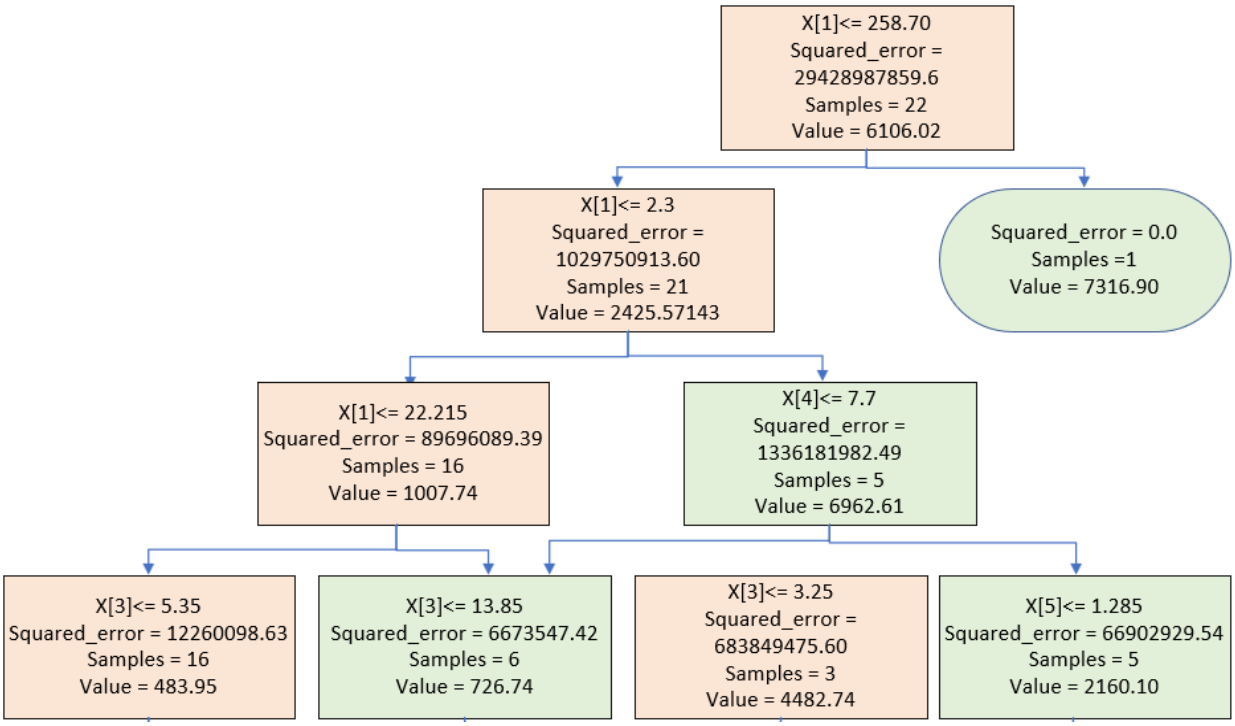

Figure 5 Visualization of the best tree DL-model "RF" (fragment)

According to the results of work in 2023, Russian confectionery factories produced more than 3.76 million tons of confectionery products, which is 3.7% more than last year's figures. In recent years, the domestic confectionery industry has demonstrated enviable stability; since 2017, production volumes have increased by 12.6%; a slight decrease was noted only in 2020 due to the pandemic. The confectionery industry's share in GDP is about 1%.

The Random Forest DL model was generated using pandas, matplotlib.pyplot, sklearn, LinearRegressio, and RandomForestRegressor libraries.

During the process of creating a DL model, the following processes occur:

1) random formation of the required number of decision trees that form the "Random Forest" ensemble, while the trees differ in the composition of the input parameters and the level of correlation between the features, as well as the numerical values of the hyperparameters of each of them;

2) The best DL-model tree was selected, which was trained on the dataset generated during the functioning of the cognitive model.

The dataset included parameters calculated based on data series for industry enterprises over 10 years. The following DL models were calculated and included in the dataset: 1) Revenue, million dollars, 2023; 2) Assets, million dollars; 3) Market share, %; 4) ROE, %; 5) ROS, %; 6) Z-Altman; 7) Intangible assets, %; 8) VaR, %; Hurwitz determinant; 9) Net profit forecast.

