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IMPROVEMENT OF ADAPTIVE MANAGEMENT OF THE ENTERPRISE IN A FUZZY ENVIRONMENT

Speciality: 5311.01 – "Organization and management of enterprises"

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ABSTRACT

of the dissertation for the degree of Doctor of Philosophy

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The dissertation work was carried out at the Department of Industrial Economics of the Azerbaijan State University of Oil and Industry.

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İMZANI TƏSDİQ EDİRƏM
ADNSU-nun Elmi katibi,
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GENERAL DESCRIPTION OF WORK

The relevance of the topic and the degree of development. Currently, the risks of a global economic recession, including the instability of both supply chains and the cost of energy resources around the world, are affecting investments, financial institutions and the economy as a whole. These reasons change over time according to demand and supply, as well as market tactics and strategies of cement companies.

As a result, in order to increase competitiveness in the market, enterprises are forced to optimize costs and implement more efficient solutions in this business, which is stimulated by some statistical and predictive data confirming that the annual demand for cement has increased by 4-5% in the Republic of Azerbaijan since 2016.

The topic of organization and management of modern enterprises has been studied in local and foreign scientific literature. Scientist-economist of our republic Safarov G.A. studied production and management issues in industrial enterprises. Safarov G.A. looked at the theoretical and methodological issues of innovation, the organization and efficiency of production maintenance in oil and gas production, the sustainable development of the oil and gas industry and the application of advanced technologies. He has conducted extensive research in the direction of the advantages and eliminating of disadvantages in this field and noted that there are many factors characterized by uncertainty in this field, for example, production volume, sales price, etc. Including Huseynov T.A., Guliyev T.A., Gafarov Sh.S., Imanov A.Sh., Nuriyev A.Kh., Shahbazov K.A., Yuzbaşyyeva G.Z., Samadzade Z.A., Farajov F.A., Atakishiyev M.Ch., Aliyev T.B., R.P. Sultanova and others have also analyzed production and management issues in industrial enterprises.

Foreign scientists V. Ya. Gorfinkel, V. A. Shvandra, M. D. Listov, V. N. Vyatkin, B. G. Litbak, K. M. Pirogov, Yu. R. Vensin and many others have also published works in this field. In these works, uncertainty is partially taken into account. However, since the inaccuracy of the information exists here, it is necessary to use fuzzy logic. This shows that the issues of organization and adaptive

management of modern enterprises in a fuzzy environment are relevant and determined the selection of the subject of the dissertation.
In connection with the increasing competition and new challenges in the market, it is required to solve the problems of sustainable development, to introduce innovations in products and services, to protect the environment, and to reduce CO2 and other exhaust gases into the atmosphere.
On the other hand, in the production of recycled raw materials and materials, protection of biodiversity and water resources, increased social responsibility, increased safety of production for nature and personnel is required. By improving product quality, optimizing costs, improving planning, and applying modern adaptive management techniques in a cement plant, the above goals can be achieved more efficiently.
It is known that one of the most important elements of planning is the results of forecasting. Planning requires especially the results of the forecasting problem which is the input based on the most accurate and proven technologies.
As a concrete example in the research, prices are used to predict the volume of cement production in the market, to analyze emissions from industrial and technological waste gases, to monitor the technical condition of production equipment to compare the results, and to make decisions in adaptive management. Therefore, taking into account the research results and applied forecasting methods, cement demand, production and price can show fairly predictable steady growth in the market for the next 1-2 years even with cyclical fluctuations and regulatory measures.

The use of traditional methods and means of enterprise management raise the following problems in a fuzzy environment during the period of economic recession risks. As a result of using the traditional methods of production and economic management, the management personnel of the enterprise operating in the local and international market often react with a delay to the changes occurring in the internal and external environment of the enterprise and the market. In addition to this situation, unprepared and forced management decisions are often objectively observed. This subsequently leads to investment and operational losses, and in critical situations, it leads to the loss of morale and image of the enterprise in the market.

As a result, the current situation in this field creates an objective necessity to conduct research on the issues of improvement and application of existing modern management methods through innovative technologies and applied science, based on the principles of sustainable development and adaptation of management. Considering the above situation and the new challenges for the cement company, it can be noted that in case of the environment with imprecise information the application of sustainable development strategy and principles is relevant for the cement company's fuzzy environment.

Purpose and tasks of work. The purpose of the work is to develop the fundamentals of the comprehensive and detailed analysis and improvement of modern enterprise management methods, including the use of sustainable development methods and innovative technologies of the adaptive management system of the enterprise in a fuzzy environment.

For this purpose, the following issues were solved in the dissertation:

- comparative research and improvement of production and economic adaptive management methods of the modern enterprise;
- improvement and experimental application of new technologies for forecasting, online monitoring and control in the cement enterprise;
- Improvement and experimental application of new planning technologies in the cement plant;

The object and subject of the study. The object of the research is the traditional production and economic management system of the cement enterprise.

It is the application of sustainable development methods in the improvement of traditional and adaptive production and business management systems of a cement enterprise based on proven innovative technologies, for example: conducting economic forecasting using the fuzzy c-means method (Fuzzy logical inference system included in the MATLAB mathematical package) and ANFIS, Adaptive fuzzy neural logic inference system, as well as effective and scientifically based Analytical Hierarchy Process (AHP) - analytical hierarchy method of processes, computerized maintenance management system, computerized system for monitoring the condition of production equipment in real time.

Basic provisions for the defense. The following main provisions and conclusions of the dissertation work are presented for defense:

- A comprehensive production and economic analysis of the results of the application of modern computerized technologies and apllication of the concept of Sustainable Development were used to improve adaptive management methods,

- An improved method of direct cost savings in the operation of production and technological equipment was proposed and implemented by monitoring the condition of these equipments in real time and providing maintenance to these equipments in the cement plant;

- The methodology of modern forecasting of market prices and the volume of cement production on scientific basis was proposed and applied;

- A methodology for qualitative adoption of adaptive management decisions in planning and optimization was proposed and studied.

