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INFORMATION SYSTEM FOR ASSESSING THE LEVEL OF HUMAN CAPITAL MANAGEMENT

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Abstract. *The article offers conceptual foundations for formalizing the process of assessing a level of human capital (HC) management at the enterprise using mathematical and computer modeling based on neural network technologies. The methodological approach for assessing the level of human capital management has been improved. This allows the use of neural network tools to identify accurately and reasonably the level of HC management with the help of self-learning multilayer perceptron. The weight coefficients of such a network were calculated. An appropriate artificial neural network – a multilayer perceptron – was built using the mathematical software MatLab and it was successfully diagnosed. The improved mathematical model for assessing the level of HC management at the enterprise makes it possible to display transparently a set of input parameters on a set of output solutions, to decompose such a process, and to simplify the procedure of its formalization. The designed neural network allows us to determine quickly and accurately the level of HC management at the enterprise. The conceptual approach proposed by the authors has several significant advantages over existing alternative methods: accuracy of assessment; taking into account a wide range of various evaluation parameters of impact; high speed of making decisions and self-learning ability. The proposed approach was successfully implemented to assess the level of HC management at 24 domestic enterprises. The information system "HC" developed by the authors allows to calculate the estimated parameters of the evaluation process; to determine the level of HC management based on the mathematical apparatus of the multilayer perceptron. Such estimates correlate with the estimates obtained by the experts of these enterprises which indicates the adequacy of the approach proposed by the authors. Therefore, the proposed information system for assessing the level of management of the HC allows accurate implementation of such a process with minimal time and money costs.*

Keywords: information system, multi-layer perceptron, human capital management, enterprise personnel

SYSTEM INFORMATYCZNY DO OCENY POZIOMU ZARZĄDZANIA KAPITAŁEM LUDZKIM

Streszczenie. *W artykule przedstawiono koncepcyjne podstawy sformalizowania procesu oceny poziomu zarządzania kapitałem ludzkim (HC) w przedsiębiorstwie z wykorzystaniem modelowania matematycznego i komputerowego opartego na technologiach sieci neuronowych. Udoskonalono podejście metodyczne do oceny poziomu zarządzania kapitałem ludzkim. Pozwala to na wykorzystanie narzędzi sieci neuronowych do dokładnej i rozsądnej identyfikacji poziomu zarządzania HC za pomocą samouczącego się perceptronu wielowarstwowego. Obliczono współczynniki wagowe takiej sieci. W programie matematycznym MatLab zbudowano odpowiednią sztuczną sieć neuronową – perceptron wielowarstwowy, która została pomyślnie zdiagnozowana. Udoskonalony model matematyczny oceny poziomu zarządzania HC w przedsiębiorstwie pozwala w przejrzysty sposób przedstawić zbiór parametrów wejściowych na zbiorze rozwiązań wyjściowych, rozłożyć taki proces i uprościć procedurę jego formalizacji. Zaprojektowana sieć neuronowa pozwala szybko i trafnie określić poziom zarządzania HC w przedsiębiorstwie. Podejście koncepcyjne zaproponowane przez autorów ma kilka istotnych zalet w porównaniu z istniejącymi metodami alternatywnymi: dokładność oceny; uwzględnienie szerokiego zakresu różnych parametrów oceny wpływu; duża szybkość podejmowania decyzji i umiejętność samokształcenia. Zaproponowane podejście zostało z sukcesem wdrożone do oceny poziomu zarządzania HC w 24 przedsiębiorstwach krajowych. Opracowany przez autorów system informatyczny „HC" pozwala na obliczenie szacunkowych parametrów procesu oceny; określenie poziomu zarządzania HC w oparciu o aparat matematyczny perceptronu wielowarstwowego. Szacunki te korelują z szacunkami uzyskanymi przez ekspertów tych przedsiębiorstw, co wskazuje na adekwatność podejścia zaproponowanego przez autorów. Dlatego też zaproponowany system informatyczny oceny poziomu zarządzania HC pozwala na dokładną realizację takiego procesu przy minimalnych kosztach czasowych i finansowych.*

Słowa kluczowe: system informatyczny, perceptron wielowarstwowy, zarządzanie kapitałem ludzkim, personel przedsiębiorstwa

Introduction and literature review

As a result of the evolution of organizational management processes human capital becomes the most important among all other types of enterprise resources.