For forecasting purposes, the decision tree regression method was used. Solving a regression problem with a decision tree using Scikit Learning proceeds in such a way that the decision tree algorithm generates a node for each attribute in the data set and places the most important attribute at the root node. Then, the next step occurs. Starting from the root node, the algorithm moves down the tree, following another node that matches our condition or "solution."

The movement procedure continues until reaching the final node containing the forecast or result of the decision tree. A binary tree is often used for classification and regression. Russian companies' products in the confectionery industry are in demand not only on the local market but also abroad.

Research has shown that market leaders have large business sizes and a highly competitive product range. This position is largely achieved due to the high quality of their products and skillful management, which allows them to minimize financial risks and build a reliable strategy for sustainable development.

Creating a fuzzy algorithm to assess the financial stability of companies in the industry seems appropriate.

3.6. Fuzzy algorithm

The fuzz algorithm describes several sequentially executed stages, with each subsequent stage receiving the values obtained at the previous step as input: start, base formation, fuzzification, sub condition aggregation, sub conclusion activation, conclusion accumulation, defuzzification, and finish. The use of fuzzy logic is important in a turbulent economy because it can be used to support decision-making in conditions of market uncertainty.

After obtaining the predicted net profit using the DL random forest method, POE and ROS were calculated, based on which the sustainability of the partner company was assessed, among many others in the industry, using the fuzzy algorithm.

It is important to calculate the forecast values of the ROE and ROS multipliers, which will allow you to select potential business partners among companies in the industry, making a "Yes/No" decision.

In today's turbulent economy, fuzzy logic is essential. It can be effective in supporting decision-making under market uncertainty. In our case, the decision to select a strategic partner company in the industry is based on an assessment of the company's sustainability and performance.

After the forecast of net profit using the DL random forest method has been successfully obtained, it seems appropriate to obtain a "Yes/No" decision on choosing a partner based on the use of the fuzzy algorithm. It is important to calculate the ROE and ROS multipliers, which will allow you to evaluate each company's effectiveness (Equation 6):

$$ROE = \frac{NetIncome}{Equity} * 100\%, \quad (6)$$

where NetIncome is the net profit;

Equity is the excess of a company's assets over its debts. Therefore, if the ROE value is 30%, this can be considered a normal value under modern conditions. If the coefficient values are high, then there is a possibility that the company has a high share of borrowed capital (a lot of debt), which

creates a financial risk. Conversely, if the company's return on equity is low, it is inefficient and will not be attractive to partners.

When using the ROE coefficient, the profitability of shares and bonds or bank deposits is not compared. ROE is a financial indicator that is convenient to use to compare the profitability of companies from different industries to find an industry with high profitability. It can be successfully used to compare the efficiency of companies operating in the same industry (e.g., metallurgy, energy, and confectionery).

Research shows that another interesting parameter is the ROS (Return on Sales). This indicator allows investors to evaluate the company's share of net profit in sales. This indicator can be calculated using the following formula (Equation 7):

$$ROS = \frac{NetIncome}{Sales} * 100\%, \quad (7)$$

where NetIncome is the company's net profit;

Sales is the company's revenue. If the ROS is below 5%, the sales profitability is considered low. If the profitability level is 5 - 20%, the profitability is average, and if it is 30% and above, then the profitability is high. It seems appropriate to divide the set of ROS values into three intervals. This is necessary and sufficient to break down the existing series of values of the feature under consideration and translate the numerical values into linguistic variables: "Bad," "Optimal," and "Unreliable." Analysis of the dynamics of the ranked series of ROS values from 0 to 21.6% for the companies under consideration allows us to assume a certain relationship between ROS and ROE. This will further support management decisions regarding the choice of a strategic partner enterprise with attractive efficiency and sustainability parameters (see Table 2).

The use of two indicators in a fuzzy model allowed us to form a fuzzy inference system that allows us to select a partner. The visualization of fuzzy logical inference was successfully obtained based on the application of fuzzy rules (see Figure 6).

The Yes/No decision is acceptable for both investing in a partner company and doing business with any of the selected companies. It seems appropriate to introduce the following designations for classifying companies into the corresponding categories: stability indicator or SI (Yes/No).

Table 2 ROS and ROE multipliers when companies are grouped

Name	ROE, %	ROS, %
Max	451.5	21.6
Min	0.0	0.2
Range of variation	451.4	21.4
Average	75.5	6.0
Number of values N	28	28
1st interval	0 - 70	0 – 3.4
2rd interval	71-300	3.5 – 6.9

The fuzzy algorithm works in such a way that several stages occur: gasification, formation of fuzzy rules for the inference system, and defuzzification. It seems appropriate to perform gasification (Table 1, Supplementary 1).

