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UKRAINE LABOUR POTENTIAL MODELLING BASED ON USING THE THEORY OF UNCLEAR LOGIC

Purpose. To develop an effective approach to assessing the labour potential of Ukraine.

Methodology. The research method is mathematical modelling based on the use of the "theory of fuzzy logic".

Findings. The factors influencing the labour potential of Ukraine are summarized and systematized, which are grouped into three groups: medical-demographic, socio-economic, and behavioural ones. The modelling algorithm is generalized and the linguistic variables that characterize the comprehensive assessment of the level of labour potential of Ukraine are proposed. A tree of logical conclusions of hierarchical relationships of factors with selected terms for evaluating the labour potential of Ukraine was built. Statistical data for Ukraine and 21 countries that are part of the EU is summarized, that made it possible to estimate the level of labour potential (R) for strategic partner countries – Poland and Ukraine, which are 6.4 and 5.95, respectively. Recommendations are offered as for the development of the labour potential of Ukraine.

Originality. The scientific novelty of the study is the development of a theoretical-methodological approach to the assessment of the labour potential of Ukraine, which allows comprehensively taking into account the system of fuzzy terms, to evaluate the medical-demographic, socio-economic and behavioural factors of influence on the labour potential of Ukraine based on the use of the theory of fuzzy logic. That, in turn, will allow increasing the effectiveness of the management decision-making system in the direction of improving all components that form the labour potential.

Practical value. The importance of assessing labour potential for Ukraine lies in many aspects, the main ones are the following: increasing the efficiency of state administration in the field of labour potential formation; timely identification of problems, determination of the state and formation of strategic prospects for its development, which will allow accelerating the process of Ukraine's transition from a candidate for EU membership to an EU member and revive the economy, that is currently based on the military rails.

Keywords: *model, labour potential, assessment, theory of fuzzy logic*

Introduction. Ukraine is gradually losing ground of training a competitive workforce. The main reasons are negative demographic trends, which are becoming worse in war conditions (increased mortality, especially among men of younger age groups, declining birth rates, reduced life expectancy, increasing levels of population aging and forced emigration, etc.). These and other social and economic problems (imbalance on the labour market, low labour productivity, low cost of labour, high level of unemployment, precarization in the labour market, low level of social protection, disregard of the population for the principles of a healthy lifestyle, etc.) hinder the development of labour potential. Thus, the importance of the problem of assessing the labour potential of Ukraine relates to the need to determine the potential capabilities of the workforce for further labour activity; problematic factors affecting the workforce; an effective approach to assessing labour potential, which would include quantitative and qualitative indicators; further prospects for the development of labour potential at the country level.

The work proposes to solve the following tasks: to justify the importance of applying the "fuzzy logic theory" in assessing the labour potential; to justify the composition of factors that are included in the mathematical model of labour potential assessment based on the use of the theory of fuzzy logic; to give a generalized algorithm for modelling labour potential; to describe the theoretical and methodological foundations of the labour potential modelling process at the macro level; to make a calculation based on the modelling of the labour potential, using the example of Poland and Ukraine as countries that have much in common, in particular: a border, a commonality in historical, geopolitical, economic and cultural processes; to propose recommendations for the development of the labour potential of Ukraine, depending on the reserves of growth based on the considered medical-demographic, socio-economic and behavioural factors, in particular, based on the statistical data of 21 countries that are part of the EU, some of them are Austria, Belgium, the Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Luxembourg, the Netherlands, Poland, Portugal, Slovakia, Slovenia, Spain, Sweden.

Today, there is no clear methodological approach that would make it possible to assess the level of labour potential at the state level. Currently, there are approaches that allow you to assess the state of the labour potential at the level of the region (territorial community), or at the level of the enterprise (institution, organization), but they are also debatable, mainly it concerns the definition of assessment criteria, factors, cost characteristics of the workforce, etc.

As a result of the conducted research, the main conclusion can be the following – a theoretical-methodological approach to the assessment of labour potential at the state level was proposed. It makes it possible to, considering systems of vague terms, carry out an assessment of medical-demographic, socio-economic and behavioural factors influencing labour potential at the country level based on the application of mathematical modelling – the "theory of fuzzy logic". It will allow one to change the approach in the state management system in the direction of identifying problems and finding rational solutions for its development qualitatively.

Literature review. In the modern military conditions of the development of the economy of Ukraine, an important task is to ensure the national viability of the country, which requires, in particular, the preservation of the labour potential of the nation [1], which is influenced by demographic factors (fertility rate, the number of the working-age population, sex-age structure of the population, mortality rate, etc.) , social factors (provision of the population: housing, educational institu-

tions, cultural objects, medical institutions, objects of household services and catering, etc.), economic factors (level of wages, level of unemployment and employment, the number of working hours, level of productivity labour, etc.) and other factors.

