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SCENARIO-BASED MODELING OF HUMAN RESOURCE DEVELOPMENT TRANSFORMATION UNDER MACROECONOMIC UNCERTAINTY: PROBLEM-ORIENTED APPROACH

The object of research is the process of problem-oriented human resource development under macroeconomic uncertainty. The proposed scenario-based modeling approach integrates tools of cognitive mapping and system dynamics modeling to construct and evaluate alternative development scenarios. A problem-oriented human resource development model was constructed based on a scenario approach, incorporating indicators and instruments at three levels of governance (macro, meso, and micro). This model enables the formulation of a well-founded set of policies and measures, taking into account macroeconomic realities, wartime risks, and institutional constraints. Development scenarios-baseline, optimistic, and pessimistic- were elaborated. Key criteria for evaluating the effectiveness of human resource development and policy directions were identified, including macroeconomic effects (growth in GDP per capita, living standards), regional effects (growth in gross regional product, reduction of unemployment), microeconomic effects (increased productivity, reduced employee turnover, improved workforce qualification), and the extent to which priority problems are addressed (brain drain, skills mismatch, etc.). The proposed system of evaluation criteria enables the alignment of objectives across different governance levels and facilitates multidimensional policy assessment. According to these criteria, all three scenarios – especially the optimistic and synergistic ones – outperform the existing inertial trajectory of development. The results demonstrate a synergistic effect of coordinated investments in human resource development across all governance levels, providing a solid foundation for national human capital development policies. The impact of the full-scale war in Ukraine was taken into account in the formulation of challenges and scenarios, and state support measures for transforming human resource development during crisis and post-war recovery were substantiated.

Keywords: *development, human resources, problem-oriented approach, scenario modeling, macroeconomic uncertainty, cognitive map.*

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1. Introduction

In the current conditions of global economic turbulence and structural imbalances, human resources (HR) development is a crucial factor in ensuring national competitiveness and sustainable economic growth. For countries with transformational economies, in particular Ukraine, the transformation of human capital is not only a response to internal socio-economic problems, but also a guarantee of macroeconomic stability. Russia's full-scale war against Ukraine, which began in 2022, has caused additional deep challenges for the economy and the labor market. Among such challenges: a sharp drop in GDP, mass displacement and migration of the population, and rising unemployment – which makes the problem of HR development even more relevant in the context of the country's post-war recovery.

This problem is also exacerbated by the lack of a scientifically sound approach to choosing human resources development tools that respond to pressing issues and create value. Often, such tools are determined without taking into account the specifics of different economic levels, which reduces the effectiveness of human potential development measures. In this context, building a structure with a set of sequential stages of modeling human resources development based on a problem-oriented approach is timely and has important practical significance. After all, such modeling of human resources development at three economic levels can become an effective argument for the implementation of reforms and the country's transition from one qualitative state to another.

But all this is complicated by the modern environment, which is characterized by significant global economic uncertainty, military challenges and escalations, large-scale geopolitical transformations, and generates a certain set of problems in the field of human resources development.

The current state of the Ukrainian labor market is characterized by significant disparities between the education system and market needs, a shortage of practical skills among graduates, insufficient interaction between business and educational institutions, and limited regional support mechanisms. These problems are exacerbated by the intensification of labor migration and insufficient investments in improving the skills of the workforce. Under such conditions, there is a growing need for a problem-oriented, multi-level strategy for the HR development, capable of adapting to uncertainty and purposefully solving specific "bottlenecks" at the macro-, meso- and microeconomic levels. Theoretical and methodological aspects of human resources development are set out in a number of scientific studies and works, but they cover only a certain economic level (micro, meso or macro).

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Thus, some of them focus on the country level, taking into account the specifics of public administration in such a category as human resources [1, 2] and analyzing the ways of their training and development [3, 4]. Other studies cover regional specifics and consider approaches to the management and development of human resources at the level of the region or certain territorial communities, which provides for its own set of relevant approaches and methods [5]. A significant part of scientific research is devoted to the features of human resources development at the level of individual business entities, taking into account the features of their activities and investment in human capital [6], the form of management and ownership [7] or the need to ensure personnel security [8]. Also, when studying human resources development, a number of approaches to human resource management have been formed in the scientific literature, among which the most common are systemic, process and functional. The systemic approach, which considers human resource development as an interconnected complex of elements and subsystems [3, 6], allows to study HR as a holistic category, but it often abstracts from the practical challenges of modernity and does not take into account crisis factors of a global scale. The process approach [7] emphasizes the sequence of procedures and functions of HR management, but remains too formalized and not always adaptive in an environment of unpredictable changes. The functional approach [2, 9] focuses on the performance of individual functions (planning, selection, training, motivation), but in isolation from complex socio-economic transformations it does not provide an answer to the question of how to ensure sustainable development of human potential under military crises, depopulation and large-scale migration.

These approaches do not take into account the specifics of the environment of global uncertainty, which is characterized by geopolitical upheavals, large-scale demographic shifts, accelerated digitalization and the destructive impact of military actions on the labor market. In these conditions, there is a need to apply a problem-oriented approach to human resource development, which is able to integrate different levels of management (macro, meso and microeconomic), ensure adaptability to crisis challenges and focus on solving specific "bottlenecks" in the development of human potential.

Empirical studies and official statistics indicate a significant reduction in human capital in different countries of the world under the influence of migration processes, demographic shifts and military conflicts. According to OECD and IOM, the size of the labor force in Eastern European countries has decreased by millions of people in recent years due to depopulation and labor migration [9–11]. Similar trends are also observed in the Baltic countries, Poland, Bulgaria and Romania, where employers are increasingly facing a shortage of qualified personnel.