The use of linguistic designations allows us to develop "rules" (Table 2, Supplementary 1). In this study, the fuzzy model is used as a "trigger" that allows classification based on the ROE and POC values calculated based on the predicted net profit for the next year, which come from the RF DL model.

As a rule, to provide graphical visualization of fuzzy inference, it is presented as a 3D surface. The Collab service was used for this, and the following Python libraries were applied: Fuzzy Logic, Skfuzzy, NumPy, and Matplotlib. The following modules were connected and used to visualize fuzzy logic: 1) package for working with fuzzy logic Scikit-fuzzy (Skfuzzy); 2) package for scientific computing NumPy; and 3) comprehensive library for creating Matplotlib visualizations.

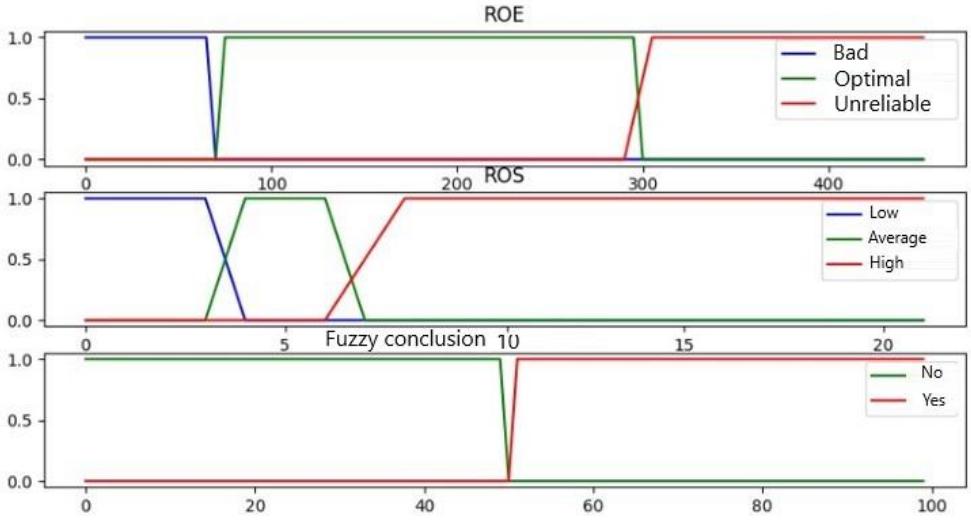

Figure 6 The visualization of fuzzy logical inference based on the application of fuzzy rules

3.7. Efficiency of using the Fuzzy methodology for selecting a partner company

The inclusion of case studies and real results enriches the study content. This is very important because it will help to contextualize the study and demonstrate its practical implications. For example, calculations show that companies receiving finished confectionery products (large retail chains) would benefit from using the proposed methodology in decision-making.

Practice shows that improper fulfillment of contractual obligations by suppliers leads to the formation of excess accounts receivable, a decrease in the turnover of current assets, a decrease in ROE (return on equity), and a decrease in profit. According to experts, Russian confectionery manufacturers have generally withstood the pressure from the United States and European countries to impose sanctions. However, the current state of the confectionery industry in Russia is characterized by the following problems: 1) negative dynamics in import and export volumes; 2) a sharp change in logistics channels for the supply of raw materials and wholesale shipment of finished products (the term "parallel import" has appeared); 3) an increase in product balances in warehouses to a record level in 2023, which is primarily due to a decrease in export flows; 4) an increase in world prices for cocoa beans; 5) increased competition in the chain retail market and an increase in the share of sales using promotions and sales. Physically, imports and exports decreased to levels of 281.7 thousand tons and 614.2 thousand tons in 2023, respectively (see Table 3).

Table 3 Balance of the Russian confectionery market in thousand tons

	2021	2022	2023	2023 in % to 2022
Domestic production	3989.7	3989.3	4216.7	105.7
Export	378.3	301.3	281.7	93.5
Import	745.3	624.6	614.2	98.3
Balance at the end of the year	125.2	207.3	108	52.1
Domestic consumption	3537.6	3765.3	3872.3	102.8

Deliveries from neighboring countries in 2022–2023, including through parallel import schemes, made it possible to partially replenish the missing volumes. The result of classifying companies by the level of ROE with Fuzzy is presented below (Figure 7).