Every sphere of human activity, especially the economy and entrepreneurship, requires competent management of human capital. The problem of management incompetence is inherent in the Ukrainian economy. This is due, in particular, to the fact that the economic process itself is future-oriented. The external environment in which economic organizations of various forms operate becomes qualitatively different: new factors of competition appear, and the degree of its variability increases. Scientifically based methods of assessing the effectiveness of human capital management, and their selection from existing alternatives are becoming increasingly important.

In recent years, various solutions have been developed for measuring human capital in the enterprise. However, they have not yet been widely used in the practice of enterprises which raises doubts about the accuracy of measurement, its reliability, and the possibility of using the results for management decisions. Insignificant use of modern automated personnel management evaluation systems causes significant problems in the management of the enterprise or organization in general and leads to significant losses because today «personnel decide everything».

Analysis of the state of the processes of assessing the level of HC management in Ukraine revealed some unresolved practical problems among which the main ones are: savings by employers on personnel resources; compensatory bureaucratic culture; incompetence and lack of discipline; wrong team; insufficient activity of governors; imperfection of the legislation.

Thus, the problem of assessing HC management is extremely relevant because it is a powerful resource and one of the main sources of profit growth. However, in most Ukrainian enterprises, the assessment of HC management is quite limited and subjective without taking into account all its characteristics and potential.

Considering the complexity of assessing the level of HC management, the need to limit the influence of subjective factors on this process, dependence on the external crisis environment, and a large number of various parameters affecting this process, it is necessary to develop mathematical methods and management models, modern tools, in particular, neural network technologies. Neural networks can solve a wide range of problems, one of the simplest and most common of which is the classification problem. Its essence consists of assigning a certain sample to one of the previously known classes.

It should be noted that the identification of the level of HC management at enterprise belongs to classification tasks, in addition, the availability of automated software tools such as MatLab significantly simplifies the process of modeling neural networks, which justifies the choice of this particular tool to solve the problem posed in the article.

At the present stage of economic development, the HC management in Ukraine despite some recovery in recent years, cannot be considered satisfactory. One of the causes of this phenomenon is the difficulty of its assessment. This leads to inaccuracies in management making decisions which in turn can not only deprive the enterprise of the expected profit but may

also cause significant material losses [1]. So, the problem of HC management is one of the most urgent today.

Matviychuk et al. [8, 10] propose an approach to building systems of fuzzy logic inference for assessing a certain resulting indicator using many influencing factors. Such systems can perform calculations with sufficiently high accuracy even in the absence of statistical material for their optimization based on expert decision-making rules and given parameters of membership functions. At the same time, they retain the possibility of improving the accuracy of modeling by adjusting to real data.

The question of the transformation of human capital reproduction was detailed considered in the work [12].

Considerable achievements in the development of the theory and practice of personnel management have been developed. In particular, in the papers [2, 5, 7, 13, 15] note that the best method of HC management is a questionnaire, which, according to the authors of the article, is not an ideal approach. It does not allow us to assess accurately the level of human capital management which is associated with the impossibility of getting rid of falsehood when the respondent fills out the questionnaire. In addition, assessing the level of HC management using the questionnaire method requires a considerable amount of time and resources. The result of the questionnaire is significantly influenced by the psychological factor: team members evaluate colleagues subjectively and under the conditions of fierce competition they can put each other the deliberately distorted assessments. During the questionnaire to avoid such risks, it's necessary to apply independent respondents (as far as possible).

In the papers [9, 11, 15] authors claim that the quality of working life, i.e. the working conditions of personnel, have the greatest impact on their motivation and the level of management, respectively. According to the authors of the article, the quality of working life occupies a prominent place in HC management, but it is not a key factor in this process. Consistency and understanding of the philosophy throughout the organization, competence, and discipline, and compliance with the corporate culture should be the main factors to be considered in the HC management process.