The theoretical-methodological, scientific-methodical foundations of the formation of the strategy for the development and preservation of the labour potential of Ukraine and the factors affecting the labour potential, in particular the study on the problem of social security in the labour market and the strategic priorities of its provision in the modern conditions of the transformation of the main threats, are considered in scientific work [2]. Social support of unemployed able-bodied citizens as a factor in the development of labour potential [3] is now extremely important, because of military conditions and a high level of labour migration [4] there is a need to provide the economy with labour and create prerequisites for the economic development of Ukraine. The impact of social security and employment policy on the correlation between migration and unemployment is discussed in detail in the work [5], particularly the importance of the implementation of effective social programs by the state aimed at overcoming unemployment and creating prerequisites for the use of labour within the country is emphasized. At the same time, the issue of increasing the intellectual and innovative potential of citizens remains relevant, which requires the organization of a system of professional development, in particular, the adoption of modern experience, in particular by students abroad and its application at domestic enterprises (institutions, organizations) [6]. The problems of innovative employment and the prospects for its implementation in the modern labour market are also an important factor in the development of Ukraine's labour potential [7]. The mechanism of motivation of labour potential is considered quite thoroughly in the work [8].

The components that form the structure of the labour potential of the enterprise and the theoretical and methodological foundations for determining the influence of factors on it are reflected in the work [9]. The development of labour potential is influenced by such factors as: professional development, level of responsibility of employees, length of service, efficiency, quality of work, labour intensity, and motivation of the workforce [10]. The structure of the labour potential of the enterprise consists of internal components (educational and qualification level of employees, state of health, professionalism, morality, remuneration system, motivation, etc. [11]) and external components (demand and supply on the labour market, political and economic state of the state, demand for specific specialties, global migration processes, salary level, etc.) [12]. For the development of the labour potential of the enterprise, the educational factor that determines the development of innovative activity is important [13].

While assessing the labour potential at the regional level, in the work [14] the index method is proposed to use, where the labour potential index is calculated, that is characterized by the following quantitative and qualitative factors, in particular: the specific weight of the population of productive age; specific weight of the population that has a certain level of education; volumes of applied, fundamental research works; migration processes; gross regional product; incomes of the population; productivity.

Despite numerous scientific studies by foreign and domestic scientists, as evidenced by the results of many scientific works, there is no single approach to assessing the level of labour potential at the macro level. It prompts the search of an optimal approach to the modelling of labour potential, which will make it possible to evaluate its value in terms of dynamics. Estimating the labour potential at the regional level using the theory of fuzzy logic is proposed in the work [15]. Many scientists used the theory of fuzzy logic in their research, when modelling economic processes and phenomena.

The main feature of choosing the method – "fuzzy logic theory" in this work for modelling labour potential at the state level is the complex combination of qualitative and quantitative factors based on the use of non-standard terms for its assessment.

Unsolved aspects of the problem. The detailed analysis of the scientific literature on the assessment of labour potential showed that there are currently many theoretical and methodological bases for its assessment at the level of regions, at the level of branches, at the level of the enterprise. At the same time, the currently unsolved problem is the evaluation of the labour potential at the macro level – at the state level, which prevents the implementation of effective state decisions in the direction of ensuring its development.

The purpose of the article. The purpose of the work is to develop an effective approach of assessing the labour potential of Ukraine.

Methods. The methodology of applying the theory of fuzzy logic is thoroughly described in some scientific works [16] and in many other scientific works. When modelling the labour potential (LP) of Ukraine (at the macro level), a certain number of parameters are unavailable for accurate quantitative measurement. For this purpose, it is possible to introduce subjective components when modelling LP, which is expressed by linguistic evaluation terms, for example, "high", "medium", "low" considering the functions of belonging to the factors of the "fuzzy set". Using a mathematical apparatus based on the "theory of fuzzy logic" [17], it is possible to build a modelling system for multifactorial analysis of LP modelling at the macro level (R).