Ukraine is a prime example of this global problem. According to the State Statistics Service and the International Organization for Migration (IOM), in 2019–2021 the workforce decreased by more than 800 thousand people, and with the outbreak of full-scale war, more than 6.7 million citizens left abroad, mainly women with children. In 2022, the unemployment rate reached 21%, but already in 2023–2024 a shortage of personnel was recorded due to mobilization, depopulation and mass migration [12]. Similar imbalances in the labor market are also characteristic of other states that have experienced military or economic upheavals, in particular Syria and Georgia.

At the same time, the reduction in public investment in education, as shown by the experience of Ukraine (decrease from 14.3% in 2021 to 8.5% in 2022) [13], has long-term consequences for the quality of human capital. The problems of skills mismatch, growing structural unemployment and regional imbalances observed among internally displaced persons and veterans in Ukraine [12, 14] are consonant with the challenges experienced by countries with similar crises.

At the same time, global trends indicate a growing role of the digital economy and knowledge-intensive industries, which puts forward new requirements for the HR development. The World Economic Forum predicts that by 2030 the introduction of new technologies may reduce 95 million jobs, but at the same time create 170 million new high-tech jobs [15]. This means that the HR should be aimed at developing competencies in the field of IT and innovation, digital literacy of all segments of the population, and the ability to quickly master new professions.

Thus, despite significant theoretical achievements in human resource development, there are clearly defined problems with existing resources. It is important to take into account their development at all economic levels. This necessitates the modeling of development scenarios to substantiate solution tools in a problem-oriented approach.

Current problems of human resource development, including in Ukraine, can be outlined as follows:

– mismatch of personnel training with the needs of the economy – there is a lack of specialists with the necessary qualifications due to the gap between educational institutions, business, industry and science and a change in the focus of priorities due to the war;
– lack of effective motivation for young people to acquire relevant skills and build a career in Ukraine, especially under forced migration;
– low awareness among young people about the possibilities of obtaining grants, training in new competencies within the framework of Ukrainian and international programs;
– limited incentives for enterprises to invest in personnel development, because enterprises "survive" under instability caused by the war (loss of infrastructure, relocation, etc.);
– insufficient competition between domestic educational institutions and foreign ones;
– outflow of qualified personnel abroad, which is caused by the war and partly by the inefficiency of the national education system (lack of a dual training mechanism, etc.).

Thus, the analysis of the literature and identification of problems revealed that there is an urgent need for *problem-oriented scenario modeling* of the HR development, which will unite different levels of government and ensure the coherence of state, regional and corporate policies in this area.

The aim of the research is to develop and apply a problem-oriented approach to scenario modeling of the development of human resources of Ukraine under macroeconomic uncertainty, in particular under a crisis caused by military actions. This involves substantiating effective directions and instruments of state support for the HR development at the macro, meso and micro levels to overcome the identified problems and increase the sustainability of the economy.

To achieve the set aim, it is necessary to complete the following research objectives:

– develop a conceptual multi-level model of problem-oriented human resources development, which includes interconnected elements and indicators at the macro, meso and micro levels;
– build a cognitive map of cause-and-effect relationships between the structural elements of the model to identify key factors and interdependencies in the HR development;
– form alternative scenarios for the development of human resources (basic, optimistic, pessimistic) taking into account the identified problems, risks (including military) and possible management decisions at different levels;
– to carry out simulation modeling of the implementation of scenarios using a computer model (Vensim environment) to quantitatively assess their impact on the target indicators of the effectiveness of the HR;
– to determine the criteria for the effectiveness of the HR and, based on multi-criteria analysis (the method of hierarchy analysis), to prioritize the areas of HR development at the state, regional and corporate levels;
– to develop practical recommendations on state support for the development of human resources in accordance with the selected priority areas, in particular policy measures to overcome the consequences of the war and ensure the restoration of the country's human potential.

2. Materials and Methods

2.1. Materials of research

The object of research is the process of problem-oriented development of human resources under macroeconomic uncertainty.

The information base was data from the State Statistics Service of Ukraine, the Ministry of Economy of Ukraine, as well as analytical reports of international organizations (International Organization for Migration, World Bank, World Economic Forum) on the development of labor potential, migration, employment and education. In particular, statistical indicators for the period 2010–2023 were used for modeling (GDP dynamics, regional GRP, state and regional spending on education, employment and unemployment levels, migration flows, enterprise performance indicators, etc.). When forming the scenarios, the shocks of 2022–2023 (fall in GDP, migration due to military actions) were taken into account, which are included in the parameters of the pessimistic scenario.

2.2. Research methods

The following general scientific research methods were used in the study:

– analysis and synthesis were used to study trends in human resource development;

– the classification method was used to classify human resource development problems and build a cognitive map of problem-oriented human resource development on this basis.

The applied research methods were the following.

Cognitive modeling. For this purpose, at the preparatory stage, a cognitive map of problem-oriented HR development was built, which reflects the cause-and-effect relationships between the main factors and indicators at three levels of management. The cognitive map allowed to formalize expert knowledge about the mutual influence of system elements (economically active population, level of education, labor productivity, training costs, economic development indicators, etc.) and identify key points of influence. The cognitive map was formed by the method of expert assessment with the participation of specialists in the field of labor economics and regional development (a total of 12 experts).

