MATHEMATICAL MODELING AND COMPUTING, Vol. 12, No. 3, pp. 794–802 (2025)

Ordering factors that determine the activity of market participants in a war-torn country considering semantic network predicates

Shtanhret A. M.[1], Korzh H. I.[1], Yatsiuk R. A.[1], Olianyshen T. V.[2], Melnikov A. V.[3]

[1]*Lviv Polytechnic National University,*
12 S. Bandera Str., 79013, Lviv, Ukraine
[2]*National Forestry Technical University of Ukraine,*
103 General Chuprynka Str., 79057, Lviv, Ukraine
[3]*IT STEP University,*
83a Zamartynivska Str., 79000, Lviv, Ukraine

(Received 12 June 2025; Revised 11 August 2025; Accepted 13 August 2025)

With the aim of clarifying the significance of individual components of the set of factors affecting the activity of labor market participants, the following has been carried out: a formalized description of the initial information field using the mechanism of semantic networks and elements of predicate logic; calculation of the significance coefficients of predicates for established types of relationships between factors; ranking of the advantages of factors using the hierarchical modeling methodology and the ranking method, as well as the synthesis of the multilevel model. The conducted analysis is based on the consideration of circumstances relevant in 2022–2025, which serves as the necessary informational foundation for making decisions aimed at developing and implementing comprehensive measures targeted at stabilizing the socio-economic situation in the country.

Keywords: *activity of market participants; factor; semantic network; types of dependencies between factors; predicates; ranking; multilevel model of factors.*

2010 MSC: 68E37 **DOI:** 10.23939/mmc2025.03.794

1. Introduction

Military operations have been taking place in Ukraine with varying degrees of intensity since 2014, but they began to have the maximum impact on the labor market in the last three years. It should be noted that in 2022, due to a significant number of refugees, whose number reached over 5.5 million people, and internally displaced persons, whose number was 4.7 million people, 16 people applied for one job. Officially, the unemployment rate reached 21.1%, compared to 9.8% in 2021. The serious competition that arose for jobs allowed employers to adjust their personnel policy, especially in terms of limiting the size, and in some cases, reducing wages, reducing the social package, and tightening requirements for applicants.

Relative stabilization of the labor market began in 2023. The features of this stage of transformation were the following: an increase in the level of wages and a different situation in the regional context, the latter of which was due to the relocation of business and the restoration of economic activity in the liberated territories.

During 2024, the number of vacancies increased while competition for them decreased, resulting in a labor shortage, the elimination of which was hindered by high rates of mobilization, active labor migration, and deep geographic and professional disproportion in the distribution of the labor force. According to a report by the National Institute for Strategic Studies, the problem of staff shortage was relevant for 74% of employers [1].

In the second half of 2024 – early 2025, new trends emerged: women's mastery of previously traditional "male" professions; an increase in the number of working teenagers; a higher proportion of working pensioners; a shortage of labor, except for the IT business; and an increase in wages.

2. Formulation of the task

The data presented indicate the instability of the domestic labor market. The dynamics of these processes were determined by a certain set of factors. Identifying such factors and determining the significance of their impact on the process allows not only to understand the reasons for the transformation of the labor market, but also serves as a necessary information basis for the development and application of comprehensive measures aimed at stabilizing the socio-economic situation in the country. The previously held generalization [2–6] allowed creating the initial basis for determining the importance of factors that influenced labor market participants at the employee level (Table 1). This allows filling the information field for analyzing the situation on the domestic labor market, because as we know, all its participants are interconnected, and therefore further research can be carried out in the direction of identifying the mutual influences of factors that affected labor market participants with their subsequent ranking by importance.

Table 1. Factors that affected Ukrainian labor market participants at the employee level during 2022–2025..