Whereas the specific values of any indicator, as a rule, are not evaluated in comparison with benchmarks or standards, such evaluation is determined not by a specific state, but by its differentiation between, for example, countries. When modelling LP, it is necessary to provide the solution of several theoretical and methodological issues:

- analysis of the main medico-demographic, socio-economic and behavioural factors that affect LP;
- search for actual values of medico-demographic, socio-economic and behavioural factors in statistical databases;
- comparison of the obtained values of medico-demographic, socio-economic and behavioural factors with standards based on research by specialists of such international organizations, in particular the Organization for Economic Cooperation and Development, the World Health Organization, the International Labour Organization, and United Nations Projects etc. and are used in the developed countries;
- construction of a tree of logical conclusion, where single circles indicate the factors affecting the level of LP and determine the algorithm of further actions;
- fuzzification of the input variables is carried out at the next stage, where the term set for evaluating each variable is specified;
- construction of the membership function of each defined term on a discrete universal set. Based on the formation of the appropriate knowledge base and using the membership functions of each term, we obtain analytical models of the membership functions of the terms and determine the values of all input variables;
- calculation of the values of the membership functions of the terms, according to the constructed logic equations and the values of the membership functions for all non-terminal vertices.

Therefore, an innovative approach is proposed, which can initiate further research on modelling LP at the macro level. The peculiarity of the expressions that form the basis of modelling of the type "IF – THEN, OTHERWISE" [18] is that, unlike quantitative models, their adequacy remains stable with certain minor deviations of input estimates in one direction or another. The set of such expressions is a set of points in space, which can be represented as "separate criteria – integral criterion" [19].

The integral criterion of LP (denoted by the English letter *D* or *R*) is proposed to be divided into intervals from 1 to 10, in particular: d_1 (the value falls into the interval [1–4]) – LP at the macro level is at a low level; d_2 (interval value [4–7]) – LP at the macro level can be estimated as average; d3 (the value lies in the interval [7–10]) – LP at the macro level is at a high level.

It is worth noting that in the case when the maximum membership functions are the same for two neighbouring terms, then in this case the interval of changes of the input parameter – *R* – should be considered as continuous and it is suggested to rank it according to a given scale, for example, $[D^1 : D_2]$. To obtain a specific value of *R* (at a given point in the factor space), i. e., that evaluates the LP, it is proposed to use the defuzzification operation. At the heart of *defuzzification* is the operation of transforming the received fuzzy information into clear, that is, into quantitative information. In works [16, 17], the definition of the fuzzy logical set *D** is given, which is based on the application of the "centre of gravity" principle, which is based on the quantitative evaluation of the complex indicator *R* at given input factors

$$D^* = (R^*) = \frac{\sum\left[D_2 + (i-1)\frac{D^1 - D_2}{m-1}\right]\mu^{ui}(D)}{\sum_{i=1}^{m}\mu^{ui}(D)}, \quad (1)$$

where *m* stands for the number of terms of variable *D*; D^1, D_2 stand for lower and upper limits of the range of variable *D*; $\mu^{ui}(D)$ stands for the function of the variable *D* belonging to the fuzzy term U_i.

$$R = f_r(X, Y, Z), \quad (2)$$

where *R* stands for a linguistic variable that characterizes the complex assessment of the state of LP at the macro level; *X* stands for a linguistic variable that characterizes medico-demographic factors; *Y* stands for a linguistic variable that characterizes socio-economic factors; *Z* stands for a linguistic variable that characterizes behavioural factors.

Medico-demographic influencing factors can be presented as follows

$$X = f_x(x_1, x_2, x_3, x_4), \quad (3)$$

where x_1 stands for the ratio of population emigration coverage by immigration; x_2 stands for share of persons of working age from 15 to 64 years old, %; x_3 stands for average life expectancy, years; x_4 stands for the level of self-assessment of health by the population as "good" and "very good", %.

Socio-economic influencing factors can be written as

$$Y = f_y(y_1, y_2, y_3, y_4, y_5, y_6), \quad (4)$$

where y_1 stands for unemployment rate, %; y_2 stands for labour productivity (GDP per hour worked), USD the United States for the PPP; y_3 stands for minimum wage, euros; y_4 stands for specific weight of research works in GDP, %; y_5 stands for specific weight of public spending on health care in GDP,%; y_6 stands for the level of coverage by private health insurance of the population, %.

Behavioural influencing factors are recorded in the following form

$$Z = f_z(z_1, z_2, z_3), \quad (5)$$

where z_1 stands for alcohol consumption per capita (aged 15+), litters; z_2 stands for specific weight of the population that has obesity, %; z_3 stands for specific weight of the population that consumes cigarettes daily (aged 15+), years.