Scenario analysis. To this end, based on the cognitive model, three scenarios for the development of human resources were identified: basic (inertial, continuation of existing trends), optimistic (increased investment in the HR development and the implementation of reforms) and pessimistic (negative scenario taking into account crisis phenomena, in particular a protracted war). The scenarios differ in the specified parameters of the policy and external environment at each level. For each scenario, potential risks were identified and measures to minimize them were provided (for example, the risk of staff turnover, the risk of budget constraints, etc.). A synergy scenario was also formed, which combines key elements of optimistic measures at all levels of management: macroeconomic, mesolevel and microlevel).

Simulation modeling. To quantitatively assess the implementation of the scenarios, a simulation model of the three-level system of the HR development was developed in the Vensim PLE 5.7a environment. The model is presented in the form of a flow and level diagram that connects the macroeconomic block (GDP, government spending, employment, etc.), the mesoeconomic block (GDP of regions, regional budgets, employment programs) and the microeconomic block (enterprise activities, personnel costs, labor productivity). The model uses system dynamics: some variables are cumulative (for example, total labor productivity, number of employed HR), some are flow (for example, growth in investment in training).

Multi-criteria analysis – to assess the effectiveness of scenarios and justify development priorities, the Analytic Hierarchy Process (AHP) method was used.

3. Results and Discussion

Fig. 1 shows the structure and sequence of stages of building a model of problem-oriented human resource development. As a result of these actions, a rational set of tools for problem-oriented human resource development is formed.

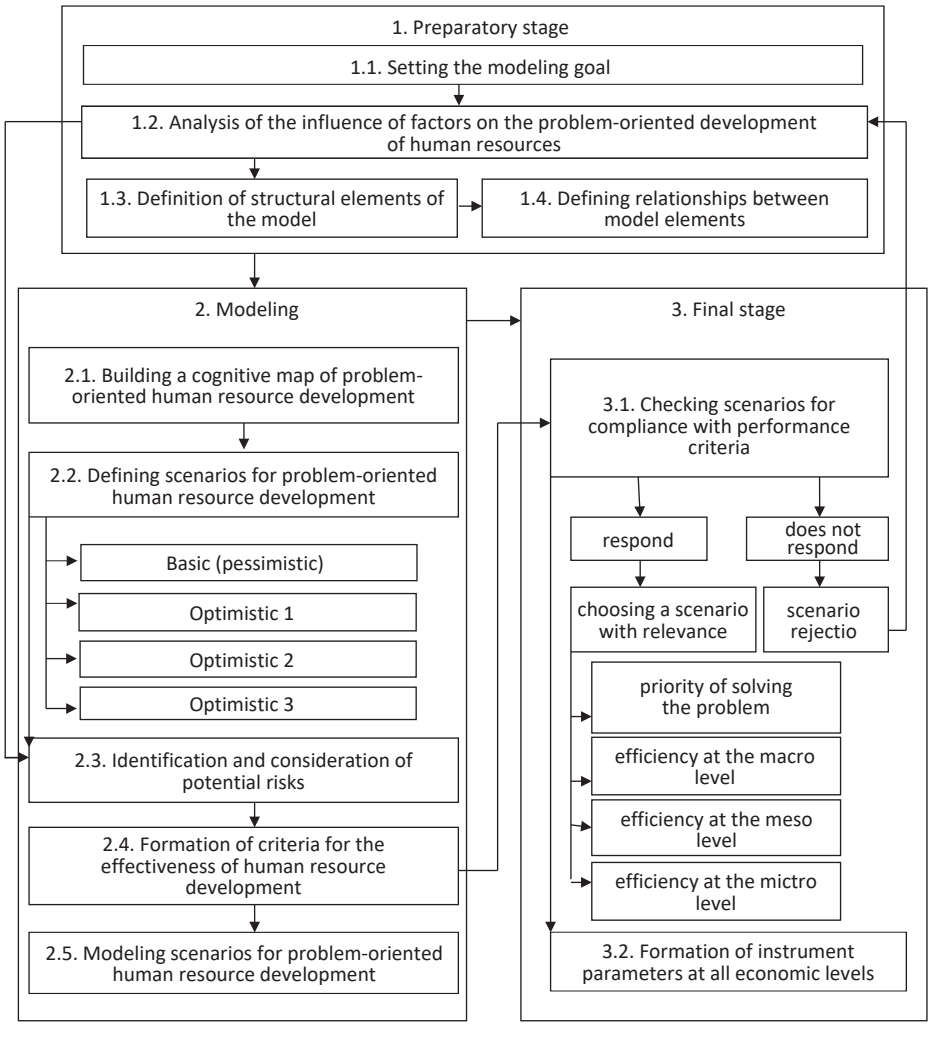

Fig. 1. Structure and sequence of stages of building a model of problem-oriented human resources development, which takes into account 3 economic levels

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According to Fig. 1, the first, preparatory stage, involves collecting and systematizing all necessary information for modeling scenarios of problem-oriented human resources development, taking into account micro-, meso- and macro-levels.

This stage is intended to identify and formulate the goal of modeling – to generate an up-to-date system of human resources development tools based on a problem-oriented approach. The complex effect of external and internal environmental factors on human resources development in the context of the chosen approach is analyzed. In addition, the key structural elements of the model are identified and the relationships between them are established. The structural elements of the model include social guarantees, costs of human resources development, economically active population, unemployment and employment levels, real wage levels, education levels and labor force needs.

In turn, these elements directly affect the macroeconomic indicators of the development of the national economy, the economies of regions and individual enterprises.

At the second stage, based on the results of the first, a cognitive map of problem-oriented development of human resources is designed by establishing cause-and-effect relationships between all structural elements of the model.