After Russia's special military operation in Ukraine (SVO) began, supplies from the "unfriendly" countries of Germany and Poland dropped sharply. The fuzzy classifier assigns the value "0" to companies with an ROE of less than 70% (marked in red). If the ROE is greater than 301%, the value "1" is assigned (marked in green). Companies with values from 71-300 fall into the middle group and receive 0.5 (marked in blue).

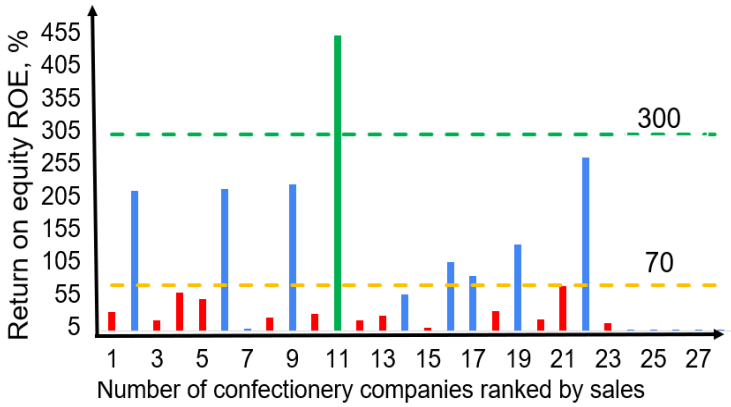

Figure 7 The result of classifying companies by the level of return on equity ROE

The result of classifying companies by the level of profitability of sales ROS with Fuzzy is presented below (see Figure 8).

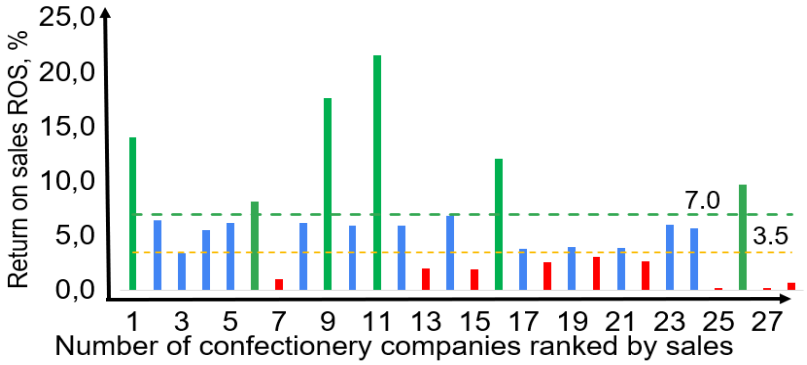

Figure 8 The result of classifying companies by the level of profitability of sales ROS with Fuzzy

The fuzzy classifier assigns the value "0" to companies with ROS of less than 3.5% (marked in red). If the ROS is more than 7.0%, the value "1" is assigned (marked in green). Companies with values from 3.1-7.0 fall into the middle group and receive 0.5 (marked in blue). For ease of visualization of the results of the algorithm for selecting partners, we number the companies in the confectionery industry in descending order of sales value, as in the histogram in Figure 4: 1.Ferrero Russia; 2.KDV Voronezh; 3.Rot-Front; 4.Red October; 5.Concern Babaevsky; 6.Association Slavyanka; 7.Green lines; 8.Plant Ozersky souvenir; 9.Sweet Sloboda; 10.Voronezh confectionery factory; 11.Confectionery factory Volzhanka; 12.Sormovskaya confectionery factory; 13.Steppe-Investments; 14.Confectionery company TAKF; 15.Donbass Confectioner; 16.Tula factory Yasnaya Polyana; 17.B&B; 18.Yuzhuralconfectioner; 19.Tomer; 20.Glazurprom; 21.Factory Chocolatier; 22.Slavkond; 23.Factory Krupskaya; 24.Confectionery company Altai; 25.At Palych's; 26.Enterprise Confil. The results of the Fuzzy Algorithm's work for 2023 are presented in Table 4.

Based on the results of work in 2023, the FA selected only 10 companies from among the 28 reviewed. They received "1" and are recommended as a reliable strategic partner.

The recommended partner companies included: 1. Ferrero Russia; 2. KDV Voronezh, 6. Slavyanka Association; 9. Sweet Sloboda, 11 Confectionery factory, Volzhanka; 14. Confectionery company TAKF; 16. Tula factory, Yasnaya Polyana; 17. B&B; 18. Tomer; 26. Enterprise Confil.