Research methods. The considered issues were solved using the Fuzzy C-means forecasting problem and using proven innovative technologies: Logical inference system for calculations ANFIS, MATLAB, analytical process hierarchy (AHP), MS Excel a spreadsheet processor.

Scientific novelty of the research. The main scientific innovations obtained in the dissertation include the following:

- As a result of the synergistic effect of applying the principles and standards of the Sustainable Development of the cement industry to solve internal and external challenges, the adaptive management method was improved;

- methods of economic forecasting of production volume, sales and cost of cement were proposed to increase the efficiency of management decisions using Fuzzy recurrent networks for forecasting, monitoring and control in a cement enterprise;

- The production volume in the cement industry for 2016-2022 was qualitatively forecasted using a recurrent neural network with evolutionary learning, which is confirmed in practice.
- For the first time, an online monitoring system (Condition Monitoring System-CMS) was implemented in the cement plant in real time for the condition of production and technical equipment.

Scientific and practical importance. In the conditions of increased market competition, new economic and technological challenges, as well as environmental requirements for product manufacturers, especially for the cement enterprise, result in the combined improvement of adaptive management methods by synergistic effect proposed in the dissertation. By applying the principles and standards of Sustainable Development, it demonstrates relatively greater efficiency.

Practically, an online CMS system was applied to control the status of production and technical equipment in real time at the cement plant. Cost savings and improved planning have been proven when using these advanced computerized systems to monitor the condition of production and maintenance equipment in real-time and thus maintain process equipment in a cement plant only in accordance with the technical condition of this equipment. Therefore this provides direct savings compared to traditional preventive maintenance.

Applied experimental studies and obtained results confirm the effectiveness of the proposed methods, as well as timely adaptation of the cement enterprise to production and technological changes both in the enterprise itself and in the rapidly changing market.

The applied experimental studies were tested, presented to the public, and also experimentally applied and confirmed with successful results in the example of the Holcim (Azerbaijan) cement company, a member of the Holcim group.

Approval of work. The main scientific and practical results of the dissertation on the application of modern technologies were distributed through digital networks and digital publishing methods, including ISSN 0949-0205, No.5-2010. It was discussed at international and republican level seminars and conferences organized by Azerbaijan State Oil and Industry University, Azerbaijan State Pedagogical University. Also, the obtained results were reported at the

WCIS-2020 international conference (11th World Conference on Intelligent systems for industrial automation) held in Tashkent.

Publications. 7 scientific articles were published on the subject of the dissertation: 2 articles were published in Web of Science, Scopus peer-reviewed scientific journals, 5 articles were published in recommended journals and conference materials of the Higher Attestation Commission. Scientific indexing of published works is as follows:

• 2 articles published in the journal are included in Scopus and Web of Science platforms.

• 5 articles published in journals and conference materials, including those recommended by the Higher Attestation Commission.

The name of the institution where the dissertation work was performed. Dissertation work was implemented in the Faculty of Economics and Management, Department of Economics of Industry, Azerbaijan State Oil and Industry University.

Structure and scope of work. The work is presented on 188 pages; consists of an introduction, 3 chapters, results, conclusion, a list of 60 titles' references used. The work consists of 56 figures and 30 tables. The total volume of the dissertation is 227,680 characters, excluding images, tables and the list of references.

In the introduction, the relevance of the researched problem is justified, the main goals and issues required to be solved are briefly stated, scientific innovations and a practical assessment of the conducted research are given.

The first chapter is mainly dedicated to the analysis of the current state of the cement industry and the adaptive methods of enterprise management, and structurally consists of 3 sub-chapters.

The first sub-chapter is devoted to the analysis of the main concepts and the comparative analysis of the economy of the cement industry and the state of the problem of adaptive management in the modern enterprise. Here, the state of the cement industry, the analysis of its main indicators and its economy, the analysis of the state of the problem of adaptive management are presented.

Based on the analysis, a system supporting adaptive management is considered.

The structure and explanation of the system involving fuzzy model and prediction methods for decision making and adaptive control of the research object is explained in detail in this chapter. To this structure. Fuzzy model and forecasting techniques are introduced for decision making and adaptive control in a cement plant.

The second sub-chapter is devoted to the identification and analysis of sustainable development methods and improvement of the adaptive management of the cement enterprise.

The third sub-chapter is devoted to the formulation of the research problem.

In the second chapter, descriptive problems of the development of an integrated methodology and the results of the application of advanced technologies and decision-making methods for adaptive management in an industrial cement enterprise are defined, analyzed and practically solved.

Sub-chapter 2.1 examines and compares the current key performance indicators of the cement plant.

Here are some key performance indicators for a cement plant:

1. EBITDA(Earnings before interest, taxes, depreciation, and amortization) = Net Income + Taxes + Interest Expense + Depreciation & Amortization (1)

2. Net Availability Index (NAI) [%]

Net Availability Index (NAI) [%] = ((Working time [h] + Downtime [h]) / Calendar time [h]) × 100

Net Availability Index (NAI) [%] = ((Working time [h] + Downtime [h]) / Calendar time [h]) × 100 (2)

- Net Availability Index Target (%) → ≥ 90% for all eligible assets

3. Maintenance cost (Δ% of baseline)

Cost of service [%] = ((actual unit cost of service − baseline) / baseline)) × 100 (3)

Cost of service [%] = ((actual unit cost of service − baseline) / baseline)) × 100

- Target cost of service [%] → ≤ 0%

4. Preventive Maintenance Procedures (PMR) %

PMR [%] = (Actual Labor on Last Confirmed Operation from PM02 WO / Total Maintenance Completed) × 100 (4)

PMR [%] = (Actual Labor on Last Confirmed Operation from PM02 WO / Total Maintenance Completed) × 100

- PMR % target → between 15% and 30%

5. PMR Efficiency [%] - Update target based on usage.

PMR efficiency [%] = (number of maintenance requests generated from PM02 WO / number of maintenance requests) x 100 (5)

PMR efficiency [%] = (number of maintenance requests generated from PM02 WO / number of maintenance requests) x 100

→ > 35%

6. Planning accuracy [%]

Planning accuracy [%] = 100x (1-($\sum ABS$ (calculated - actual) hours of work for all confirmed planned / actual hours of work for all completed planned (6)

Planning accuracy [%] = 100x (1-($\sum ABS$ (calculated - actual) hours of work for all confirmed planned / actual hours of work for all completed planned.