Factor name	x_j
Low personal security level	x_1
Problems with access to quality educational services and healthcare	x_2
Insufficient financial resources to improve personal professional level	x_3
Insufficient level of remuneration	x_4
Lack of support for improving individual human capital	x_5
Insufficient protection against employer arbitrariness	x_6
Limited practice of individual non-material incentives	x_7

Based on our own work and the work of other researchers [5–11], we will carry out a formalized description of the source information field using the mechanism of semantic networks and elements of predicate logic; calculate the weight coefficients of predicates for the established types of relationships between factors; ranking the advantages of factors using the hierarchical modeling methodology and the ranking method and synthesis of a multilevel model of the priority of the influence of factors that influenced participants in the Ukrainian labor market at the employee level.

3. Methodology

The set of factors is given as a set of linguistic variables: $X = \{x_1, \ldots, x_j\}$.

It is necessary to establish the existence of a relationship between the factors, that is, paired influences between them, and to construct a binary dependence matrix Z for the set of vertices X, using the following condition:

$$x_{ij} = \begin{cases} 1, & \text{if } i \text{ depends on } j, \\ 0, & \text{if } i \text{ does not depend on } j. \end{cases} \tag{1}$$

As a result, we obtain the dependency matrix Z of the size $i \times j$.

Expressed as a matrix, dependencies allow us to construct a semantic network of relationships between factors in the form of an indicative graph that visualizes them. The vertices of the graph are elements of the subset X, and the arcs connect adjacent pairs of vertices (x_i, x_j), the relation between them indicating a certain dependency of one factor x_i on another x_j.

Based on the graph for each factor, we build hierarchical trees of their relations with other factors considering the influences of both types – direct and indirect, that is, indirect, passing through another factor. Vertex x_j is reached from vertex x_i if there is a path in the directed graph that leads from vertex x_j to vertex x_i.

Using hierarchical trees of relationships between factors, we build a modified scheme for representing these relationships, which, in addition to the factor number, shows the directions of direct influence of each factor and the paths of dependence on other factors.

To calculate the total weight values of the direct and indirect influences of factors and their integral dependence on other factors, appropriate notations should be introduced: let z_{ij} be the number of influences or dependencies for the j^{th} factor ($j = 1, \ldots, n$); w_i is the i-type weight. At the same time, we will distinguish such types of relationships between factors that depend on the value of the relationship index for a certain type. The notations will be: $i = 1$ — influences of the 1^{st} order; $i = 2$ — influences of the 2^{nd} order; $i = 3$ — dependencies of the 1^{st} order; $i = 4$ — dependencies of the 2^{nd} order. When performing calculations, we set some conditional values for the weight coefficients in relation to the types of dependencies. We will assume that for the influences of both types the weights will be positive, i.e. $w_1 > 0$, $w_2 = \frac{w_1}{2}$, therefore for the dependencies they will be negative, i.e. $w_3 < 0$, $w_4 = \frac{w_3}{2}$.

The integral weight values of factors by the sums of weights of all types of relations are denoted by S_{ij}:

$$S_{ij} = \sum_{i=1}^{4} z_{ij} w_i, \quad j = 1, \ldots, n. \tag{2}$$

where n is factor number.

For both types of influences, the weights will be positive and will have the following conditional values: $w_1 = 10$, $w_2 = 5$. For the dependencies, accordingly, they will be negative, namely: $w_3 = -10$, $w_4 = -5$. In case of no relations, $z_{ij} = 0$.

Since according to the given initial conditions $w_3 < 0$ and $w_4 < 0$, then, accordingly, $S_{3j} < 0$ and $S_{4j} < 0$. To bring the weight values of the factors "to the origin", that is, to obtain positive values, it is necessary to move the histogram of the integral graphical representation of all types of relations up by

$$\Delta_j = \max |S_{3j}| + \max |S_{4j}|, \quad j = 1, \ldots, n. \tag{3}$$

Considering (3), the formula, that will provide the calculation of numerical priorities of factors, will have the following form:

$$S_{Fj} = \sum_{i=1}^{4} z_{ij} w_i + \max |S_{3j}| + \max |S_{4j}|, \quad j = 1, \ldots, n. \tag{4}$$

The S_{Fj} values will serve as the basis for ranking the degree of influence of factors, which in turn will determine the priority levels of the compared factors.