Abbas [1], and Greasley K. and Thomas P. suggest [4] evaluating the level of HC management by determining the correct behavior of employees. Evaluation by this method studies the employee's behavior according to various parameters which is convenient. However, this method also has many disadvantages, including a certain circumstance that leads to the impossibility of making a generalized conclusion, the need to classify the results of observation, many distracting factors, the risk of averaging, and the need for large resource costs.

In the investigations [6, 16] point out that the effectiveness of the organization's personnel primarily depends on its intensity and level of commitment. We can refuse this statement using the example of the outstanding Nucor Corporation (it is the largest steel producer in the United States) and their philosophy of management founded by CEO F. Kenneth Iverson (1965). His management philosophy has been used as a model for other companies around the world. Iverson vigorously advocated some lean management personnel, a decentralized decision-making structure, and an egalitarian work environment. At Nucor, he reduced the number of management levels to four – the janitor was promoted to four positions below the CEO. In addition, he located the company's headquarters far away from any production facilities and gave each plant a great latitude in making marketing and production decisions. Under his leadership, Nucor did away with executive perks such as reserved parking spaces and special health benefits and Iverson was known to personally answer his phone calls when he was at the corporate office where 22 employees were enough to manage the entire multibillion-dollar corporation. It can be concluded that the level of commitment, work intensity, and high comfort are far from key indicators of the company's personnel efficiency.

Therefore, existing HC management methods are imperfect, as they do not take into account the wide range of factors of such a process caused by the impact of both internal and external environments. This is due to their incompleteness, inaccuracy, lack of an automated approach to estimation in HC management, and inability to self-learn.

The presence of a large array of routine calculations of impact parameters and the need to take into account a large number of various evaluation parameters make it necessary to use an artificial intelligence tool for personnel management. Therefore, the authors of the article propose to assess the level of human resource management using an artificial neural network – a multi-layer perceptron. This evaluation method has several advantages over standard solutions. Training of an artificial neural network is carried out based on an error propagation algorithm which allows you to determine the level of HC management with minimal time and money costs and with high accuracy.

Thus, the article aims to assess the level of HC management (to further minimize it) by developing and applying an appropriate methodological approach based on neuro-network technologies.

1. Mathematical model for assessment of HC management

Formal problem statement. It is advisable to consider the making decision process for assessing the level of HC management as a system consisting of a certain set of standard subsystems and their elements (procedures, actions, operations) that interact with each other, the number and composition of which can change depending on the conditions of the external and internal environments of the business entity. The input element of the system is information about the problem area (initial information) and the output one is a set of output solutions.

Let's consider the problem of assessing the level of HC management at the enterprise as follows. The subject of the study is the personnel of the enterprise (organization), characterized by a set of input parameters X, $X = (x_i)$. The level of human capital management at the researched enterprise must be assigned to one of the classes from the set of possible initial solutions Y, $Y = (y_n)$, thereby solving the classification problem. To solve such a problem it is necessary to determine the optimal set of estimated parameters x_i, $i=\overline{1,n}$ this process, that one satisfies the conditions of completeness, efficiency, and minimality.

According to the completeness criterion, it is necessary to generate such a set of input parameters that would fully characterize the level of HC management at the enterprise (organization). Next, from the set of evaluation parameters formed according to the criterion of completeness, we will remove those from them that do not satisfy the second criterion – efficiency. Further, according to the minimality criterion, it is necessary to exclude the correlated, collinear ones among the set of parameters selected according to the previous two criteria.

Thus, to determine the level of HC management the authors of the article justified (according to the above three criteria) the need to determine the set $\boldsymbol{X}$, $\boldsymbol{X} = \{x_i\}$ of such input evaluation parameters x_i, $i=\overline{1,9}$.

Let's consider precisely the set $\boldsymbol{X} = \{x_1,\ldots,x_9\}$ of estimated input parameters for determining the level of HC management: x_1 – personnel turnover rate, x_2 – coefficient of effective use of working time, x_3 – coefficient of labor discipline, x_4 – personnel loyalty, x_5– labor activity, x_6 – profitability of human capital using, x_7 – efficiency of management, x_8 – share of management costs, x_9 – the ratio of the number of managerial employees to the average number of employees.

For assessment of the set $\boldsymbol{X}$ of input parameters, we have to use the set $\boldsymbol{X}^* = \left\{x_1^*,\ldots,x_{22}^*\right\}$ of appropriate initial input parameters.