The evaluation of the values of the linguistic variables given in the relations (2–5) is performed based on the application of the corresponding terms. The number of terms in LP modelling can be different for the proposed variables (factors). Thus, the terms for evaluating such a variable as – "coefficient of coverage of emigration" by immigration are defined as follows: "Low" (L); "Average" (A); "High" (H), with a universal set in the interval [1–5]. The tree of logical conclusion of hierarchical relationships of factors that allow one to assess the state of LP of Ukraine is shown in graph 2, where the root of the tree is the level of LP, and the leaves, respectively, medico-demographic, socio-economic, behavioural factors that have an impact on this level.

Results. The justification of the limits based on a universal set of factors (3–5) was carried out based on statistical material for 21 countries that are part of the EU and Ukraine (Table 1).

The limits of the universal set of factors are shown in Table 2. For the example of the factor – x_1, the minimum value is 1, and the maximum value is 5 ($U(x_1) = 1–5$). The characteristics of factors (universal set and terms for assessment) as linguistic variables are presented in Table 2.

For example, the membership function for the factor – x_1 is constructed. To linguistically evaluate this factor, a set of

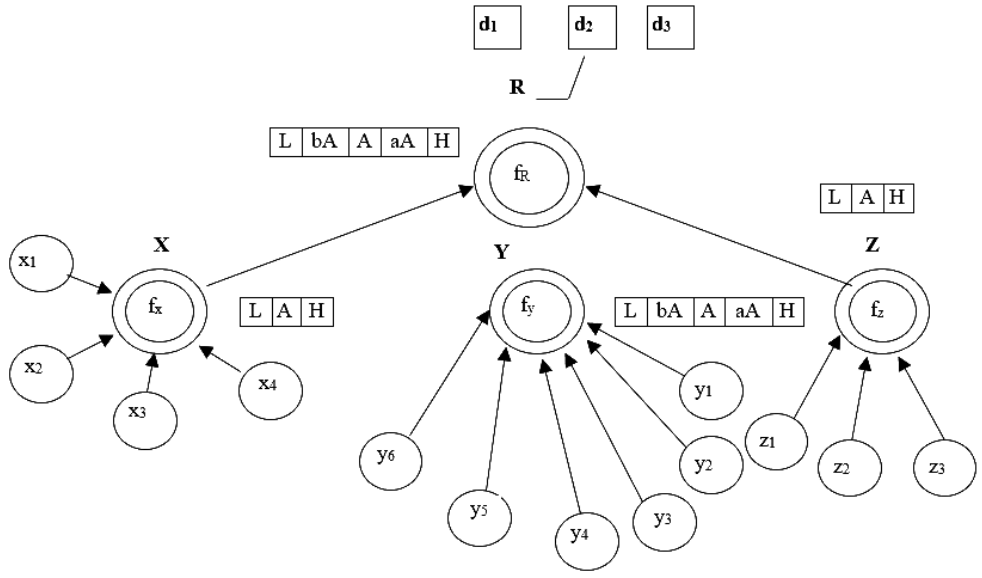

Fig. 1. Tree of logical conclusion of hierarchical relationships of factors:

L, bA, A, aA, H stand for terms for evaluation (*respectively*: *L* – "*low level*"; *bA* – "*below average level*"; *A* – "*average level*"; *aA* – "*above average level*"; *H* – "*high level*")

Table 1

Statistical data of individual EU member states and Ukraine for substantiating the limits on the universal set of factors *X, Y, Z* [20]