→ > 90%

Subchapter 2.2 analyzes the application of methods for cost optimization and adaptive management through local technologies.

Subchapter 2.3 analyzes the decision and practical application of real-time applied science, forecasting methods, condition monitoring and maintenance of production equipment under the condition of cost optimization and adaptive control.

In the third chapter computer simulation and applications are reflected. Analytical methods for cost optimization and production planning and their computer implementation are discussed here. The reviewed methods are proposed for a fundamentally new computerized approach to task planning and cost optimization, management decision-making. At this time, the following pre-programmed "Order Priorities" for 7 items and services are selected based on the technical and economic requirements. These advantages has been proposed based on a practical and logical approach to achieve the most effective result in accordance with reality, i.e. to make the prioritizing the list and thus dynamically under fuzzy conditions mode to contribute to costs optimization with high-quality management decision. The 7 main elements or criteria are as follows:

1) Current Stock - of CS (priority - minimum quantity)

2) PR - order record (priority - "Urgent" indicator in PR status)
3) Criticality (priority maximum - 5, minimum -1)
4) Estimated price (priority - minimum price per unit)
5) Total cost (priority is the minimum total cost of spare part or service)
6) Order Quantity-OQ (priority - minimum units), annual consumption of YC, OQ=YC-CS.
7) Delivery date (priority - earlier delivery)

The primary goal is to sort orders and services according to the customer's demand.

Method 1: **Ranking model.** The RF ranking function is based on using 7 criteria to perform the ranking.

$$RF(X)=RF(x1,x2,\ldots,x7)=w1*F1(x1)+w2*F2(x2)+\ldots+w7*F7(x7) \quad (7)$$

RF(X) for a specific service/order

$$F1(x1) = (x1)/5 \quad (8)$$

$$F2(x2) = 1\text{-sigmoid}(x2min, x2max, k1*x2, 0.01) \quad (9)$$

$$F3(x3) = 1\text{-sigmoid}(x3min, x3max, k2*x3, 0.01) \quad (10)$$

$$F4(x4) = 1\text{-sigmoid}(x4min, x4max, k3*x4, 0.01) \quad (11)$$

$$F5(x5) = 1\text{-sigmoid}(x5min, x5max, k4*x5, 0.01) \quad (12)$$

$$F6(x6) = 1\text{-sigmoid}(x6min, x6max, k5*x6, 0.01) \quad (13)$$

$$F7(x7) = 1, \text{ if } (x7=\text{"Urgent"}) \text{ or } 0, \text{ otherwise} \quad (14)$$

Special settings w1, w2, w3, w4, w5, w6, w7, k1, k2, k3, k4, k5 are subjectively evaluated based on experience.

The proposed model, which serves to rank the list of desired services or orders, is effectively tuned based on the available data for which the relevant ranking is known.

According to the proposed feasibility, the data table (where part of the data from the existing filename list is used) is sorted by an experienced expert. The model is then corrected using a function minimization and optimization algorithm (for example, an evolutionary algorithm). A fragment of the computer solution of this problem is given below:

Cost function: CF= Sum(i=1,N-1){ D(RF(-DesiredRank(i)), -RF(DesiredRank(i+1))) }

Error function: EF= Sum(i=1,N-1){ D(RF(DesiredRank(i+1)), RF(DesiredRank(i))) }

D(y1,y2)= 0, if (y1>y2) or (y2-y1), otherwise.

//A possible solution *S* constitutes of values of parameters: w1, w2, w3, w4, w5, w6, w7, k1, k2, k3, k4, k5

//Whether Solution S_1 is better than S_2 is defined as follows:

IF CF(S_1)<CF(S_2)
    THEN IF EF(S_1) ≤0 OR EF(S_1) ≤EF(S_2) THEN S_1 IS BETTER THAN S_2
    ELSE S_1 IS NOT BETTER THAN S_2
ELSE IF CF(S_2)<CF(S_1)
    THEN IF EF(S_2) ≤0 OR EF(S_2) ≤EF(S_1) THEN S_1 IS NOT BETTER THAN S_2
    ELSE S_1 IS BETTER THAN S_2
ELSE
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ELSE

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ELSE

IF EF(S_1)<EF(S_2) THEN S_1 IS BETTER THAN S_2

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Method 2. Neural network model.

Instead of the RF-ranking function, a 7-input artificial neural network (ANN) is used. The network is trained using the cost and error functions proposed above.

Using data clustering. If the amount of data is very large, the data can be grouped into multiple clusters (for example, 10 clusters) and the proposed methods can be applied to the centers of the clusters.

ANNs are formed from three layers. These layers are - Input layer, Intermediate (Hidden) layer and Output layer.

Input layer. Neurons in this layer receive information from the outside world and transmit it to intermediate layers. In some networks, no data processing takes place at the access layer.

Intermediate (Hidden) layer. Data from the input layer is processed and sent to the output layer. The processing of these data is realized in intermediate layers. A network can have more than one intermediate layer.

Output layer. The neurons in this layer process the information from the intermediate layer to produce the output that needs to be produced for the set of input data received from the input layer of the network. The extracted output is sent to the outside world.