Let's consider the process of the mapping $\boldsymbol{X}^* \rightarrow \boldsymbol{X}$.

The input parameter of HC management – x_1 – personnel turnover indicator – is defined as

$$x_1 = \frac{x_1^*}{x_2^*} \quad (1)$$

where x_1^* – is the number of employees dismissed at their will and due to violations of labor discipline, x_2^* – average number of employees.

$$x_2 = \frac{x_3^*}{x_4^*} \quad (2)$$

where x_3^* – is the worked time, x_4^* – maximum possible working time fund.

$$x_3 = \frac{x_5^* - x_8^*}{x_2^*} \quad (3)$$

where $x_5^* - x_8^*$ – total number of cases of violation of labor discipline: x_5^* – number of cases of delays; x_6^* – number of absentee sessions, x_7^* – the number of cases of appearance at work in a drunken state, x_8^* – the number of cases of untimely or incomplete performance of labor duties;

$$x_4 = \frac{x_{10}^* - x_{12}^*}{x_9^*} \quad (4)$$

where x_9^* – compliance with norms, rules, and traditions of the organization, x_{10}^* – trust, and respect for management, x_{11}^* – the absence of information leakage, x_{12}^* – participation in the public life of the organization;

$$x_5 = \frac{x_{14}^* - x_{16}^*}{x_{13}^*} \quad (5)$$

where x_{13}^* – initiative, x_{14}^* – dedication, x_{15}^* – conscientiousness, x_{16}^* – enthusiasm.

$$x_6 = \frac{x_{17}^*}{x_{18}^*} \quad (6)$$

where x_{17}^* – is the company's net profit, x_{18}^* – the average number of employees of the enterprise.

$$x_7 = \frac{x_{19}^*}{x_{20}^*} \quad (7)$$

where x_{19}^* – is sales revenue (excluding VAT), x_{20}^* – circulation costs.

$$x_8 = \frac{x_{21}^*}{x_{20}^*} \quad (8)$$

where x_{20}^* – the circulation costs, x_{21}^* – administrative expenses.

$$x_9 = \frac{x_{22}^*}{x_{18}^*} \quad (9)$$

where x_{18}^* – the average number of employees of the enterprise, x_{22}^* – number of management personnel.

Accuracy of the level of HC management's assessment determines the use of the following set **Y** of output parameters, $\mathbf{Y}=\{y_n\}$:

y_1 – high level of HC management;
y_2 – the average level of HC management;
y_3 – low level of HC management.

Finally, the mathematical model of the process of assessing the level of HC management can be represented in such a way

$$\mathbf{Y} = \mathrm{F}(\mathbf{X}),\ \mathbf{X}=\{x_i\},\ i=\overline{1,9},\ \mathbf{Y}=\{y_n\},\ n=\overline{1,3},\ \mathbf{X} = \mathrm{F}(\mathbf{X}^*)$$

$$\mathbf{X}^* = \left\{x_j^*\right\},\ j=\overline{1,22} \quad (10)$$

$$x_1 = f\left(x_1^*, x_2^*\right);\ x_2 = f\left(x_3^*, x_4^*\right);\ x_3 = f\left(x_2^*, x_5^*, \ldots x_8^*\right);\ x_4 = f\left(x_9^*, \ldots, x_{12}^*\right);$$

$$x_5 = f\left(x_{13}^*, \ldots, x_{16}^*\right);\ x_6 = f\left(x_{17}^*, x_{18}^*\right);\ x_7 = f\left(x_{19}^*, x_{20}^*\right);\ x_8 = f\left(x_{20}^*, x_{21}^*\right);$$

$$x_9 = f\left(x_{18}^*, x_{22}^*\right)$$

As noted above, to formalize the process (10) of mapping a set of initial input parameters to the set of output solutions, the authors of the article suggest using an artificial neural network. Its training is carried out using the method of error propagation.

2. Formalization of the process of output vector estimation

The work of a neural network consists finding of functional dependence

$$\mathbf{Y} = \mathrm{F}(\mathbf{X}) \quad (11)$$

where **X** – the input vector, $\mathbf{X} = \{x_i\},\ i=\overline{1,9}$, **Y** – the output vector $\mathbf{Y}=\{y_n\},\ n=\overline{1,3}$.