If the forecast value of companies' net profit in 2024 decreases, for example, by 10%, then the number of stable strategic partners may decrease (see Table 5).

Table 4 Results of the Fuzzy Algorithm's work for 2023 (fragment)

	Net profit, thousand dollars	ROE, %	ROS, %	Fuzzy ROS	Fuzzy ROE	FUZZY result
1.Ferrero Russia	83395.5	28,3	14	1	0	1
2.KDV Voronezh	29730.7	214,3	6,5	0,5	0,5	1
3.Rot-Front	7316.9	16,3	3,4	0,5	0	0
4.Red October	10390.4	57,7	5,5	0,5	0	0
5.Concern Babaevsky	8770.6	48,7	6,2	0,5	0	0
6.Association Slavyanka	11043.1	216,7	8,1	1	0,5	1
7.Green lines	1008.1	2,8	1,1	0	0	0
8.Plant Ozersky souvenir	5123.2	20	6,2	0,5	0	0

Table 5 Fuzzy modeling of the dynamics of sustainable companies in the confectionery industry with a decrease in profit for 2024

	Forecast for 2024, intervals of profit decrease, %				
	-10%	-20%	-30%	-40%	-50%
Number of companies considered	28	28	28	28	28
Number of recommended reliable companies	9	6	5	5	4
Share of recommended companies to the total, %	32.1	21.4	17.9	17.9	14.3

The calculations showed that if the economic situation starts to deteriorate, then the number of reliable companies will be 9, or 32.1% of the total, with a 10% decrease in profit. Ultimately, if profit decreases by 50%, the number of reliable companies will decrease to 4, or 14.3% of the total number of companies in the sample.

3.8. Discussion

Among the possible forecasts for the development of innovations in the real sector of the economy, the following can be identified: the structure of the digital industry in the real economy segment will increase significantly; businesses can transform from a simple organization into an aggregator of value. Forecasting accuracy questions are relevant in all areas (Amalia et al., 2024a; 2023).

Further research, as the results obtained show, will be directed in several directions. First, the modern points of view of both domestic and foreign scientists on the categories: sustainable development, circular economy, and centers of sustainable growth should be studied.

Second, to study in more depth the processes of economy digitalization, to consider the trends that determine the prerequisites for the further development of a new technological order, the basis of which is: cognitive models, information technology (IT) technologies, and artificial intelligence systems. The emergence of new technologies in combination with the "green economy" in the centers of sustainable growth (SDGs) opens up opportunities not only to effectively conduct business but also to take care of nature and solve social problems, i.e., to ensure sustainable growth and development of society as a whole.

Problems associated with sustainable development, ensuring high competitiveness, are the subject of study by several domestic and foreign scientists. However, certain aspects of creating a unified concept of financial sustainability require further scientific research.

In our opinion, the algorithm for calculating network reliability and the likelihood that the current supply chain not only matches the demand, budget, and production capabilities of suppliers, which was proposed by Lin and Lin (2024), is very practical. Their approach is interesting because it considers suppliers' level of sustainability. To diversify sources by studying the dynamics

of cash flows to avoid a liquidity crisis, Alam et al. (2024) proposed grouping suppliers in accordance with destructive risks.

Jayani Ishara Sudusinghe and Seuring investigated supply chains and sustainability performance in the circular economy and developed a conceptual framework for identifying appropriate collaborative practices. These practices are useful for improving symbiotic relationships and increasing sustainability performance (Sudusinghe and Seuring, 2022). Typically, to improve operational efficiency and effectiveness, companies interact and collaborate with each other. Over the years, this perspective has received considerable attention in relation to sustainability and supply chain management (SCM).

Hans-Jörg Bullinger concluded that changes in markets mean that key roles and mechanisms for generating profit or increasing market share are no longer working. As practice has shown, in economic turbulence, achieving your own growth is important to avoid being crowded out by "successful" companies (Bullinger, 1999). An important basis for ensuring the sustainable development of companies is the further use of AI. A significant amount of scientific research has been devoted to the effective use of AI to ensure financial sustainability.