As in biological neural networks, the main element in artificial neural networks is the artificial neuron. An artificial neuron is the smallest and basic information processing unit that is the basis for the operation of the ANN. All the neurons involved in the network receive one or more inputs and produce a single output. These outputs can be outputs to the outside of the artificial neural network or can be used as inputs to other neurons. Although there are some differences in the developed network models, an artificial neuron model with its general characteristics consists of 5 components.

These are: Inputs, Weights, Merge Function, Activation Function, Output.

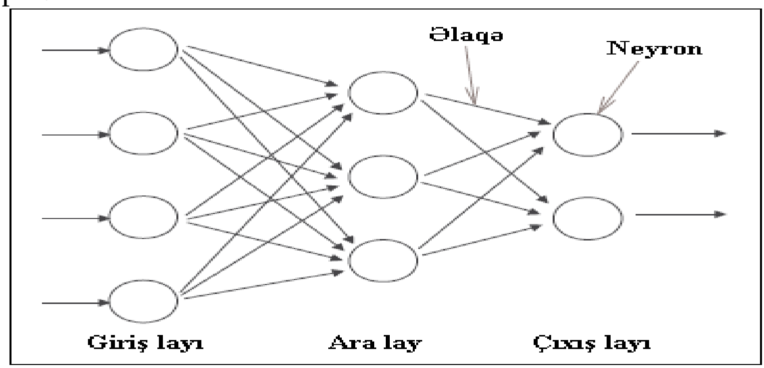

Figure 1. The structure of a neural network.

Our goal in this work is to forecast cement production using Fuzzy c-means (combined with Fuzzy Inference System) and ANFIS included in the MATLAB mathematical package and compare the results of these methods. To achieve this goal, the following works should be carried out:

1) Research of ANFIS and Fuzzy c-means method;
2) Setting the necessary issue in the selected field of application;
3) Obtaining data and putting it in the necessary form for solving the problem;
4) Implementation of the model training process by both methods;
5) Application of the resulting rules to current data;
6) Analysis and comparison of forecast results.

Fuzzy C-Means. Fuzzy C-Means algorithm attempts to minimize the sum of squared errors. The algorithm is based on the iterative minimization of the following objective function:

$$J(W,C) = \sum_{j=1}^{k} \sum_{i=1}^{n} w_{i,j}^{p}\, dist(x_i, c_j)^2$$

The following condition is satisfied for the sum of degrees of membership of a given element xi to all clusters:

$$\sum_{j=1}^{k} w_{i,j} = 1$$

The following condition is satisfied for the sum of membership degrees of all elements in each cluster:

$$0 < \sum_{i=1}^{n} w_{i,j} < n$$

The corresponding cj centroid for a Cj cluster is defined as:

$$c_j = \frac{\sum_{i=1}^{n} w_{i,j}^{p} x_i}{\sum_{i=1}^{n} w_{i,j}^{p}}$$

The fuzzy partition update formula can be obtained by minimizing the objective function with the constraint that the sum of the weights equals 1:

$$w_{i,j} = \frac{(1/dist(x_i, c_j)^2)^{\frac{1}{p-1}}}{\sum_{q=1}^{k}(1/dist(x_i, c_q)^2)^{\frac{1}{p-1}}}$$

ANFIS. A typical rule set for a first-order Sugeno fuzzy model with two fuzzy If-Then rules is expressed as:

If $(x_1\ A_1)$ *və* $(x_2\ B_1)$ *Then* $f_1 = p_1x_1 + q_1x_2 + r_1$

$$If\ (x_1\ A_2)\ və\ (x_2\ B_2)\ Then\ f_2 = p_2x_1 + q_2x_2 + r_2$$

ANFIS (Adaptive Neuro Fuzzy Inference System) has a 5-layer feedforward ANN structure. The tasks of these layers can be specified as follows:

Layer-1: Each joint i participating in this layer is an adaptive joint whose output is defined as follows:

$$O_{1,i} = \mu_{A_i}(x_1),\ \ i = 1,2 \quad \text{və} \quad O_{1,i} = \mu_{B_{i-2}}(x_2),\ \ i = 3,4$$

Layer-2: Each joint in this layer is a stable joint that outputs the product of the signals it receives and is denoted by **Π**. The output of layer 2 can be described as follows:

$$O_{2,i} = w_i = \mu_{A_i}(x_1) \times \mu_{B_i}(x_2)\ ,\quad i = 1,2$$

Layer-3: Each joint involved in layer 3 is a stable joint denoted by N. Each joint i in this layer calculates the ratio of the degree of truth of the i -th rule to the sum of the degrees of truth of all the rules:

$$O_{3,i} = \overline{w}_i = \frac{w_i}{w_1 + w_2}, i = 1,2$$

Layer-4: Each joint i belonging to this layer is an adaptive node whose node function is as follows:

$$O_{4,i} = \overline{w}_i f_i = \overline{w}_i(p_i x_1 + q_i x_2 + r_i)\quad)$$

Layer-5: The final layer, layer 5, involves a fixed, single joint, denoted by Σ, which collects all incoming signals to calculate the total output. The output of this joint is written as:

$$O_{5,1} = Toplam\ çıxış = \sum_i \overline{w}_i\, f_i = \frac{\sum_i w_i f_i}{\sum_i w_i}$$

Prediction issues. Application of three-layer recurrent neural network technology was done. A three-layer Recurrent Neural Network (RNN) with five inputs, seven hidden neurons, and one output was established to predict cement production volume for 2017-2022.