The cognitive map presented in Fig. 2 reflects the relationships between all components of the system of problem-oriented development of human resources at three economic levels. The integral indicator of such development depends on the results of the activities of business entities, on the regional development of human resources (through the solution of identified problems), as well as on national measures that promote problem-oriented development of human resources.

Analysis of the cognitive map shows that the development of human resources is determined by coordinated actions at three economic levels. At the micro level, this is the efficiency of enterprise activities, at the meso level, the development of human resources in the regions by solving identified problems, at the macro level, state support for problem-oriented development of human resources.

The growth of qualitative and quantitative characteristics of human resources (through the education system, advanced training, reducing unemployment, etc.) leads to an increase in labor productivity and improvement of financial and economic indicators of enterprises. As a result, economic growth of individual territorial communities, regions and Ukraine as a whole is ensured. In turn, irrational use of human potential and inefficient development (the outflow of qualified personnel between regions or abroad, high unemployment, low quality of education) slows down economic development and poses a threat to economic security.

State policy affects the system through mechanisms for financing education, regulating the labor market, providing social guarantees, etc., forming the basic conditions for the functioning of other levels.

Thus, a cause-and-effect chain is formed. The demand of business entities for labor, which arises as a result of the expansion of activities or the lack of employees with the necessary qualifications, determines the number of employees and the total employment of human resources. The expenses of entrepreneurs on personnel development affect the level of qualifications and competitiveness of personnel, and therefore, on labor productivity and the results of the activities of enterprises. The results of the activities of enterprises, in turn, determine the possibilities of creating new jobs and additional hiring of personnel. This affects the level of unemployment, employment and overall economic activity of the population, which, in turn, affects the total labor productivity at the national level.

The growth of financial results of enterprises and other business entities has another advantage: tax revenues to local and state budgets increase. This creates additional competitive opportunities for the development of human resources, in particular through the financing of state and regional target programs in the field of human resources development, focused on solving problems of a certain level.

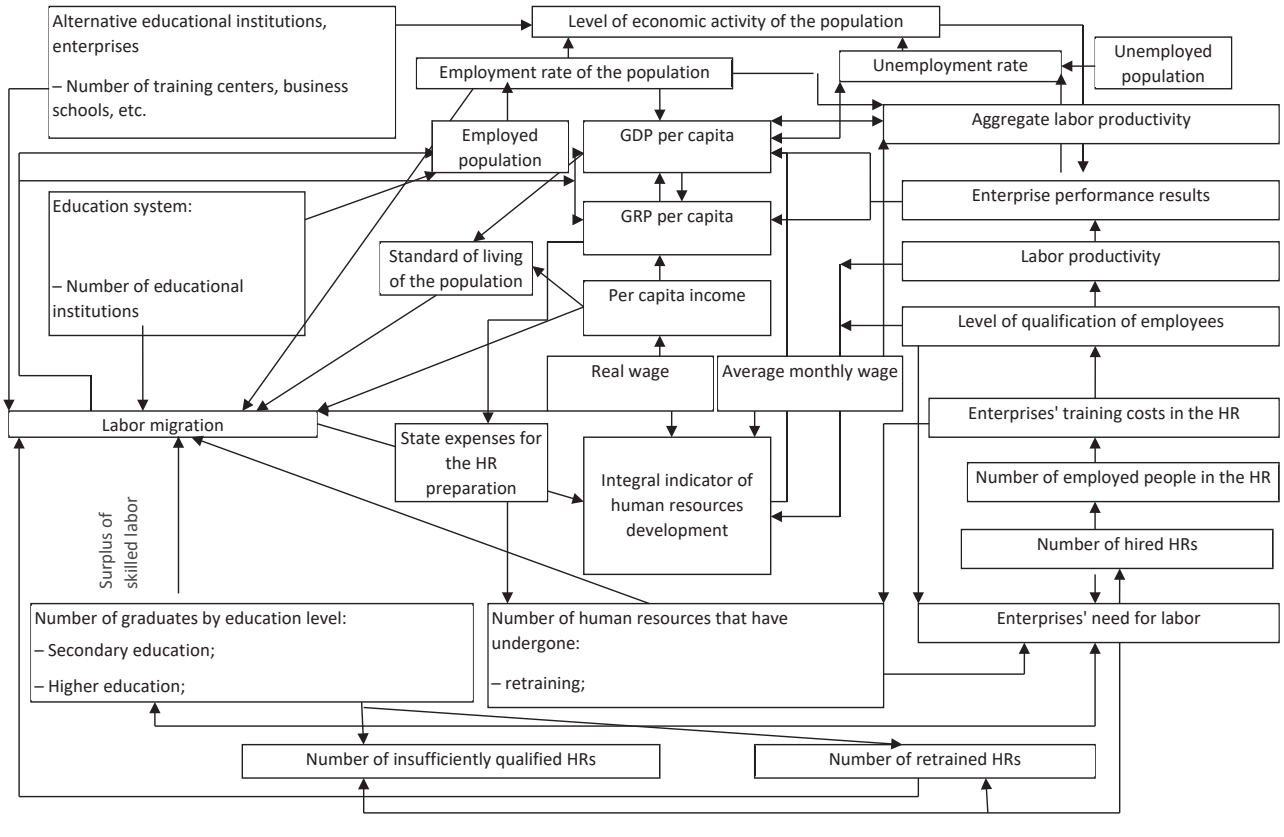

Fig. 2. Cognitive map of problem-oriented human resource development

The level of wages at enterprises depends on the financial results of their activities and labor productivity, which, in turn, is determined by the qualifications of employees and the volume of enterprise expenses for personnel development. The motivational aspects of problem-oriented human resource development depend on the level of wages and working conditions, as well as the state of personnel development at the enterprise.