Further actions are related to the need to consider not only the relationships between factors but also the influence of predicates. A formalized description of the obtained dependencies can be implemented using the semantic network mechanism and its mapping based on the introduced types of dependencies between factors and the logic of predicates.

The predicate language constructs used to describe a semantic network consist of simple (atomic) predicates and logical connections: $\wedge$ is logical "and"; $\vee$ is logical "or"; $\leftarrow$ is logical "if"; $\forall$ is commonality quantifier (for all); $\exists$ is existence quantifier (at least one exists).

For numerical identification of predicates, predicate weight coefficients are given, the essence of which will be to determine the numerical measure of strengthening or weakening of the interaction between factors depending on the attached linguistic predicates and types of dependencies, where k_{ip} are predicate weight coefficients that identify the strengthening of influences or dependencies for the p^{th} predicate of the i^{th} influence type. The relationship between the weight coefficients of the predicates are finally established as follows:

$$k_{2,p_l} = \frac{k_{1,p_l}}{2}; \quad k_{4,p_l} = \frac{k_{3,p_l}}{2},$$

where l is predicate number.

Considering the relationship between the weight coefficients of the predicates, below is the linguistic interpretation of the predicates of various types of relationships between factors and their numerical conditional weights (Table 2).

Table 2. The value of the weight coefficients of predicates in relation to dependency types.

l	Influence predicate	$k_{1,pl}$	$k_{2,pl}$	Dependency predicate	$k_{3,pl}$	$k_{4,pl}$
1	Determines	4	2	Is determined by	4	2
2	Forms	4	2	Is formed by	4	2
3	Causes	3	1.5	Is caused by	3	1,5
4	Becomes basis	4	2	Is based on	4	2
5	Anticipates	2.5	1.25	Is anticipated by	2.5	1.25
6	Considers	2.5	1.25	Is considered by	2.5	1.25
7	Affects	3	1.5	Receives	3	1.5

The factor x_j is characterized by the set M_{ij}, where the first digit of the number in the name of the set determines the type of relation and the second digit indicates the ordinal number of the factor:

$$x_j \subset M_{ij} = \{k_{i,p1}, \ldots, k_{i,pl}\}, \tag{5}$$

where x_j are the factors that affected labor market participants (in our case $j = \overline{1,7}$); M_{ij} are sets of coefficients, attached to the factors, which identify direct (indirect) influences (dependencies) of the first (second) order ($i = \overline{1,4}$); $k_{i,pl}$ — predicate weight coefficients that identify the strengthening of influences or dependencies for the p^{th} predicate of the i^{th} influence type, where l is the predicate number ($l = \overline{1,7}$). In the case of no relations $k_{i,pl} = 0$.

Let us form sets for the x_j factor, whose elements will be formalized generalized mappings of numerical values of predicates considering all types of relations. In this case, the number of elements in the sets will be denoted by the magnitude z_{ij}, the value of which is determined from the systems of equations formed on the basis of the following expression (5):

$$M_{ij} = \left\{m_{ij_1}, \ldots, m_{ij_{z_{ij}}}\right\}. \tag{6}$$

The averaged values of the predicate amplification coefficients for the factor x_j and the sets formed from expression (6) are obtained from:

$$k_{ij} = \sum_{r=1}^{z_{ij}} \frac{m_{ij_r}}{z_{ij}}, \quad i = 1,2,3,4; \quad j = 1, \ldots, n. \tag{7}$$