The error propagation algorithm is represented as shown in figure 1.

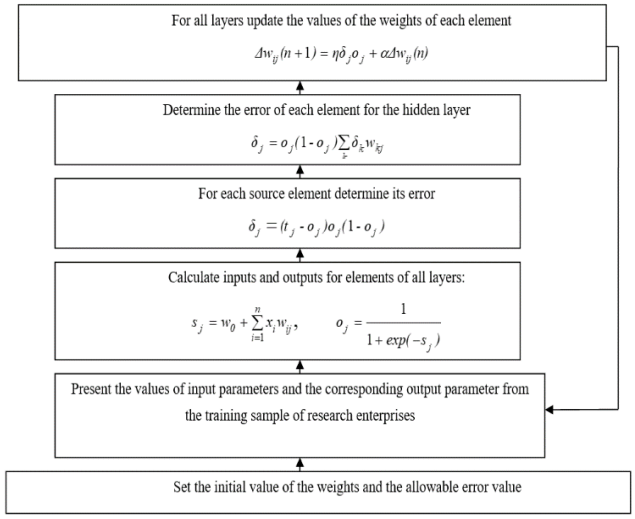

Fig. 1. The error reverse propagation algorithm multi-layer perceptron's learning

The considered algorithm is used to train a multilayer perceptron – a neural network of direct signal propagation (without feedback), in which the input signal is transformed into an output signal by sequentially passing through several layers.

In addition to the input and output, the multilayer perceptron has one or more intermediate layers which are called hidden. They perform the intermediate signal conversion in such a way that the output classifier neuron receives already linearly distributed sets to its inputs.

To determine the number of neurons in the hidden layers of a neural network it's necessary to use the following relation:

$$\frac{N}{10} - n - m \le L \le \frac{N}{2} - n - m \quad (12)$$

where n – number of input signals, m – number of output signals, N – the number of elements in the training sample.

Let's determine the required number of neurons in a neural network to assess the level of HC management at the enterprise.

To train the neural network we use a training sample compiled from the database of 24 enterprises, that is $N = 24$.

Since, $n = 9$, $m = 3$, then by relation (1) we determine:

$$\frac{24}{10} - 9 - 3 \le L \le \frac{24}{2} - 9 - 3 \quad (13)$$

As $L \le 4$, thus, the neural network for assessing the level of HC management contains four neurons in a hidden layer.

It is known that one hidden layer of neurons with a sigmoid activation function is sufficient to approximate any function with high accuracy. In addition, such a network can simultaneously approximate both the function itself and its derivative.

Let's consider the neural network for assessing the level of HC management at the enterprise which consists of three layers: input, hidden, and output and the number of neurons in the hidden layer is 4. The multilayer perceptron for estimation of the level of HC management in the information system is shown in figure 2.

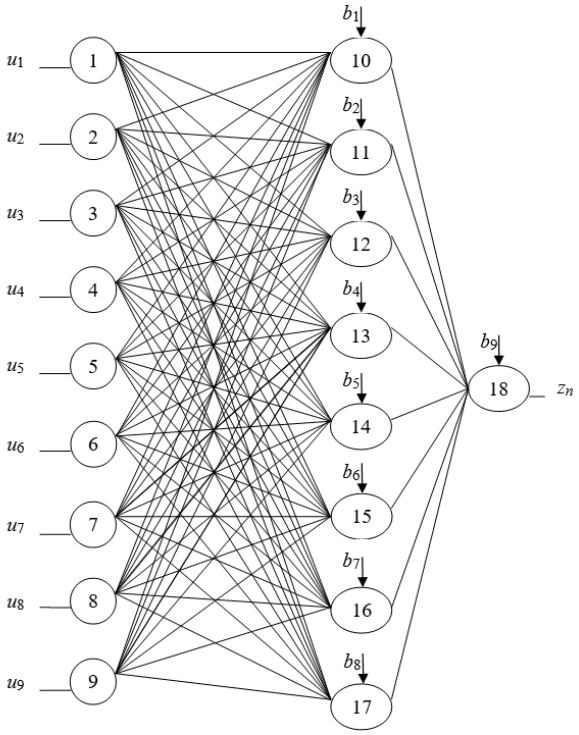

Fig. 2. Multilayer perceptron for assessing the level of HC management

To assess the level of HC management it is suggested to use the following method of encoding the variables of the neural network as a division of a separate interval into segments depending on the number of researched levels the length of which is proportional to the number of examples of each level of research in the training sample:

$$\Delta z_n = \frac{N_n}{P} \tag{14}$$

where Δz_n – length of the n-th segment, N_n – number of examples of the n-th class, P – total number of examples.