A critically important factor in human resource development, which is implemented using a problem-oriented approach, is the educational background. That is, higher and vocational education institutions that are able to provide high-quality competitive training, generate the necessary professional competencies for certain territorial communities and Ukraine as a whole. The number of educational institutions in a particular region is not a decisive indicator (quantity does not equal quality), but the presence of educational institutions creates conditions that affect migration processes. Young people strive to study in regions where there are appropriate institutions, or go abroad for education. In the context of transformations caused by Russia's military aggression against Ukraine, higher and vocational education institutions must be proactive. That is, they must compete by improving the quality and innovation of the educational process, integrate the latest methods and tools of education that are characteristic of the digital economy, and take into account the needs of business and the state during the post-war economic recovery. The most important thing is the quality content of the educational process – highly professional teaching staff, modern equipment, training and practical centers, etc. Training at the enterprise level is currently problematic in Ukraine due to the Law of Ukraine "On Professional Development of Employees" [16], which limits the ability of business entities to issue official documents on advanced training in production (due to a complex licensing procedure). This indicates the need for deregulation measures [17]. At the same time, all the conditions for organizing high-quality professional training of personnel exist directly at enterprises that have a modern material and technical base and qualified specialists.

The motivation of human resources for development is also influenced by the presence of regional development HR programs, a developed educational infrastructure, specialization of educational institutions, as well as training and retraining programs implemented by employment services in the region and the country. If there are no proper incentives and opportunities for professional growth of employees at the enterprise or regional level, this encourages them to look for alternative paths of development. As a result, migratory sentiments are formed, which leads to both interregional and external labor migration.

The mobility of labor resources depends on a number of socio-economic factors: the level of income of the population, the level of wages, the availability of development programs at the state, regional and corporate levels, the quality of education and vocational training, etc. In turn, the mobility of personnel affects the level of the economically active population, the quality of human potential, the volume of gross regional product (GRP) and gross domestic product (GDP).

The competitiveness of educational and training institutions is determined by the amount of funding for training, retraining and advanced training of employees from the state, regional authorities and business. The competitive position is also formed by the quality of educational programs and the level of professionals involved in training (mentors, coaches, trainers). The absence of competitive educational institutions at the meso level (the level of a territorial community or region) encourages migration processes: young people go to study abroad, and qualified employees look for better opportunities outside the region or country. Educational institutions graduate a certain number of specialists with a certain level of qualification. However, the real needs of the labor market in comparison with the available number of specialists of different educational levels and specializations determine the share of human resources that are insufficiently qualified or require retraining.

The results of cognitive modeling were used as the basis for developing a simulation model of the action of human resource development scenarios using a problem-oriented approach.

The second stage of the constructed model of problem-oriented human resources development is modeling. At this stage, four scenarios of human resources development are formed on the basis of the cognitive map, each of which provides for a corresponding set of management measures and parameters determined as a result of the study.

The basic (pessimistic) scenario assumes the invariance of HR development indicators at all economic levels and the forecasting of integral indicators of problem-oriented HR development at the macro-, meso- and micro-levels in the horizon of 5 years. This scenario is inertial (reference) and is used for comparison with the proposed optimistic scenarios in order to assess their effectiveness according to the specified criteria.

Scenario 1 ("optimistic – 1", macro-level). Priority of human resources development at the national level. Within the framework of this scenario, direct state spending on education and training increases (to the level of ~6.78% of GDP, which corresponds to the historical maximum of previous years) and indirect investments in human capital are made through the introduction of a tax discount (about +0.14 pp) on expenses of individual entrepreneurs and their employees for advanced training and retraining.

Scenario 2 ("optimistic – 2", meso-level). Emphasis on regional human resources development policy. Expenditures of regional budgets on education increase by approximately 5% with a continuation of the trend of increasing the share of local budgets in financing education. Regional programs to stimulate labor productivity are additionally implemented.

Scenario 3 ("optimistic – 3", micro-level). Strengthening human resource development at the enterprise level. It is expected that business spending on personnel (training, retraining) will increase by an average of 0.9–2.9% compared to the baseline level by creating appropriate incentives and requirements for enterprises.

To verify the implementation of the above scenarios, a simulation model was created in the Vensim PLE 5.7a environment (Fig. 3).

The base scenario was determined by forecasts based on trends (linear, logarithmic, power) with a coefficient of determination of 0.89–0.98. The level of statistical significance of the parameters of trend models is 0.05. The performance indicators of the scenarios were determined by one- and two-factor models with a coefficient of determination of 0.76–0.94 for macroeconomic indicators and 0.83–0.99 for meso- and microeconomic indicators.

The indicators of the effectiveness of the proposed scenarios are performance indicators: the value of GDP per capita, GRP per capita, labor productivity; staff turnover; the number of people who have improved their qualifications.

The baseline scenario (pessimistic) is defined ыas conditionally unchanged, in which human resources development is carried out along an inertial trajectory, without the introduction of new policy instruments. It is used as a benchmark for comparing the effectiveness of optimistic scenarios.

Scenario 1 (macroeconomic) is a priority for human resources development at the macro level. It involves increasing direct state funding for education to the maximum level of previous years (up to 6.78% of GDP); making indirect investments in human capital by introducing a tax discount of +0.14 pp on training expenses for individual entrepreneurs (IEOs) and their employees.