Country	Factors of influence												
	Medico-demographic				Socio-economic						Behavioural		
	x_1^2	x_2^1	x_3^1	x_4^2	y_1^1	y_2^1	y_3^1	y_4^2	y_5^1	y_6^3	z_1^2	z_2^3	z_3^2
Austria	1.53	66.30	81.30	74.00	6.20	69.60	–	3.22	12.20	37.80	11.30	27.80	–
Belgium	1.95	63.90	81.90	75.40	7.80	73.60	20,600.0	3.38	–	98.00	–	19.90	–
Czech Republic	2.01	63.40	77.40	63.40	2.80	43.50	7462.4	1.99	–	–	11.60	18.50	16.60
Denmark	0.91	63.50	81.40	71.20	5.00	75.80	–	2.97	10.80	33.40	9.70	–	–
Estonia	1.87	63.20	76.90	58.40	6.20	42.90	7351.2	1.75	7.50	–	10.50	18.00	17.90
Finland	3.55	61.70	82.00	69.80	7.60	61.90	–	2.91	–	22.40	8.20	23.90	12.00
France	9.23	61.60	82.50	68.50	7.90	66.70	19568.8	2.35	12.40	–	10.40	17.00	25.50
Germany	1.33	64.10	80.90	63.80	–	68.30	20,076.3	3.13	12.80	35.40	–	23.60	–
Greece	1.43	63.20	80.30	78.40	14.80	33.20	9545.6	1.51	–	15.30	–	–	–
Hungary	0.91	65.00	74.50	62.00	4.30	39.90	5839.7	1.60	–	–	10.40	33.20	–
Ireland	2.00	65.30	–	83.70	6.20	66.00	22,254.9	1.08	6.70	46.30	10.10	23.00	–
Italy	4.93	63.50	82.90	72.80	9.50	54.60	–	1.51	9.50	–	–	–	18.80
Latvia	1.21	63.20	73.40	49.70	7.50	41.40	6293.8	0.71	–	18.90	12.10	–	–
Luxembourg	1.74	69.40	82.80	73.50	5.20	99.00	2789.01	1.07	–	–	–	–	16.90
Netherlands	1.51	64.60	81.50	78.00	4.20	67.70	23,014.4	2.32	11.20	83.70	7.20	–	14.40
Poland	2.85	65.90	75.60	61.60	3.40	41.50	77,162.9	1.39	6.60	47.00	–	23.10	–
Portugal	–	64.10	81.20	51.20	6.60	40.50	9765.9	1.62	11.20	28.10	–	28.70	–
Slovak Republic	–	66.80	74.80	65.10	6.80	48.10	7842.2	0.91	–	–	9.90	17.00	–
Slovenia	2.07	64.00	80.90	67.10	4.80	47.10	12,892.8	2.14	9.20	88.00	9.80	–	–
Spain	2.27	66.00	83.30	73.00	14.80	51.80	13,951.4	1.41	–	–	7.80	–	19.80
Sweden	2.46	62.20	83.20	76.50	8.70	43.70	–	3.49	11.40	–	7.50	–	9.50
Ukraine	1.04	67.40	69.77	50.20	10.30	–	2535.7	–	3.90	4.70	8.60	18.50	–

Notes: 1 – data of 2021; 2 – data of 2020; 3 – data of 2019

Table 2

Characteristics of factors as linguistic variables

Variable designation and name	Universal set	Terms for assessment
x_1	1–5	Low (L), average (A), high (H)
x_2	17–75	Low (L), average (A), high (H)
x_3	0–100	Low (L), average (A), high (H)
x_4	0–60	Low (L), average (A), high (H)
y_1	0–12	Low (L), below average (bA), above average (aA), high (H)
y_2	20–100	Low (L), below average (bA), average (A), above average (aA), high (H)
y_3	1400–15400	Low (L), below average (bA), average (A), high (H)
y_4	0–4	Low (L), below average (bA), above average (aA), high (H)
y_5	0–12	Low (L), average (A), high (H)
y_6	4–84	Low (L), below average (bA), above average (aA), high (H)
z_1	0–16	Low (L), average (A), high (H)
z_2	0–40	Low (L), average (A), high (H)
z_3	0–28	Low (L), average (A), high (H)

vague terms “high”, “medium”, “low” are used. The factor (x_1) is given on the universal set $U(x_1) = (1–5)$. The matrix showing pairwise comparisons of different values of the factor (x_1) to the term “low” is given below [16, 17]

$$A^H(x_1) = \begin{array}{c|ccccc} & U_1 & U_2 & U_3 & U_4 & U_5 \\ U_1 & 1 & 7/9 & 5/9 & 3/9 & 1/9 \\ U_2 & 9/7 & 1 & 5/7 & 3/7 & 1/7 \\ U_3 & 9/5 & 7/5 & 1 & 3/5 & 1/5 \\ U_4 & 9/3 & 7/3 & 5/3 & 1 & 1/3 \\ U_5 & 9 & 7 & 5 & 3 & 1 \end{array}$$

In the above matrix, based on [16, 17], the elements of the last row are determined, and the rest of the following elements $U_1–U_5$ are calculated accordingly, and the results are shown in Table 3. The matrices of pairwise comparisons for other terms are calculated in the same way.

The obtained results, as shown in Table 3, of membership functions are normalized by dividing by the largest degree of membership. As a result, the x_1 factor is presented in the form of various fuzzy sets, and an example of its calculation for the term “low” is as follows

$$\left(\frac{1}{1};\frac{0.78}{2};\frac{0.56}{3};\frac{0.33}{4};\frac{0.11}{5}\right).$$

An example of membership functions for parameter x_1 is shown in Fig 2.