According to Blackburn O, Paavo Ritala P, and Joona Keranen View J, digital platform technologies will help ensure sustainable development. Within the framework of the platform, these technologies will enable circular business models that reduce the use of resources and materials through recycling in large ecosystems (Blackburn et al., 2022). Authors Pan and Nishant (2023) focused on AI technology as it can help achieve digital sustainability. The authors identified the following aspects related to AI: 1) understanding; 2) relations between supply participants; 3) green creativity skills; 3) metrics; 4) strategies; and 5) improving AI tools. By highlighting the nuances associated with AI for digital sustainability, argue that they are poised to provide clear directions for future research.

Sjodin et al. (2023) analyzed leading B2B digital services companies to conceptualize the predictive and prescriptive capabilities of AI. Consequently, they found a solution that led to improved resource efficiency. The authors identified two innovative classes of business models using AI: not only optimization and automation solutions but also their main factors contributing to the creation of cyclical value (Sjodin et al., 2023).

The approach proposed by the authors of this article can be used in the future to "label" datasets for DL NNs "DL RF Classifier." Moreover, the fuzzy model can be improved in such a way that it could include not only ROE and ROS as input parameters but also many others, if appropriate. According to Sunhee Yoon and his colleagues, an important trend is the formation of strategic partnerships in the supply chain using green supply chain management methods, which ensures high efficiency (Youn et al., 2013). In line with this trend, research into financing sustainable smart city projects through public-private partnerships and green bonds by Jing Xu (Jing and Wayne, 2024) plays an important role. In addition, the use of companies' human capital to partner with universities plays an important role, as reflected in Albats et al. (2020).

According to Dwivedi et al. (2023) the rapid development of AI technology is driving economic growth and social empowerment. This development has attracted researchers to systematically study the associated challenges and opportunities.

Several studies on technology forecasting, sustainable development, green economy, and social change are of great scientific interest. For example Zhu and Cunningham (2022) proposed and demonstrated a hierarchical model that selectively combines topics at different levels of generality, allowing one to concisely consider the complex structure of knowledge in a scientific journal. In examining issues at the intersection of technology and society, Ashraf et al. (2022) used bibliographic linking to identify seven thematic clusters that have attracted disproportionate attention over the past decade and are likely to influence the future trajectory of development. Singh et al. (2020) and co-authors focused on identifying key factors that influence journal growth, such as publication evolution and citation patterns, top-cited articles, and lead authors. This has generated fragmentation and the belief that reviews can facilitate synthesis and integration.

Sustainable development is a complex system that includes many aspects of society, economy, resources, and the environment. Assessing the level of sustainable development and studying the relationship between the SDGs to promote sustainability play an important role.

Pradhan et al. (2024) showed that urban agriculture is related to all the Sustainable Development Goals and can be made more sustainable by taking advantage of opportunities and overcoming barriers.

Jia et al. (2024) first proposed a localized system for assessing sustainable urban development. Subsequently, the authors examined spatiotemporal variations and target uniformity of sustainability. Finally, the synergies and trade-offs between the SDGs were identified. In a critical study of the sharing economy, Ahmad et al. (2024b) concluded that the initial rise of the sharing economy does not lead to short-term changes in sustainable development. Its long-term impact becomes positive and contributes to sustainable development. Scientific research aimed at applying AI technology to social sustainability, business ethics, and other factors is of great practical importance for selecting a strategic partner.

Artificial intelligence (AI) has a huge economic impact on manufacturing, but its thoughtless integration poses social and environmental risks. According to a group of scientists led by Besinger et al. (2024), the integration of RAI into further research in these areas is essential to reduce risks and generate business benefits. The authors identified manufacturing-specific RAI parameters, including accountability, explainability, fairness, human-centeredness, sustainability (green AI), privacy, and security.

Terra et al. (2024) proposed a hybrid approach to assessing decision-making in the context of sustainable development. The approach combines the methods of MCDA, CoCoSo, and simple aggregation of preferences expressed by ordinal vectors principal components (SAPEVO-PC).

Sudha and a group of scientists (Sudha et al., 2024) used machine learning classifiers to gain deep insights into consumer data to make informed business decisions that will increase revenue and improve customer satisfaction. Simultaneously, the experimental methodology proposed by the authors uses various machine learning classifiers to analyze consumers. The list of classifiers includes K-NN, C4.5, RF, RT, LR, MLP, and NB. The C4.5 model has higher prediction accuracy than other ML classifiers.