Simulation results of scenario 1: over 5 years, GDP per capita increases by 1.5–1.7% above the baseline scenario; GRP per capita on average by region – by 1.9% (the largest increase in Chernivtsi region – 3.1–3.6%, the smallest in Kyiv – 0.9–1.0%). Annually, an additional 20% of individual entrepreneurs and their employees improve their qualifications (thanks to a tax incentive).

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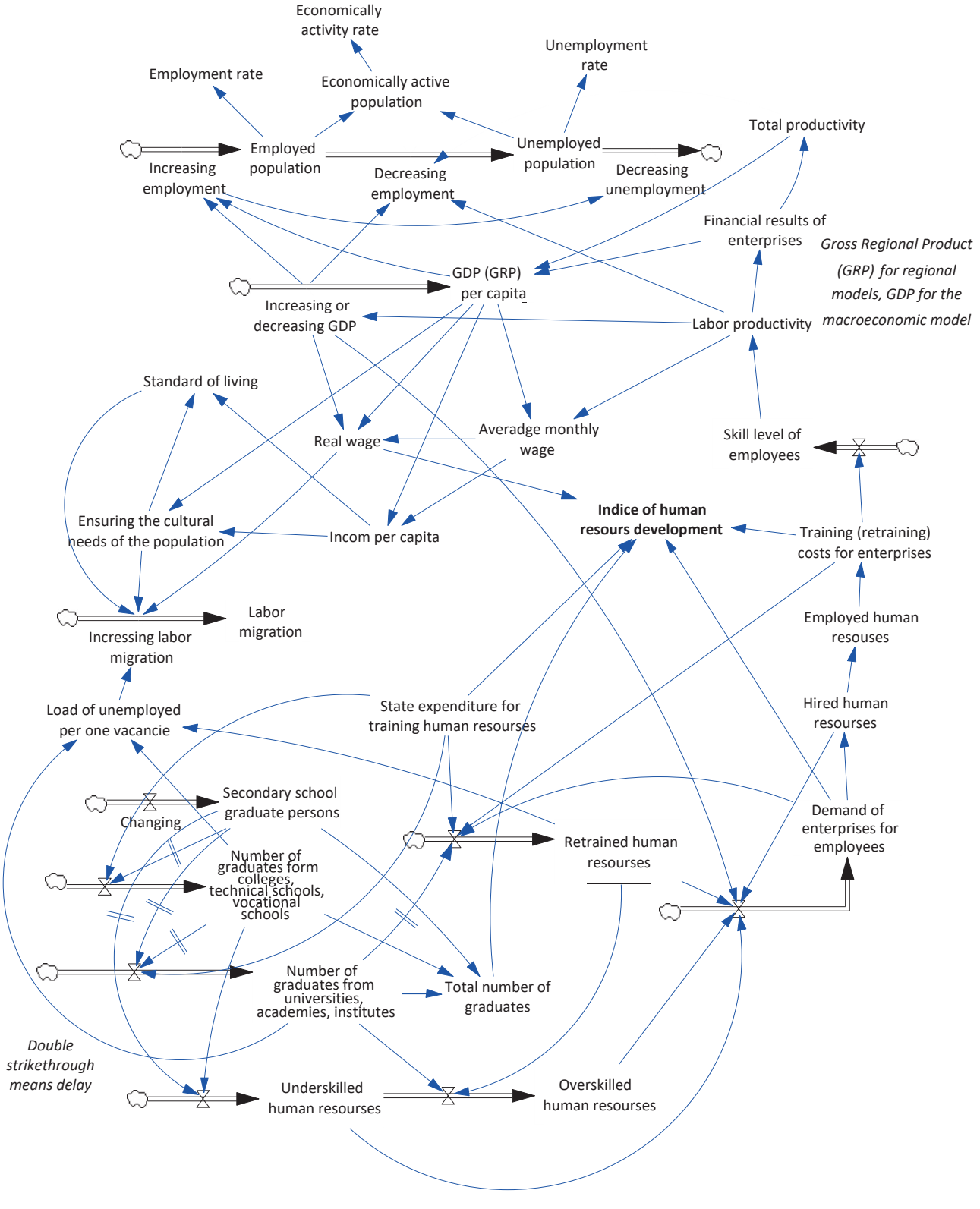

Fig. 3. Flow and cause-and-effect diagram for a 3-level model of problem-oriented human resource development

Scenario 2 (mesoeconomic) – emphasis on the regional HR development policy. Initial conditions: an increase in regional budget expenditures on education by 5% with a continuation of the trend of increasing the share of local budgets in financing education; implementation of regional programs to stimulate labor productivity. Simulation results of scenario 2: total GDP of Ukraine in 5 years exceeds the baseline scenario by 2.3–2.8%; total spending on education increases by 0.3 pp of GDP. GRP per capita by region – by 2.3–2.8% above the baseline level. Labor productivity (average for the economy) increases by 1.4% compared to the baseline.

Scenario 3 (microeconomic) – strengthening the development of human resources at the level of individual enterprises. It assumes an increase in the costs of business entities for personnel (training, retraining) by an average of 0.9–2.9% compared to the baseline (due to incentives and business requirements).

Results of scenario 3: GDP per capita increases by 0.56–1.1% above the baseline; average monthly wage – by 3.7%; labor productivity – by 0.6%. The share of employees who annually improve their qualifications increases by 3%, and staff turnover (labor turnover) decreases by 0.16–0.25 pp compared to the baseline.