Table 3

Degrees of belonging of elements to terms [16, 17]

Degrees of belonging of elements to terms	Elements				
(factor x_1)	u_1	u_2	u_3	u_4	u_5
$\mu_L(u_i)$	0.36	0.28	0.20	0.12	0.04
$\mu_A(u_i)$	0.152	0.212	0.273	0.212	0.152
$\mu_H(u_i)$	0.04	0.12	0.20	0.28	0.36

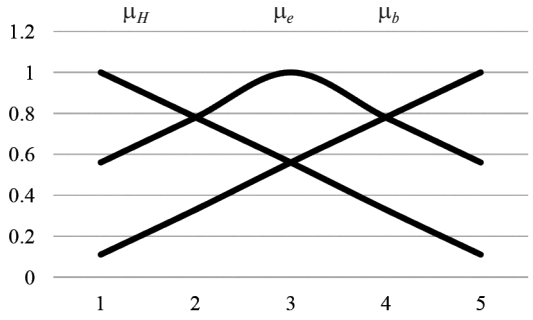

Fig 2. The membership functions of the parameter x_1 – "Coefficient of coverage of emigration by immigration"

The next step of modelling is the construction of fuzzy logic equations. These equations connect the membership functions of different levels, considering the input and output variables, which are reflected in the constructed logical conclusion tree (graph 2). To compile fuzzy logical equations, knowledge bases are set in the form of expert statements "IF" – "THEN" about the relations of fuzzy terms of input and output linguistic variables, considering the constructed ratios – (2–5). Knowledge bases and systems of fuzzy logic equations for dependence 2 are given in Table 4.

We present a system of fuzzy logic equations for $\mu d_1 - \mu d_3$, which are based on the knowledge base (Table 4).

$$\mu(d_1) = \mu Lx \wedge \mu Ly \wedge \mu Hz \vee \mu Lx \wedge \mu Ly \wedge \mu Hz \vee \vee \mu Lx \wedge \mu Ly \wedge \mu Az; \quad (6)$$

$$\mu(d_2) = \mu Lx \wedge \mu Ly \wedge \mu Az \vee \mu Lx \wedge \mu Ay \wedge \mu Az \vee \vee \mu Ax \wedge \mu Ay \wedge \mu Az; \quad (7)$$

Table 4

Knowledge bases and systems of fuzzy logic equations for dependence (2)

IF			THEN
Medico-demographic factors of influence (X)	Socio-economic influencing factors (Y)	Behavioural influencing factors (Z)	Labour potential of the country (R)
Low (L)	Low (L)	High (H)	d_1 – the level of the country's labour potential is low
Low (L)	Low (L)	High (H)	
Low (L)	Low (L)	Average (A)	
Low (L)	Low (L)	Average (A)	d_2 – the level of the country's labour potential is average
Low (L)	Average (A)	Average (A)	
Average (A)	Average (A)	Average (A)	
Average (A)	Average (A)	Average (A)	d_3 – the level of the country's labour potential is high
Average (A)	High (H)	Low (L)	
High (H)	High (H)	Low (L)	

$$\mu(d_3) = \mu Ax \wedge \mu Ay \wedge \mu Az \vee \mu Ax \wedge \mu Hy \wedge \mu Lz \vee \vee \mu Hx \wedge \mu Hy \wedge \mu Lz. \quad (8)$$

Linguistic statements (6–8) correspond to the received fuzzy logical equations at the corresponding hierarchical level: system (R), medical and demographic influencing factors (X), economic factors (Y), behavioural factors (Z). Factors *X, Y, Z* associate membership functions according to input and output variables, based on the use of "min" and "max" operations in their construction. That is, the logical operations "AND" ($\wedge$) and "OR" ($\vee$), as can be seen from the given systems of fuzzy logical equations, involve the replacement of the operations "max" and "min" over the membership functions [16, 17]

$$\mu(a) \wedge \mu(b) = \min [\mu(a), \mu(b)];$$

$$\mu(a) \vee \mu(b) = \max[\mu(a), \mu(b)].$$

The above algorithm is based on the hypothesis of identifying a linguistic term by the maximum of the membership function (MF). In addition, it generalizes the hypothesis to the entire knowledge matrix. Applying membership functions (MF) and calculating according to the appropriate formulas, analytical models of the MF estimates of the input variables for all used terms were determined. According to the constructed MF of each term on the discrete universal set, using logical equations (2–5) of the MF values for all non-thermal vertices, the MF value of term-estimates for all variables and the MF value for all non-thermal vertices were obtained.