The experimental results of the computer simulations are described below. The network uses no activation (only distribution neurons) (1st), a hidden (2nd) layer based on a sigmoidal activation function, and an output layer (3rd layer) based on a linear activation function. It has been shown that three layers of neurons in perceptron networks are sufficient to approximate most numerical input-output values with desired accuracy. Neurons of the 1st (input) layer are distributed only without changes in the input signals[3]:

$$\tilde{y}_i^{(1)}(t) = \tilde{x}_i^{(1)}(t) \qquad (15)$$

The outputs of neurons of the 2nd (hidden) layer are calculated as follows:

$$\tilde{y}_i^{(2)}(t) = F\left(\tilde{\theta}_i^{(2)} + \sum_j \tilde{x}_j^{(2)}(t)\tilde{w}_{ij}^{(2)} + \sum_j \tilde{y}_j^{(2)}(t-1)\tilde{v}_{ij}^{(2)}\right) \qquad (16)$$

here $F(s) = \frac{s}{1+|s|}$ (17)

The neurons in the third (output) layer are linear and their outputs defined as follows:

$$y_i^{(3)}(t) = \theta_i^{(3)} + \sum_j x_j^{(3)}(t)w_{ij}^{(3)} + \sum_j y_j^{(3)}(t-1)v_{ij}^{(3)} \qquad (18)$$

Formally, all signals and parameters (weights and thresholds) can be represented by fuzzy numbers with an arbitrary type of membership function (for example, triangular fuzzy numbers) or ordinary fixed numbers.

Results of practical application of cement cost forecasting methods.

The prediction using fuzzy neural network and Sugeno logical inference algorithm is based on the following calculations[3]. The Sugeno model is expressed by 2 rules:

If $(x_1 A_1)$ and $(x_2 B_1)$, $f_1 = p_1 x_1 + q_1 x_2 + r_1$ (19)

If $(x_1 A_2)$ and $(x_2 B_2)$, $f_2 = p_2 x_1 + q_2 x_2 + r_2$ (20)

The neural network consists of 5 layers. The goal is to predict the market cement value and determine its using digital data. The data set consists of 18 data sets covering 18 years of data. 2/3 of the neural network data was used to train it and 1/3 of it was used to make the prediction based on the model. A part of the input data is given in Table 1, a fragment of the rules and their membership functions - in Figure 3.

Table 1. A fragment of primary data

f(t-2)	f(t-1)	f(t)
2.5	2.5	2.5
4.0	4.1	4.5
4.5	4.5	4.5
4.5	3.1	4.5
5.0	5.5	6.0
6.0	6.0	6.8
6.0	6.5	6.0
6.0	6.5	6.0
6.0	6.5	6.0
6.0	6.5	6.9
6.3	5.7	6.0
6.0	5.5	5.0
4.5	5.5	5.3

The following rules were obtained based on the Fuzzy-C-means method using the initial data.

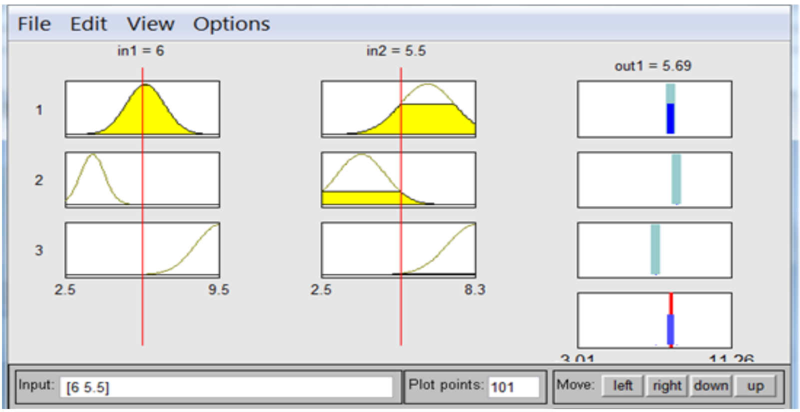

Figure. 3. Description of fuzzy rules derived from data

Solving the problem in two ways (ANFIS and Fuzzy C-means) was solved and it was checked which one is more efficient. The test result for 2016-2018, 2022 is shown in Figure 4.

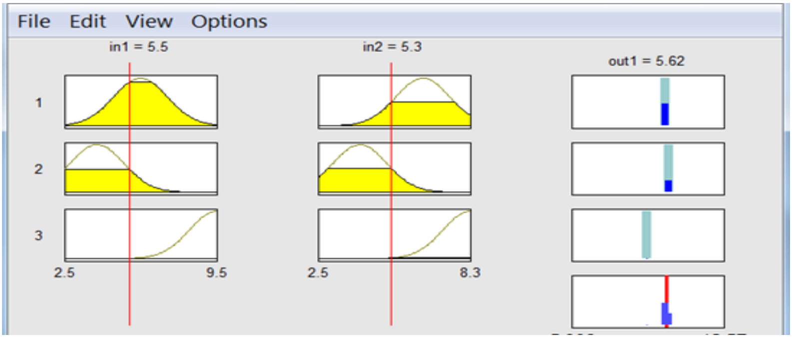

Figure. 4. Prediction value of the market price of the cement for 2016-2018,2022 years. (prediction data obtained by fuzzy clustering)
Below is the error mean squared error on the forecast values (RMSE) is calculated by the formula:

$$RMSE = \sqrt{\frac{\sum(x-\bar{x})^2}{N-1}}$$

The resulting RMSE and prediction data are presented in Table 2:

Table 2. Fragment of real and predicted data obtained by fuzzy clustering.

#	year	AZN			Prediction, AZN
		X1	X2	X3	Yn
1	2000	2,5	2,5	2,5	2,56
2	2001	4,0	4,1	4,5	4,29
3	2002	4,5	4,5	4,5	4,82
4	2003	4,5	3,1	4,5	4,42
	…	…			
15	2014	6,3	5,7	6,0	5,73
16	2015	6,0	5,5	5,0	5,35
17	2016	4,5	5,5	5,3	5,62
18	2017	5,5	5,3	5,62	5,81
19	2018	5,3	5,6	5,81	5,94
RMSE=0,198221%					

RMSE and prediction data were obtained based on fuzzy neural network. It is presented in Table 3 and Figure 5. The results show that the fuzzy neural network allows for more reliable and accurate prediction results.
Below are the prediction values obtained by fuzzy neural network.