We obtain the refined weight values of the factors G_{ij} by multiplying the coefficients k_{ij} by the total partial weights S_{ij}:

$$G_{ij} = \sum_{i=1}^{4} k_{ij} S_{ij}, \quad j = 1, \ldots, n. \tag{8}$$

Positive values of the same type can be obtained by shifting the received numerical results (both positive and negative) by the amount

$$\Delta_j = \max |G_{3j}| + \max |G_{4j}|, \quad j = 1, \ldots, n. \tag{9}$$

Considering (8) the final expression for calculating the refined weight values of factors will have the following form:

$$G_{Fj} = \text{INT}\left(\sum_{i=1}^{4} (k_{ij} S_{ij} + \Delta_j)\right), \quad j = 1, \ldots, n. \tag{10}$$

To consider the additional influence of predicates, which, in its turn, will provide refined levels of importance of factors, calculations are performed using expressions (7), (8) and (10).

The calculations will result in a ranking of factors that affected labor market participants at different levels, considering the importance of semantic network predicates that identify the strengthening or weakening of relationships between factors.

4. Research results

According to the above algorithm, the first step was to identify the relationships between factors that influenced labor market participants at the employee level, according to the requirement (1):

	x_1	x_2	x_3	x_4	x_5	x_6	x_7
x_1	0	1	0	0	0	1	0
x_2	0	0	0	0	0	0	0
x_3	0	1	0	0	0	0	0
x_4	0	0	1	0	1	0	0
x_5	0	0	0	0	0	0	0
x_6	0	0	0	1	1	0	0
x_7	0	0	1	0	1	0	0

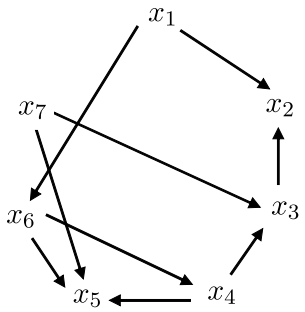

Fig. 1. Graph of relationships between factors influencing labor market participants at the employee level.

Next, we define relationship semantic network dependencies between factors in the form of an indicative graph (Figure 1), which visualizes them.

Based on the graph for each of the factors that influenced labor market participants at the employee level (Figure 1), we build hierarchical trees of their relationships with other factors (Figure 2), taking into account the influences of both types — direct and indirect, that is, indirect, passing through another factor.

Using hierarchical trees of factor relationships (Figure 2), we construct a modified diagram of relationships between factors (Figure 3), which, in addition to the alphanumeric designation of the factor, shows the directions of direct influences of each factor and the paths of dependence on other factors.

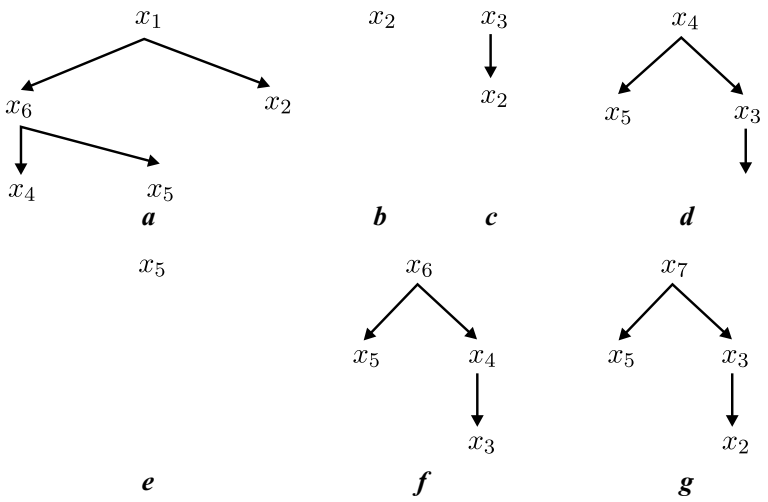

Fig. 2. Graphs of multilevel hierarchical relationships between factors that affected labor market participants at the employee level.