The numerical value of z_n for the n-th class will be the center of the segment Δz_n (see figure 3).

The training sample used for training a neural network for assessing the level of HC management contains data from 24 enterprises, i.e. N = 24: 5 of which have a high level of HC management (N_1 = 5), 7 – an average level (N_2 =7) and 12 of them are characterized by a low level of HC management (N_3 =12).

Then, using (3) we obtain the following values for the length of the segments:

$$\Delta z_1 = \frac{5}{24} = 0.2\ ;\ \Delta z_2 = \frac{7}{24} = 0.3\ ;\ \Delta z_3 = \frac{12}{24} = 0.5$$

We determine the numerical values of z_n corresponding to the centers of the segments Δz_n and obtain the following values of the initial parameters:

$$z_1 = \frac{0.2}{2} = 0.1\ \ z_2 = 0.2 + \frac{0.3}{2} = 0.35\ \ z_3 = 0.2 + 0.3 + \frac{0.5}{2} = 0.75$$

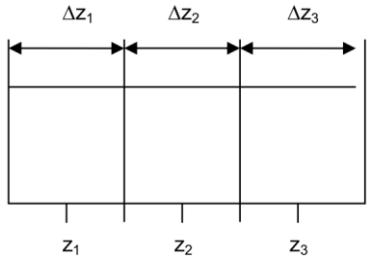

Fig. 3. Illustration of the method of encoding variables taking into account the number of examples of each level of research in the training sample

3. Experiment

Let's consider the operation of the information system formalized based on the approach described above in the example of a sample of 24 enterprises from various branches of business.

The values of estimated parameters xi for these enterprises were calculated using the proposed information system based on the input parameters x^*_j and their corresponding dependencies (1)–(9) (see table 1) for the 9 output layer u_j : (2.2428, 0.20647, 3.2976, 3.2641, 0.7628, 1.8265, -4.3193, -4.0444) and 9 values of b_j : (3.1833, -1.0321, 6.9265, 6.5313, -1.4661, 4.236, -1.0453, 2.875, -1.3526).

Diagnostics of the artificial neural network were carried out based on the data of the relevant experimental sample using the MatLab mathematical software package. Thus, its efficiency was confirmed.

Table 1. Values of estimated parameters

Enterprize	x_1	x_2	x_3	x_4	x_5	x_6	x_7	x_8	x_9
1	5.62	88.03	0.6	4.0	1.0	85.0	74.2	23.4	0.1
2	1.02	5.27	2.3	0.7	7.33	6.14	4.7	6.3	1.8
3	1.2	9.4	1.8	1.03	5.3	8.2	8.32	5.8	2.07
4	6.1	76.4	0.88	5.2	2.6	73.0	76.07	22.8	0.22
5	0.97	6.12	3.41	0.86	7.47	7.84	6.37	4.93	2.8
6	3.05	42.6	1.39	1.8	3.12	46.0	28.4	12.6	0.95
7	2.87	48.1	1.62	1.73	4.02	43.8	31.0	10.7	1.02
8	4.2	43.4	1.7	2.05	3.28	39.2	34.7	10.29	0.5
9	1.3	6.5	4.8	0.63	8.67	11.4	3.9	5.13	3.2
10	1.07	4.76	3.2	0.82	9.3	8.42	7.87	4.95	2.6
11	6.24	73.05	0.84	6.37	3.2	69.6	76.2	27.4	0.43
12	2.88	39.6	1.49	2.8	4.02	43.0	27.4	10.6	0.94
13	1.04	4.36	2.28	0.67	7.28	12.2	10.8	7.3	1.68
14	1.31	5.23	1.93	0.84	5.33	13.5	14.26	8.02	1.92
15	3.08	40.61	2.25	1.82	2.92	45.8	27.43	13.5	0.94
16	1.34	5.28	2.9	0.76	8.53	7.2	6.28	6.31	1.85
17	5.86	83.04	0.61	4.3	1.37	80.5	71.6	25.42	0.14
18	1.07	6.42	2.57	0.64	7.53	6.19	4.9	7.04	2.45
19	3.14	41.2	1.41	1.73	3.17	46.2	27.62	12.57	0.94
20	1.1	5.38	2.73	0.67	6.83	6.24	4.17	6.41	1.76
21	1.46	9.26	3.07	1.24	8.03	7.05	4.27	7.31	3.08
22	5.45	69.8	0.62	4.3	1.7	78.4	70.6	24.2	0.25
23	3.08	38.8	1.57	1.78	3.42	39.7	27.5	13.2	0.93
24	1.26	7.82	2.61	0.63	6.88	9.3	6.4	5.2	1.75