#	year	AZN			Proved Prediction, AZN
		X1	X2	X3	Yn
1	2000	2,5	2,5	2,5	2,56
2	2001	4,0	4,1	4,5	4,29
3	2002	4,5	4,5	4,5	4,82
4	2003	4,5	3,1	4,5	4,42
	…	…			
15	2014	6,3	5,7	6,0	5,73
16	2015	6,0	5,5	5,0	5,35
17	2016	4,5	5,5	5,3	5,62
18	2017	5,5	5,3	5,62	5,81
19	2018	5,3	5,6	5,81	5,94
RMSE=0,198221%					

Table 3. Real and predicted data,

#	year	AZN			Prediction
14	2013	6.0	6.5	6.9	6.44
15	2014	6.3	5.7	6.0	5.63
16	2015	6.0	5.5	5.0	5.58
17	2016	4.5	5.5	5.3	5.58
18	2017	5.5	5.3	5.62	5.28
19	2018	5.3	5.62	5.81	6.05
	RMSE=0,123882%				

the results obtained by fuzzy neural network and clustering are given below. All calculations were performed using Matlab and MS Excel environment [3].

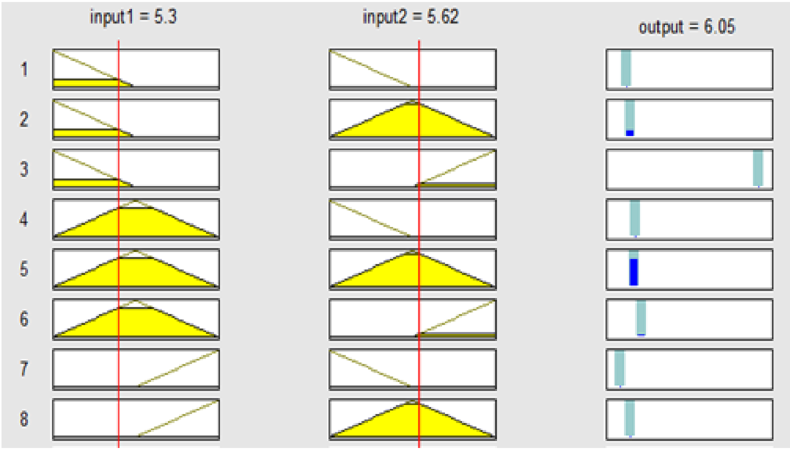

Figure. 5. The forecast value of the market price of cement - for the years 2018-2022

The market price of cement was obtained using a fuzzy neural network.

Table. 4. Real and predicted prices

Real	Predicted	
6.9	6.44	0.446669
6	5.63	0.020069
5	5.58	0.036736
5.3	5.58	0.036736
5.62	5.28	0.241736
5.81	6.05	0.077469
5.771667		0.015347

Table 5. The predicted value of the market price of cement

2018,2022 years

2013	6.9	6.44
2014	6	5.63
2015	5	5.58
2016	5.3	5.58
2017	5.62	5.28
2018	5.81	6.05

Real and predicted results are shown in the graph (Figure 6).

Results of practical application of economic forecasting methods on production and sales volumes.
A three-layer recurrent neural network RNN [4-7] with five inputs, seven hidden neurons and one output was created to forecast the volume of cement production for 2017-2022.
Considering the macroeconomic statistics, the RNN was trained using the data given below.
Real and predicted results are shown in the graph (Figure 6).

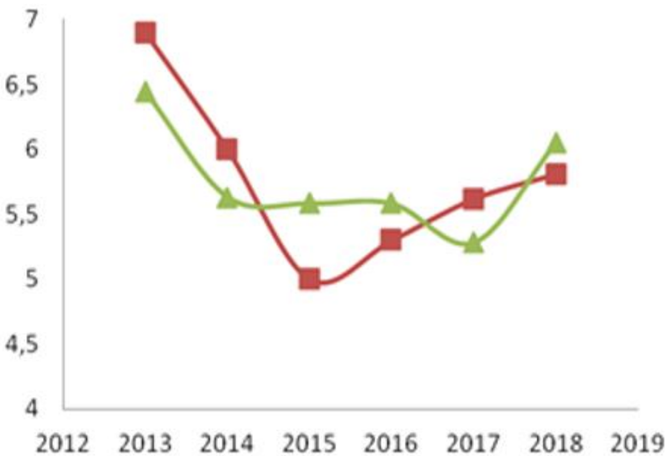

Image. 6. Real and forecast prices.

Costs: cement production X1 (t); ready concrete production X2 (t-2); construction brick production X3 (t-2); Consumer price inflation X4 (t); The average price of oil is X5 (t).
Products: production (sale) of cement X1 (t + 1).
Table 6. Macroeconomic statistics determined by the RNN.

year	Cement production (thousand tons)	Concrete production (thousand tons)	Construction brick production (thousand cubic meters)	Inflation, consumer prices (annual %)	Average oil price (USD)
2005	1538.0	1916.0	161.0	9.6	48.89
...	......	......	...... _	......	......
2017	2879.8	-	-	12.9	48.73

X1(2018) = 3444,7;
X1(2019) = 3132,9;
X1 (2020 - 2022) = 2746,5.

Prediction method based on fuzzy recurrent neural networks.