Synergy scenario – simultaneous implementation of key measures of scenarios 1–3. That is, a combination of: stimulating spending on advanced training (tax discount, as in scenario 1), increasing the amount of funding for education from regional budgets (as in scenario 2) and increasing enterprise spending on personnel training (as in scenario 3).

The synergistic effect turned out to be higher than the total effect of individual scenarios: over 5 years, GDP per capita exceeds the baseline scenario by an average of 2.01%; GRP per capita – by 2.12%; labor productivity – by 1.1%. Personnel turnover is reduced by 0.1–0.29 pp compared to the baseline. This demonstrates that the simultaneous implementation of measures at all levels provides an additional increase in efficiency due to synergy (mutual reinforcement of results).

All three target scenarios outperform the baseline in terms of efficiency criteria, with a particularly noticeable increase in macro- and meso-indicators in scenarios 1–2, while scenario 3 has a more significant impact on micro-level indicators (reduction in turnover, advanced training). The comprehensive scenario proved the need for parallel use of instruments at all levels: for example, the optimal combination of policies (state investments, regional programs, corporate training) made it possible to achieve maximum growth in GDP and productivity while minimizing negative phenomena in the labor market.

For each scenario, compliance with the criteria for the effectiveness of human resource development was checked. It was determined that the proposed scenarios (especially the synergistic one) meet the set criteria – they provide an economic effect at the macro-, meso- and micro-levels and are aimed at priority problems.

Using the method of hierarchy analysis, priorities for human resource development directions were formed at three economic levels.

Thus, at the state level, the main areas of human resources development, taking into account the problem-oriented approach, are recognized as:

– introduction of changes in regulatory documents regulating the labor market;

– implementation of the most relevant socio-economic reforms (educational, pension);

– tax incentives for social and labor relations and de-shadowing of the labor market.

The urgent and priority areas at the level of territorial communities and regions are:

– harmonization of local regulations with national ones;

– coordination of interaction between higher education institutions, employment centers and employers;

– programs to support small businesses, youth employment and reduce unemployment;

– creation of incentives for enterprises that create new jobs.

At the level of individual business entities, the following priority areas have been identified:

– formation of a problem-oriented human resources management system;

– introduction of flexible systems of motivation and personnel release;

– development of corporate social responsibility;

– adaptive mechanisms for human resources management taking into account socio-psychological problems (such as reducing stress levels, improving working conditions).

The indicated areas of human resources development will contribute to reducing wage arrears, slowing down the migration of talents, reducing shadow employment, increasing productivity and loyalty of employees. This ultimately has a positive impact on the financial and economic indicators of enterprises and the country's economy as a whole.

Thus, the research results include: a constructed model and scenarios for human resources development; a quantitative assessment of the effects of implementing the scenarios; determining priority areas for the HR development. The next step is to form a "road map" on this basis – a phased plan for implementing the concept of problem-oriented HR development in the short and medium term.

The results obtained confirm the hypothesis of the need for a comprehensive, coordinated approach to human resources development. The simulated scenarios show that isolated measures at one level (for example, only state investments or only the efforts of enterprises) have a limited effect. The greatest increase in indicators is achieved with the simultaneous implementation of measures at the macro-, meso- and micro-levels, which ensures synergy. This is consistent with the ideas of a systemic approach to human resources management, where results depend on the coherence of policies at different levels. In particular, state investments in human capital will be ineffective without the active participation of business in personnel development, and vice versa – corporate HR initiatives require the support of a favorable regulatory environment. The developed cognitive model of HR development integrates indicators of different levels of management. It allows to see a holistic picture of problems and relationships. For example, the problem of "shortage of personnel with the necessary qualifications" is associated not only with the education system (meso-level), but also with migration (macro-level) and the practice of personnel management at enterprises (micro-level). This approach allows to better assess the side effects of policies. This model showed: an increase in state funding for education without reforms in the labor market may lead to a continued outflow of youth abroad if jobs and incentives to work in Ukraine are not created. Therefore, parallel measures are proposed – tax benefits for businesses that hire young specialists or invest in their training.

It is worth noting that the results of the study were obtained assuming stabilization of the macroeconomic situation after 2025 and a gradual recovery of the economy. The pessimistic scenario modeled the impact of military actions for several years, but did not take into account extremely negative options (escalation of the war, complete loss of certain territories). Therefore, these results should be considered indicative for recovery policies.

Comparison with studies of other countries that have experienced crisis shocks shows common features: investing in human capital is a determining factor in post-crisis economic recovery. For example, the experience of EU countries after the 2008 financial crisis proved that those states that actively implemented retraining and employment support programs overcame the recession faster. For Ukraine in the conditions of war and post-war times, this means the need to concentrate resources on preserving and developing human potential in order to have a basis for rebuilding the country. The proposed problem-oriented approach allows to clearly direct efforts to critical areas – to reduce the outflow of personnel, provide opportunities for young people and displaced persons to realize themselves within the country, and raise labor productivity to a competitive level.

From the point of view of state policy, the results of the scenario analysis can be used as the basis for a "roadmap" for the transformation of the HR development. Such a road map should contain specific tasks, deadlines, and responsible persons at each level. For example, according to the results of scenario 1, the task of increasing education funding is obvious – even in difficult wartime budgetary conditions, it is important to protect expenditure items for training human resources. Scenario 2 emphasizes the role of regions – therefore, it is advisable to stimulate regional state administrations to develop regional programs for human potential development (including using funds from international donors for recovery). Scenario 3 and the expert examination confirm that without the active involvement of business, the effect will be limited – therefore, additional tax incentives and grant programs are needed for enterprises that invest in employee training, especially in critical industries and regions.