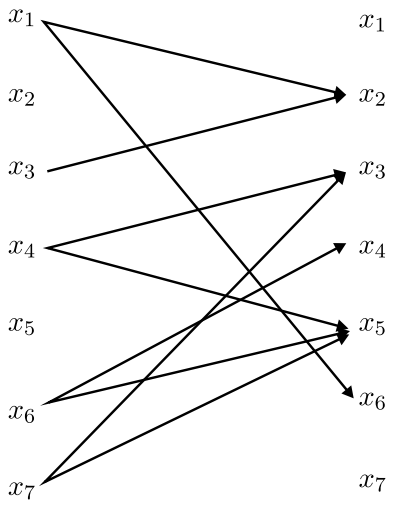

Fig. 3. Diagram of the relationships between factors affecting labor market participants at the employee level.

It is necessary to obtain numerical weights of the influence of factors that affected labor market participants at the employee level. Calculations will be carried out on the basis of graphs and diagrams shown in Figures 2 and 3, the analysis of which allows obtaining quantitative indicators of various types of relationships attached to each of the factors.

The calculation of the total numerical priorities of factors for the four types of relationships that we have identified is carried out using formulas (2) and (4), and the results obtained are listed in Table 3.

Table 3. The value of the weight coefficients of predicates in relation to dependency types.

j	z_{1j}	z_{2j}	z_{3j}	z_{4j}	S_{1j}	S_{2j}	S_{3j}	S_{4j}	S_{Fj}
1	2	2	0	0	20	10	0	0	70
2	0	0	2	2	0	0	–20	–10	10
3	1	0	2	1	10	0	–20	–5	25
4	2	1	1	1	20	5	–10	–5	50
5	0	0	3	1	0	0	–30	–5	5
6	2	1	1	0	20	5	–10	0	55
7	2	1	0	0	20	5	0	0	65

As a result of these actions, a preliminary order of the levels of priority influence of factors was obtained. Since the graphical relations declared in the semantic network are accompanied by additional linguistic characteristics specified by atomic predicates that strengthen or weaken the interaction between factors, it is advisable to take into account their influence on the overall factor priorities, which, understandably, will cause the modification of the data given in Table 3 and will determine the ranks and their corresponding final levels of factor weight.

The relationships between factors in the network (Figure 3) have the following formalized representation:

$(\forall x_{ij})$ $[\exists(x_{11}) \leftarrow$ anticipates $(x_{11}, x_{12}) \wedge$ considers $(x_{11}, x_{16})]$;
$(\forall x_{ij})$ $[\exists(x_{12}) \leftarrow$ is anticipated by $(x_{12}, x_{11}) \wedge$ is caused by $(x_{12}, x_{13})]$;
$(\forall x_{ij})$ $[\exists(x_{13}) \leftarrow$ causes $(x_{13}, x_{12}) \wedge$ is determined by $(x_{13}, x_{14}) \wedge$ is caused by $(x_{13}, x_{17})]$;
$(\forall x_{ij})$ $[\exists(x_{14}) \leftarrow$ determines $(x_{14}, x_{13}) \wedge$ anticipates $(x_{14}, x_{15}) \wedge$ is caused by $(x_{14}, x_{16})]$;
$(\forall x_{ij})$ $[\exists(x_{15}) \leftarrow$ is anticipated by $(x_{15}, x_{14}) \wedge$ is caused by $(x_{15}, x_{16}) \wedge$ is anticipated by $(x_{15}, x_{17})]$;
$(\forall x_{ij})$ $[\exists(x_{16}) \leftarrow$ causes $(x_{16}, x_{14}) \wedge$ causes $(x_{16}, x_{15}) \wedge$ is anticipated by $(x_{16},\ x_{11})]$;
$(\forall x_{ij})$ $[\exists(x_{17}) \leftarrow$ causes $(x_{17}, x_{13}) \wedge$ anticipates $(x_{17}, x_{15})]$.

According to the expression (5) the factor x_1 is characterized by the set M_{11}, x_2 — by the set M_{12} and so on. Next, it is necessary to substitute into the expressions (5) the numerical values of the corresponding coefficients from Table 2, taking into account the formalized reflection of the relationships between the factors that affected labor market participants at the employee level.