The main prediction results were prepared with RNN:
X1(2018) = 3444,7;
X1(2019) = 3132,9;
X1(2020 - 2022) = 2746,5. [4-7]

Table 7. Actual and predicted data obtained using RNN

Inputs					Output
X1(t)	X2(t-2)	X3(t-2)	X4(t)	X5(t)	X1(t+1)
1538.0			9.6	48.89	1622.0
……..	……..	……..	……..	……..	……..
2306.9	1692.	426.1	12.4	38.17	2879.8
2879.8	942.1	280.6	12.9	48.73	

RMSE = 1.57E-10 was obtained with the evolution-based learning algorithm (DE-differential evolution).

Calculations (made based on Excel XLMINER on the Microsoft platform).

Monitoring technology is also discussed in this chapter [1]. There is a need to define enterprise-wide perspectives and integrated software and hardware architectures to achieve savings and synergies through partnerships between business partners and consumers.

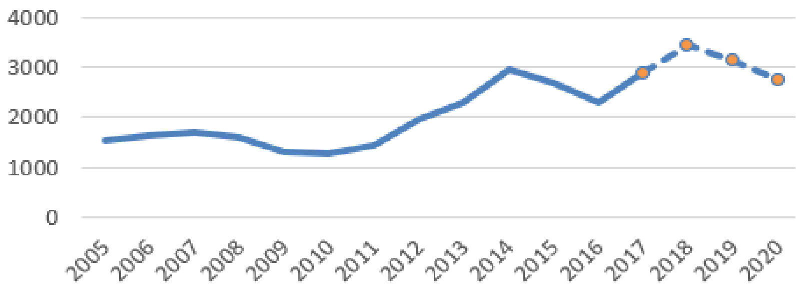

Figure 7. Actual and predicted production results for production 2020-2022

On the basis of the example of the former Garadag Cement (currently Holcim (Azerbaijan)), modern online technologies and the condition monitoring program were implemented using the online management system of PRÜFTECHNIK GmbH. [1]
Preventing interruptions in the production process allowed the operation to be successful. Thus, early analysis allowed planned maintenance, which significantly reduced production and operating costs. Therefore, Holcim (Azerbaijan) has also approved the use of an online management system as a modern technology to increase equipment reliability, ensure production availability and reduce maintenance costs.
In fact, before the installation of the online CMS, the total cost of maintaining the observed production equipment for five months was Euro 51803 (Figure 8).
The goal was to reduce costs to Euro 14500 , which means a reduction of 3.6 times. In fact, maintenance costs amounted to Euro 2134, which means 24.3 times reduction in total maintenance costs over the next five months. As a result, maintenance costs were reduced by up to 4% compared to the baseline [1].

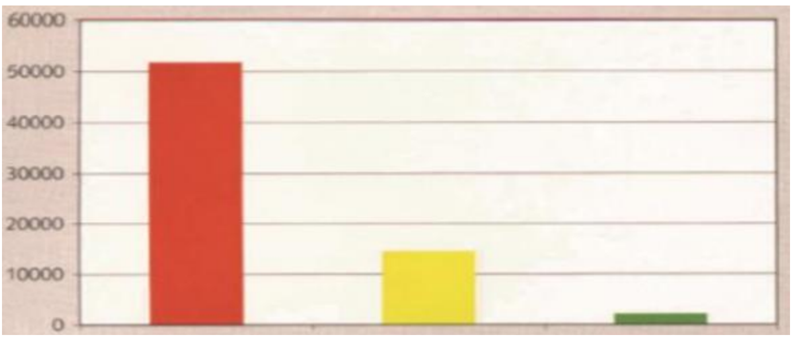

Figure. 8. Service cost savings.

Additional improvements have been made by reducing the costs of unscheduled shutdowns of controlled lines of process equipment (Figure 9). The frequency and duration of unscheduled stoppages and unscheduled work has been significantly reduced [1].

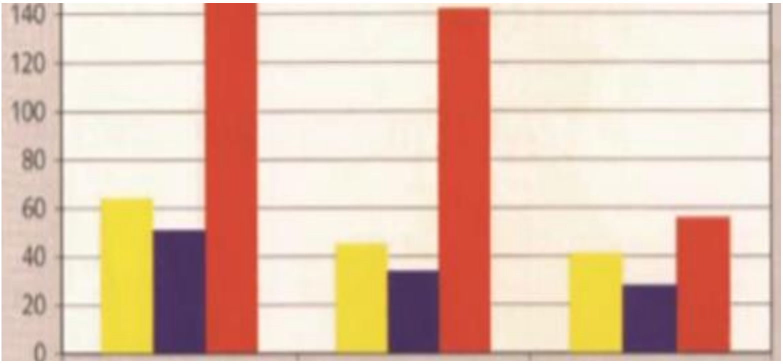

Figure. 9. Cost reduction in unplanned downtime

In fact, in the example of a cement plant, there are criteria for successful application of modern technologies through adaptive management, first priority, efficiency, feedback, improvement and rejection of complex methods. One of the main conditions for the successful implementation of adaptive management is the application of modern marketing analysis and planning through the Computerized Maintenance Management System CMMS in the cement plant. This approach is useful for timely decision making by management.

In the third chapter, the experimental verification of the proposed technology and methods was carried out. Experimental verification is performed using the functionality of the MATLAB software tool.

Each experimental verification procedure is presented in a separate subsection of the dissertation and is briefly described below:

• *In sub-chapter 3.1*, the experimental verification of the proposed methodology and the practical application of the results of modern forecasting for production planning in a cement enterprise were carried out. Also, a computerized method procedure was proposed for cost optimization in a cement plant.

• *In sub-chapter 3.2* there were the algorithm-program tasks made, justified and solved. Algorithms were developed for solving the proposed methods.

• *In sub-chapter 3.3* the computer simulation was carried out.