The authors of the article have developed the software tool "HC" which allows to:

- calculate estimated parameters to identify the HC management level;
- determine the level of HC management based on the mathematical apparatus of a multilayer perceptron.

The software for the realization of the "HC" information system consists of the following modules:

1) the input of initial parameters;
2) assessment of evaluating parameters and output parameters:
   - the parameters of assessing HC are being estimated;
   - based on the neural network the inputs and outputs of all elements are being identified;
3) making decisions about the level of the HC management.

The possible meanings of output parameters are: $z_1 = 0.1$; $z_2 = 0.35$; $z_3 = 0.75$.

So, the level of management is identified as:

- high level of HC management, if $z = z_1$;
- medium level of HC management, if $z = z_2$;
- low level of HC management, if $z = z_3$.
- obtaining a final decision about the level of the HC management.

As a software environment for the development of the "HC" information system for assessing the level of HC management was chosen Python 3.X. It is the interpreted high-level object-oriented programming language with strict dynamic typing.

Thus, using the information system "HC" proposed by the authors the level of HC management at 24 enterprises of various branches of economic activity was assessed. Thus, the levels of the HC management of enterprises No 1, 4, 11, 17, 22 are high. Enterprises No 6, 7, 8, 12, 15, 19, and 23 have the level of management which is defined as middle. The level of HC management of enterprises No 2, 3, 5, 9, 10, 13, 14, 16, 18, 20, 21, 24 is low. Such estimates correlate with the estimates obtained by the experts of these enterprises which indicates the adequacy of the approach proposed by the authors.

4. Conclusions

The main scientific result of the research is the development of conceptual foundations for formalizing the process of assessing the level of HC management using mathematical and computer modeling based on neural network technologies.

The weight coefficients of the artificial neural network – a multi-layer perceptron was calculated using the test sample data using the MatLab mathematical software package. Its diagnostics were performed and its functionality was confirmed.

The information system "HC" developed by the authors allows:

- to calculate the estimated parameters of the evaluation process;
- to determine the level of HC management based on the mathematical apparatus of the multilayer perceptron.

As the software environment for the development of this IS was chosen Python which is an interpreted high-level object-oriented programming language with strict dynamic typing.

The proposed IS "HC" was tested on the databases of the work of 24 domestic enterprises. The enterprises' No 1, 4, 11, 17, and 22 level of HC management is high. The level of HC management at the enterprises No 6, 7, 8, 12, 15, 19, 23 is defined as middle. Enterprises No 2, 3, 5, 9, 10, 13, 14, 16, 18, 20, 21, 24 have a low level of HC management. Such estimates correlate with the estimates obtained by the experts of these enterprises which indicates the adequacy of the approach proposed by the authors. It should be noted that obtaining such expert data is quite a time-consuming, expensive, and non-automated process. At the same time, the conceptual approach proposed by the authors has many significant advantages over existing alternative HC management methods:

1) evaluation accuracy;
2) decision-making based on a wide range of different evaluation parameters;
3) productivity;
4) self-learning ability.

Therefore, the proposed information system for assessing the level of management of the HC allows accurate implementation of such a process with minimal time and money costs.

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