We will obtain four systems of equations of the sets of coefficients attached to the factors that identify the following:

– direct influences of the first order:

$$x_1 \subset M_{11} = \{k_{1,p_5}; k_{1,p_6}\}; \quad x_2 \subset M_{12} = \{0\}; \quad x_3 \subset M_{13} = \{k_{1,p_3}\};$$
$$x_4 \subset M_{14} = \{k_{1,p_1}; k_{1,p_5}\}; \quad x_5 \subset M_{15} = \{0\}; \quad x_6 \subset M_{16} = \{k_{1,p_3}; k_{1,p_3}\};$$
$$x_7 \subset M_{17} = \{k_{1,p_3}; k_{1,p_5}\}.$$

– direct dependencies of the first order:

$$x_1 \subset M_{21} = \{k_{2,p_5}; k_{2,p_6}\}; \quad x_2 \subset M_{22} = \{0\}; \quad x_3 \subset M_{23} = \{k_{2,p_3}\};$$
$$x_4 \subset M_{24} = \{k_{2,p_1}; k_{2,p_5}\}; \quad x_5 \subset M_{25} = \{0\}; \quad x_6 \subset M_{26} = \{k_{2,p_3}; k_{2,p_3}\};$$
$$x_7 \subset M_{27} = \{k_{2,p_3}; k_{2,p_5}\}.$$

– indirect influences of the second order:

$$x_1 \subset M_{31} = \{0\}; \quad x_2 \subset M_{32} = \{k_{3,p_5}; k_{3,p_3}\}; \quad x_3 \subset M_{33} = \{k_{3,p_1}; k_{3,p_3}\};$$
$$x_4 \subset M_{34} = \{k_{3,p_3}\}; \quad x_5 \subset M_{35} = \{k_{3,p_5}; k_{3,p_3}; k_{3,p_5}\};$$
$$x_6 \subset M_{36} = \{k_{3,p_5}\}; \quad x_7 \subset M_{37} = \{0\}.$$

– indirect dependencies of the second order:

$$x_1 \subset M_{41} = \{0\}; \quad x_2 \subset M_{42} = \{k_{4,p_5}; k_{4,p_3}\}; \quad x_3 \subset M_{43} = \{k_{4,p_1}; k_{4,p_3}\};$$
$$x_4 \subset M_{44} = \{k_{4,p_3}\}; \quad x_5 \subset M_{45} = \{k_{4,p_5}; k_{4,p_3}; k_{4,p_5}\};$$
$$x_6 \subset M_{46} = \{k_{4,p_5}\}; \quad x_7 \subset M_{47} = \{0\}.$$

According to the expression (6), we will form for the first factor (for our specific case) the sets, the elements of which are formalized generalized mappings of numerical values of predicates taking considering all types of relations. In this case, we will denote the number of elements in the sets by z_{ij}:

$$M_{11} = \{m_{111}; m_{112}; \ldots; m_{11z_{11}}\}; \quad M_{21} = \{m_{211}; m_{212}; \ldots; m_{21z_{21}}\};$$
$$M_{31} = \{m_{311}; m_{312}; \ldots; m_{31z_{31}}\}; \quad M_{41} = \{m_{411}; m_{412}; \ldots; m_{11z_{41}}\}.$$

The average values of predicate action amplification coefficients for the first factor and the sets are obtained based on (7):

$$k_{11} = \sum_{r=1}^{z_{11}} \frac{m_{11r}}{z_{11}}; \quad k_{21} = \sum_{r=1}^{z_{21}} \frac{m_{11r}}{z_{31}}; \quad k_{31} = \sum_{r=1}^{z_{31}} \frac{m_{11r}}{z_{21}}; \quad k_{41} = \sum_{r=1}^{z_{41}} \frac{m_{11r}}{z_{41}}.$$

To implement the defined algorithm, we calculate the average values of the coefficients and the refined weight values of the factors based on the data obtained from Table 3 and using (7), (8) and (10). The results of the calculations are summarized in Table 4, in which the consideration of the additional influence of predicates provides refined levels of importance of the factors.