In accordance with the constructed MF values of each term on the discrete universal set, logical equations (2–5) are used to determine the MF values of the terms-estimates for all variables and the MF values for all non-terminal vertices. We will arrange the complex indicator R on a scale from 1 to 10. After that, we will divide the indicated interval into three intervals, we can obtain intervals, that is, the corresponding three decisions regarding the assessment of the level of LP (d_1, d_2, d_3). Approbation of the proposed model (R) was carried out based on statistical data of 2019, because all statistical data in the OECD and the State Statistics Service of Ukraine for all factors *X, Y, Z* in 2020–2021 are not enough. This is due to the spread of the COVID-19 pandemic, Russia's war against Ukraine, and the worsening of social and economic crises in the world. The initial data for determining R on the example of Poland and Ukraine are given in Table 5.

Applying defuzzification (1) and the initial data shown in Table 5, we obtain a quantitative assessment of the complex indicator R, using the example of Poland and Ukraine with the given input factors

$$D^*_{Poland} = \frac{0.227 \cdot 1 + 0.454 \cdot 5.5 + 0.454 \cdot 10}{0.227 + 0.454 + 0.454} = 6.40;$$

$$D^*_{Ukraine} = \frac{0.271 \cdot 1 + 0.371 \cdot 5.5 + 0.371 \cdot 10}{0.271 + 0.371 + 0.371} = 5.95.$$

Thus, because of the application of defuzzification, a quantitative assessment of the value of the labour potential level was obtained, using the examples of Poland and Ukraine. Therefore, as on January 1, 2020, the level of the labour potential of Poland is 6.40, which falls into the interval [4–7] – "average". As for Ukraine, the corresponding value is 5.95, which also belongs to a similar interval, but the value for Ukraine is lower, for example, in comparison with Poland by 7.03 %. The obtained value makes it possible at the level of the governments of these countries to make strategic decisions on increasing the level of labour potential and to get as close as possible to the values of the most developed countries in the world, in particular the EU.

Conclusion. In the theoretical part of the work, the problem of assessing the labour potential is substantiated, where attention is particularly focused on the fact that currently there is no single clear mechanism for assessing the state of the labour po-

Table 5

Initial data for evaluating the country's LP (on the example of Poland and Ukraine) [20] (data of 2019)

Variable designation and name	Country	
	Poland	Ukraine
X stands for *Medico-demographic influencing factors:* x_1 stands for the ratio of population emigration coverage by immigration	3.72	1.04
x_2 stands for share of persons of working age from 15 to 64 years old, %	66.90	67.40
x_3 stands for average life expectancy, years	78.00	72.01
x_4 stands for the level of self-assessment of health by the population as "good" and "very good", %	59.80	50.40
Y stands for *Socio-economic influencing factors:* y_1 stands for unemployment rate, %	3.30	8.20
y_2 stands for labour productivity (GDP per hour worked), USD the United States for the PPP	44.50	42.49
y_3 stands for minimum wage, euros	6480	1416
y_4 stands for specific weight of research works in GDP, %	1.32	0.43
y_5 stands for specific weight of public spending on health care in GDP,%	6.50	3.20
y_6 stands for the level of coverage by private health insurance of the population, %	47.00	4.70
Z stands for *Behavioural influencing factors:* z_1 stands for alcohol consumption per capita (aged 15+), litres	11.00	8.90
z_2 stands for specific weight of the population that has obesity, %	23.10	18.50
z_3 stands for specific weight of the population that consumes cigarettes daily (aged 15+), years	17.10	24.20

tential at the state level. The opinions of foreign and domestic scientists were analysed regarding what factors the development of labour potential depends on. On this basis, the work systematized such main factors influencing the labour potential at the state level as: demographic, medical, economic, social and behavioural ones, which, accordingly, made it possible to group them as follows: medical and demographic ones (emigration coverage ratio of population emigration; share of persons of working age from 15 to 64 years; average life expectancy; self-assessment of health); socio-economic ones (unemployment rate, labour productivity, minimum wage, share of scientific and research work in the country's GDP, share of public health care expenditures in the country's GDP; level of private health insurance coverage of the population); behavioural ones (alcohol consumption per capita, proportion of the population with obesity, proportion of the population aged 15 and over who consume cigarettes daily). The given groups and factors are not final and may be adjusted, supplemented, or replaced. At the same time, in particular, the advantage of this systematization of factors is that they are reflected in the official statistics of EU countries and Ukraine, which greatly simplifies the process of modelling labour potential at the state level.

In the theoretical and methodological part of the work, the main aspects of the application of the theory of fuzzy logic as an important scientific approach to modelling labour potential are given, and attention is focused on solving several theoretical and methodological issues of the use of the theory of fuzzy logic, which today is sufficiently thoroughly described in foreign and domestic literature. In addition, the work summarizes the modelling algorithm based on the application of fuzzy logic theory and offers linguistic variables that characterize the comprehensive assessment of the country's labour potential level, in particular: medical-demographic, socio-economic and behavioural ones. Based on this, a tree of logical conclusions of hierarchical relationships of factors with selected terms for evaluation was built, that determines the logic of modelling.