MAIN RESULTS

Within the framework of the thesis, the following studies were conducted and the following results were obtained:

1. A comprehensive analysis and improvement of adaptive management methods was carried out along with the synergistic effect of applying "sustainable development" principles and standards.
2. New methods using macro-economic indicators have been applied while implementing the prediction algorithm with evolutionary learning using RNN technology - Fuzzy recurrent neural network (RNN), Fuzzy C-means method and ANFIS. Based on tools such as the MATLAB mathematical package, effective prediction results were obtained, as well as a comparison of the results of these methods was given. These technologies allow to qualitatively predict the production volume and demand, prices in the example of the cement industry in 2016-2022.
3. A computerized method is proposed to improve production and economic planning and cost optimization in a cement enterprise to achieve economic and technological Key Performance Indicators.
4. Real-time CMS Condition Monitoring System and CbM method (Condition Based Maintenance) experimentally implemented for the Production and Technical Equipment in the cement plant. Practically the cost optimization was proven through condition-based operation, providing direct savings compared to traditional Preventive equipment. As a result, the above mentioned CbM and online CMS implementation ensured the prevention of unplanned downtime and breakdowns and the achievement of KPIs in the cement plant over a long period of time.
5. Experimental computer simulations were carried out for the improvement of adaptive control methods at the cement plant and effective results were obtained that were practically confirmed.
6. The application of the analytical hierarchy of processes in making quality management decisions and cost optimization is proposed and analyzed.

The research results and the set of joint methods are universal in solving production safety problems, adapting management, optimizing operating costs, planning, sustainable development and achieving the economic and technological key performance indicators of the cement enterprise in the industry 4.0.

This research has been tested, presented to the public, also experimentally applied and confirmed with successful results in the example of the cement industry, especially Holcim (Azerbaijan), a member of the Holcim group. Applied tested methods can be used to improve production and economic management in any type of industrial and commercial enterprises in developed countries, including the Republic of Azerbaijan. The proposed approach enables predictions based on fuzzy information, eliminates prediction problems based on partially uncertain information, allows researchers to analyze their models and correct errors in the modeling process. For example, in fuzzy modeling, because the result depends on the membership function, the selected implication, and the logical inference method, a high-quality model can be obtained by changing the choice at these stages.

Fuzzy neural networks are more effective because they allow to overcome the shortcomings of fuzzy logic and neural networks, and their successful use in prediction has been confirmed in scientific literature, and the prediction values given in the work also show that this method is an effective tool. The prediction results obtained on the basis of the recurrent neural network and the evolutionary calculation algorithm prove the accuracy of the prediction and confirm the necessity of using artificial intelligence tools in the adaptive management of the enterprise.

The main provisions of the dissertation work, the obtained results and proposals were reflected in the following published articles and theses of the author:

1. Wirtsch.-Ing. Robert Schmaus, Nazim Huseynov. Garadagh Cement ensures production uptime using online Condition Monitoring System (CMS). „ZKG INTERNATIONAL", ISSN 0949-0205, No. 5-2010, pp.14-16. Official Journal of: Federal German Association of the Lime Industry, Federal German Association of the Gypsum Industry, www.zkg-online.info

2. Huseynov Nazim Tofig oglu. Synergy of the University and Cement Industry Sectors in Application to Cement Market Price Innovative Forecasting in Azerbaijan. International Journal of Modern Engineering Research, IJMER, ISSN:2249-6645, October 2016, pp.79-86
3. Gardashova L. Huseynov N, Cement Industry Overview and Market Price Forecasting in Azerbaijan, 2016, Int.Journal of Engineering Research and Application, IJERA, ISSN: 2248-9622, Vol.6, Issue 10, (Part-1) October 2016, pp.32-38
4. Hüseynov Nazim Tofiq oğlu. "Qeyri-səlis mühitdə müəssisənin adaptiv idarəolunmasının təkmilləşdirilməsi". Xülasə. ADNSU-nin Konfrans materialları, Azərbaycan, Fevral 21, 2018. Məruzə.
5. Гусейнов Назим Тофиг оглу. Применение нейронной сети для принятия управленческих решений на производстве. ADPU. Doktorantların və gənc tədqiqatçıların XXII Respublika elmi konfransı. 2018-cı il Noyabrın 22-23. Məruzə, məqalə 3 səh.
6. Huseynov Nazim Tofiq oglu. Advanced technologies ensuring improvement of management in enterprises when uncertainty in the Industry 4.0. Azərbaycan Dövlət Neft və Sənaye Universitetinin 100 illik yubileyinə həsr edilmiş gənc tədqiqatçı və doktorantların onlayn Elmi Konfransı 2020-cı il May 7-8. Məruzə, məqalə 5 səh.
7. Huseynov Nazim Tofiq oglu. Application of modern technologies for plan-ning improvement and saving on costs in the enterprise of the industry 4.0. // "Advances in Intelligent Systems and Computing" Volume 1323; 11th World Conference "Intelligent System for Industrial Automation" (WCIS-2020)"; ISSN 2194-5357 ISSN 2194-5365 (electronic); ISBN 978-3-030-68003-9 ISBN 978-3-030-68004-6 (eBook); pp. 272–279, 2021; https://doi.org/10.1007/978-3-030-68004-6_35

Applicant's personal contribution to co-authored published works:
[1] – the results were certified by Holcim and Pruftechnik. It gives effective results in Group and the cement plant.

Effective results confirmed by theoretical and production-economic studies, application of software, experimental verification, practical application in the cement plant.

[3] – the theoretical and marketing research, analysis of results and research design in the article format.

The defense of the dissertation will take place on October 31, 2022 at 12:00 at a meeting of the Dissertation Council FD 2.22, operating at the Azerbaijan State University of Oil and Industry.

Address: AZ1010, Baku city, Azadlig avenue, 34, Azerbaijan State University of Oil and Industry.

Electronic versions of the dissertation and abstract are posted on the official website of the Azerbaijan State University of Oil and Industry.

The dissertation can be found in the library of the Azerbaijan State University of Oil and Industry.

And the second abstract was sent to the required addresses on September 30, 2022.

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