Table 4. Results of the ranking of factors affecting labor market participants at the employee level.

j	k_{1j}	k_{2j}	k_{3j}	k_{4j}	D_{1j}	G_{2j}	k_{3j}	G_{4j}	G_{Fj}
1	2.5	1.25	0	0	50.0	12.5	0	0	196.5
2	0	0	2.8	1.4	0	0	–56.0	–14.0	64.0
3	3.0	1.5	3.5	1.8	30.0	0	–70.0	–9.0	85.0
4	3.3	1.6	3.0	1.5	66.0	8.0	–30.0	–7.5	170.5
5	0	0	4.0	2.0	0	0	–120.0	–10.0	4.0
6	3.0	1.5	2.5	1.25	30.0	7.5	–56.0	0	115.5
7	2.8	1.4	0	0	56.0	7.0	0	0	197.0

The result of the ranking is a multilevel model (Table 5) of the priority influence of the identified factors affecting market participants at the employee level, which was obtained with the consideration of the weight of the predicates of the semantic network (Table 2) identifying the strengthening or weakening of the relationships between factors.

Table 5. Priority of factors affecting participants on the Ukrainian labor market at the employee level during 2022–2025.

Factor name	x_j	Weight
Limited practice of individual non-material incentives	x_7	197.0
Low personal security level	x_1	196.5
Insufficient level of remuneration	x_4	170.0
Insufficient protection against employer arbitrariness	x_6	115.5
Insufficient financial resources to improve personal professional level	x_3	85.0
Problems with access to quality educational services and healthcare	x_2	64.0
Lack of support for improving individual human capital	x_5	4.0

5. Conclusions

The conducted research enables us better understanding of the degree of influence of the outlined factors on the participants of the labor market of Ukraine at the employee level. It is important to emphasize the fact that it is typical to consider the transformation of the labor market under the influence of key factors. Such an analysis is usually descriptive in nature. The proposed approach is not only different, but also significantly more complex and allows for a more accurate result. It also allows describing the situation at the level of economic entities, individual industries, and the national level. The results obtained can become an information basis for making the necessary managerial and regulatory decisions to achieve dynamic equilibrium in the labor market, which is a necessary basis for stabilizing the socio-economic situation in the country.

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Упорядкування факторів, що визначають активність учасників ринку праці воюючої країни, з урахуванням предикатів семантичних мереж

Штангрет А. М.[1], Корж Г. І.[1], Яцюк Р. А.[1], Олянишен Т. В.[2], Мельников О. В.[3]

[1]*Національний університет "Львівська політехніка", вул. С. Бандери, 12, 79013, Львів, Україна*
[2]*Національний лісотехнічний університет України, вул. Генерала Чупринки, 103, 79057, Львів, Україна*
[3]*ІТ СТЕП Університет, вул. Замарстинівська, 83а, 79000, Львів, Україна*

З метою з'ясування вагомості окремих складових сукупності факторів, що впливають на активність учасників ринку праці здійснено: формалізований опис вихідного інформаційного поля з використанням механізму семантичних мереж та елементів логіки предикатів; розрахунок коефіцієнтів вагомості предикатів для встановлених типів зв'язків між факторами; ранжування переваг факторів засобами методології моделювання ієрархій та методу ранжування та синтез багаторівневої моделі. Проведений аналіз грунтується на врахуванні обставини актуальних у 2022–2025 рр., що є необхідною інформаційною основою для прийняття у подальшому рішень з метою розроблення й застосування комплексних заходів націлених на стабілізацію соціально-економічних ситуації в країні.

Ключові слова: *активність учасників ринку праці; фактор; семантична мережа; типи залежностей між факторами; предикати; ранжування; багаторівнева модель факторів.*