In the practical side of the work, statistical data was collected of 21 countries which are part of the EU and Ukraine for modelling the labour potential, in particular among such EU countries as: Austria, Belgium, the Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Luxembourg, the Netherlands, Poland, Portugal, Slovakia, Slovenia, Spain, Sweden and Ukraine, that got membership before joining the EU in 2022. The analysis of statistical data for the given countries made it possible to determine the limits on the universal set of groups of factors *X, Y, Z* proposed in the work and to propose terms for evaluating the relevant factors. In the calculations of labour potential modelling, two countries were chosen – Poland and Ukraine, which have much in common in terms of geographical, socio-economic, political, and other parameters. Applying the theory of fuzzy logic, modelling of labour potential was carried out, which made it possible to determine its level, that, for example, was ($R = 6.4$) for Poland and ($R = 5.95$) for Ukraine. This is the basis for making decisions by the governments of these countries in the direction of the development of labour potential.

Thus, modelling the labour potential at the state level and assessing its significance is extremely important for any country in the world, in particular the countries that are part of the EU and Ukraine, which has officially got EU membership. As on January 1, 2020, Ukraine has a 7.03 % lower LP level compared to, for example, Poland, and even more compared to other EU countries. Therefore, in order for Ukraine to join the EU more quickly, in particular, in our opinion, it is necessary to improve every factor that is included in the following groups: "medical-demographic", "social-economic" and "behavioural" ones. Therefore, it is now necessary to strategically solve such problems as: reducing the mortality rate of the population, in particular economically active citizens; increase in average life expectancy; encouraging the population to a healthy lifestyle; reducing the level of industrial and domestic injuries, in particular injuries and deaths from political (military) conflicts; raising the educational level of the population; motivation of the population to participate in continuous education; reducing the level of labour emigration and encouraging the immigration of highly qualified specialists; the development of motivational mechanisms in the payment of labour, taking into account the current conditions of precariousness in the labour market, the impact of pandemics and the development of remote employment; raising the standard of living of citizens and ensuring a decent salary, in particular the minimum wage; creation of innovative mechanisms for the creation of new jobs in the conditions of socio-economic, political and medical-demographic crisis; creating conditions for increased labour productivity, in particular by motivating businesses to implement innovations in all areas of economic activity, etc.

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Моделювання трудового потенціалу України на основі використання теорії нечіткої логіки

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Мета. Розробка ефективного підходу до оцінювання трудового потенціалу України.

Методика. Методом дослідження є математичне моделювання на основі використання «теорії нечіткої логіки».

Результати. Узагальнені й систематизовані фактори впливу на трудовий потенціал України, що згруповані у три групи: медико-демографічні, соціально-економічні й поведінкові. Узагальнено алгоритм моделювання та запропоновані лінгвістичні змінні, що характеризують комплексне оцінювання рівня трудового потенціалу України. Побудоване дерево логічного висновку ієрархічних зв'язків факторів з обраними термами для оцінювання трудового потенціалу України. Узагальнені статистичні дані по 21 країні, що входять до ЄС, та по Україні, які дали можливість оцінити рівень трудового потенціалу (*R*) для країн-стратегічних партнерів – Польщі та України, який відповідно становить 6,4 та 5,95. Запропоновані рекомендації щодо розвитку трудового потенціалу України.

Наукова новизна. Новизною дослідження є розробка теоретико-методологічного підходу до оцінювання трудового потенціалу України, що дозволяє комплексно, з урахуванням системи нечітких терм, оцінити медико-демографічні, соціально-економічні й поведінкові фактори впливу на трудовий потенціал України на основі використання теорії нечіткої логіки. Це, у свою чергу, дозволить підвищити ефективність системи прийняття управлінських рішень у напрямі покращення всіх складових, що формують трудовий потенціал.

Практична значимість. Важливість оцінювання трудового потенціалу для України полягає в багатьох аспектах, серед них головними є: підвищення ефективності державного управління у сфері формування трудового потенціалу; своєчасне виявлення проблем, визначення стану та формування стратегічних перспектив його розвитку, що дозволить прискорити процес переходу України від кандидата на членство в ЄС до члена ЄС і відродити економіку, яка нині перебуває на військових рейках.

Ключові слова: *модель, трудовий потенціал, оцінювання, теорія нечіткої логіки*

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