In previous studies related to the use of enterprise development forecasts, the author used AI systems. Thus, Lomakin (Lomakin, 2023a) obtained an accurate forecast of the value of the "Stability Coefficient" parameter using the Random Forest ML deep learning model, reflecting the stability of the Russian economy. Lomakin and colleagues (Lomakin et al., 2023b) proposed an original approach that involves the use of the mathematical apparatus of the Random Forest DL artificial intelligence system to forecast the company's net profit, as well as the HAM for selecting reliable counterparts and assessing the effectiveness of this choice.

As practice shows, artificial intelligence systems continue their rapid development. The results achieved by Yudan Whulanza and his colleagues in the field of brain-machine interface and brain reverse engineering (Whulanza, 2024) should be taken into account in future research. Brain reverse engineering is an interdisciplinary field that combines neuroscience, engineering and technology, including for the development of "smart" production.

Artificial intelligence is important to apply in bankruptcy prediction. The main contribution of Pham et al. (2025) in this study is the creation of a hybrid model that effectively combines multiple machine learning (ML) algorithms with advanced data using the Synthetic Minority Oversampling Tomek (SMOTE Tomek) method or the SMOTE-Edited Nearest Neighbor (SMOTE-ENN) data resampling method to improve the accuracy of bankruptcy prediction (Pham et al., 2025).

The results of the study obtained by Naghipour M. et al., who proposed a review of works aimed at studying significant data, functions and used AI models, to determine the level of performance in the subject area (Naghipour et al., 2024), are of practical significance.

Convolutional neural networks are a promising approach. Author Muhammad Abdullah proposed using a combination of lightweight pre-trained convolutional neural networks and long short-term memory to detect violence in videos in real time (Abdullah et al., 2023).

The solution proposed by the author Asvial et al. (2023) to solve problems in engineering, industry and healthcare using artificial intelligence-based applications seems promising (Asvial, 2023). The application areas of AI are vast. AI is widely used in the fields of industrial automation, healthcare, transportation, finance, entertainment, and many others. It continues to evolve along with advances in technology and research, with the ultimate goal of creating systems that will have human-level intelligence and capabilities.

The use of Fuzzy algorithms for modeling business processes is of great importance. For example, Jesus Soto proposed optimization of interval fuzzy integrators of the 2nd type in Ensembles of ANFIS (adaptive neuro-fuzzy inference systems) models for forecasting Dow Jones time series (Soto et al., 2015a), and also obtained a forecast of time series using ensembles of ANFIS models with particle swarm optimization for fuzzy integrators (Soto et al., 2015b), Apoorva Vikrant Kulkarni developed a model for social sustainability and business ethics (Kulkarni, 2024).

4. Conclusions

In modern conditions, ensuring companies' sustainable development is of great importance. The financial stability of partner enterprises largely determines the sustainable development of the company. During the study, a random forest DL model was developed, a net profit forecast for the next year was obtained, and the forecast indicators of ROE and ROS were calculated. The authors proposed a methodology for assessing the reliability of a partner based on the deep learning model DL-model "Random Forest", which returned a forecast of the company's profit, which was then used in the fuzzy classifier. The Fuzzy model uses the following parameters: ROE and ROS. Both indicators are calculated using the DL model's forecast value of net profit. Based on the results of work in 2023, the fuzzy algorithm selected only 10 companies out of the 28 companies considered to be Russian confectionery companies. They received a rating of "1" and are recommended as a reliable strategic partner. The recommended partner companies included: Ferrero Russia (1), KDV Voronezh (2), Slavyanka Association (6), Sladkaya Sloboda (9), Volzhanka Confectionery Factory (11), TAKF Confectionery Enterprise (14), Yasnaya Polyana Tula Factory (16), Guest House (17), Tomer (18), and Konfil Enterprise (26). The proposed methodology allows us to model the situation in the confectionery industry relative to the sustainable enterprise dynamics. Calculations have shown that with a 10% decrease in profit, the number of reliable enterprises will be 9 or 32.1% of the total. Ultimately, with a 50% decrease in profit, the number of reliable enterprises will decrease to 4, or 14.3% of the total number of enterprises in the sample.

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Author Contributions

Authors' contributions: Nikolay Lomakin, Alexander Anisimov and Elena Antysheva designed the experiment. Tatyana Agievich, Olga Yurova and Uranchimeg Tudevdagva collected and processed the input data. Dmitry Rogachev and Nikolay Lomakin wrote the code, ran the model, and analyzed the output data. Nikolay Lomakin supervised the experiment and wrote the manuscript. All authors contributed equally to the work, the results of which are presented in this paper.

Conflict of Interest

The authors declare no conflicts of interest.

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