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Thus, the peculiarity of the obtained results lies in the synthesis of three methodological components – cognitive mapping, simulation modeling and hierarchy analysis – to solve the complex problem of the HR development in an unstable environment. Such a multidisciplinary approach allows to take into account a wide range of factors and obtain more substantiated recommendations than when using any one method.

The results of the study in the form of scenarios at three economic levels can be used in practice (for example, in the activities of executive authorities and local government bodies when developing employment strategies) and contribute to increasing the effectiveness of state policy and regional development of labor potential. As well as ensuring the socio-economic stability of the country in the long term in the context of demographic changes, labor migration, war crises or post-war reconstruction.

The proposed methods of scenario and simulation modeling can be used to predict labor shortages, develop retraining and retention programs, and adapt personnel policy to new socio-economic challenges.

A limitation of the model is that it mainly focuses on quantitative indicators of the HR development. However, qualitative aspects – such as employee motivation, innovative activity, adaptability to change – are difficult to formalize, but significantly affect the success of the implementation of scenarios. The war highlighted new factors, in particular, the psychological state of labor resources (stress, loss of motivation) and demographic losses. This study does not take them into account directly, but the recommendations for socio-psychological support for personnel partially address these problems. Another limitation is that the results of the model are relevant for states facing large-scale population movements, regional imbalances, or the need for rapid structural restructuring of the labor market.

Further research may be aimed at refining the scenarios taking into account real post-war conditions, when new data becomes available on the return of migrants, labor market needs in infrastructure reconstruction, etc.

4. Conclusions

1. The study demonstrates a comprehensive scenario approach to problem-oriented human resource development in Ukraine, taking into account three levels of management – macro-, meso- and micro-economic. Unlike previous studies, which mostly focus on individual aspects of employment policy or educational reform, this work proposes a holistic model that takes into account systemic relationships between economic, educational, social and migration factors. The problem-oriented model of human resource development is developed on the basis of a scenario approach, it integrates indicators and tools of three levels of management (macro, meso, micro).

2. Based on the multi-level model, a cognitive map of cause-and-effect relationships between key factors that influence human resource development (economic, social, educational, migration factors) is constructed, and provides a comprehensive analysis of problems and opportunities.

3. Alternative scenarios for the transformation of the HR development in Ukraine are proposed: basic (inertial), optimistic (enhanced development with reforms) and pessimistic (crisis scenario, taking into account the consequences of the war).

4. Simulation modeling in the Vensim environment made it possible to quantitatively assess the impact of each scenario on target indicators: GDP and GRP per capita, labor productivity, employment and staff turnover, training coverage, etc. It was established that the optimistic scenario provides an increase in GDP per capita of up to 2.8% over 5 years compared to the basic one, the pessimistic scenario provides the least progress (or even deterioration of a number of indicators), and the synergy scenario (combined) provides the maximum total effect (growth in GDP per capita by ~2%, labor productivity by ~1.1% and a decrease in staff turnover by 0.2 pp relative to the basic one).

5. Key criteria for the effectiveness of the HR development for assessing scenarios and policy directions are identified. These include macroeconomic, regional and microeconomic effects and the degree of resolution of priority problems (brain drain, skills mismatch, etc.). The macroeconomic effect is the growth of GDP per capita and living standards. The regional effect is realized through the growth of GRP, the reduction of unemployment. And the microeconomic effect is an increase in productivity, a decrease in staff turnover, and an increase in employee qualifications. It is shown that the system of criteria allows for the coordination of goals at different levels and a multi-faceted assessment of policies. According to these criteria, all three developed scenarios (especially the optimistic and synergistic) significantly outperform the existing inertial development trajectory.

6. Recommendations are proposed for state support for the transformation of the HR development based on the results obtained. In particular: even under limited government resources, it is advisable to increase investments in human capital (funding education, supporting retraining and advanced training programs, especially for internally displaced persons and veterans). At the tax and regulatory level, employers should be encouraged to invest in personnel development (through tax credits, grants, benefits for businesses that create new jobs or train young people). It is also necessary to develop institutional interaction (the "education-science-business" trio) to coordinate supply and demand in the labor market. It is urgent to accelerate the adoption of a new version of the Labor Code and regulations that legalize flexible forms of employment and remote work, which are important in war and post-war times. It is important to implement a national program for "returning talents" – measures to reintegration of Ukrainian labor migrants and prevent "brain drain" (creation of highly productive jobs, raising salaries in critical industries, providing housing, etc.).

The war factor was taken into account when forming scenarios and proposals. It was shown that the war became a powerful destructive factor for the HR development (migration, job losses, worsening working conditions), therefore scenario planning should include crisis and post-crisis options. It is recommended to allocate a block of human potential development with clear goals in the state strategy for post-war recovery. The first goal is to return and effectively attract human capital that was lost during the war. The second is to ensure psychological rehabilitation and retraining of veterans and victims. The third is to create conditions for preventing mass emigration of youth by providing them with prospects in Ukraine. Policy measures should be problem-oriented – that is, aimed at solving specific identified problems in the sphere of labor and education, taking into account international experience and best practices.

Conflict of interest

The authors declare that they have no conflict of interest in this research, including financial, personal, authorial or other, which could affect the work and its results presented in this article.

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The manuscript has no related data (all data are provided in the text or available from open statistical sources).

Use of artificial intelligence

The authors confirm that they did not use artificial intelligence technologies when creating the presented work.

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