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INNOVATIVE MANAGEMENT OF LABOUR POTENTIAL IN THE DIGITALIZATION SYSTEM OF FINANCIAL AND ECONOMIC SECURITY OF THE SMART ECONOMY

Lyudmula Pronko
PhD in Economics, Associate Professor, Dean of the Faculty of Management and Law, Vinnytsia National Agrarian University, Vinnytsia, Ukraine;
ORCID: 0000-0001-5633-901X

Polina Puzyrova
D.Sc. in Economics, Professor of the Department of the Smart Economics, Kyiv National University of Technologies and Design, Kyiv, Ukraine;
e-mail: puzyrova@ukr.net
ORCID: 0000-0003-0839-8730
(Corresponding author)

Vitalii Sobchyshyn
PhD in Economics, Associate Professor of the I. Markina Department of Management, Poltava State Agrarian University, Poltava, Ukraine;
ORCID: 0000-0001-9230-2118

Larysa Varava
D.Sc. in Economics, Professor, Head of the Department of Management and Administration, Kryvyi Rih National University, Kryvyi Rih, Ukraine;
ORCID: 0000-0003-1069-1645

Denys Zakharov
Candidate of Technical Sciences, Doctoral Student of the Department of Entrepreneurship and Business Administration, O. M. Beketov National University of Urban Economy in Kharkiv, Kharkiv, Ukraine;
ORCID: 0009-0006-5751-6771

Olena Vynogradova
D.Sc. in Economics, Professor, Head of the Department of Marketing, State University of Information and Communication Technologies, Kyiv,
ORCID: 0000-0002-7250-5089

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ABSTRACT

The article explores the specifics and features of assessing innovative labour potential management in the system of digitalization of financial and economic security of the smart economy. A methodology for forecasting the dynamics of innovative labour potential management has been developed, which allows taking into account development trends and adapting to changes that arise in the current activities of business entities. The proposed methodology provides effective data modelling that takes into account both stable and variable factors that are important for maintaining a balance between innovation and security. The developed forecasting methodology allows not only to assess changes in labour potential but also helps in making decisions during adaptive management in the conditions of rapid digitalization of the economy. A comprehensive assessment of the state of labour potential is presented using mathematical and economic modelling and data integration methods based on the modified principal component. The forecasting results showed trends in the decline of the economically active population, employment, and the number of full-time employees in Ukraine due to external economic and social factors, including Russian aggression. The results of the article will be useful to a wide range of readers, in particular for managers of enterprises and organizations involved in human resources management and economic security, as well as for economists and analysts involved in forecasting changes in the economy.

Keywords: labour potential, wages, employees, innovative management, smart economy, digitalization, financial and economic security, competitiveness

JEL Classification: O33, J21, L86, M12

INTRODUCTION

The importance of innovative labour potential management in the context of digitalization of financial and economic security of the smart economy is determined by modern trends in economic development, which require adaptation to rapid changes in the technological environment. In the context of digitalization, enterprises must integrate the latest technologies to ensure high productivity and economic security. In this regard, strategic labour potential management becomes a key element that contributes to the effective use of human resources through the implementation of digital tools, automation and data analysis. Such management not only ensures the growth of individual and collective efficiency of employees but also allows for the adaptation of business models to new labour market requirements, reducing costs and increasing the competitiveness of the enterprise. An important aspect is also the integration of new digital platforms for monitoring and ensuring financial and economic security, which allows for minimizing risks and optimizing processes in conditions of complex economic changes. Thus, innovative workforce management is the basis for creating an adaptive and sustainable economy that is able to respond to the challenges of digital transformation and maintain financial stability in a smart economy. Forecasting the dynamics of innovative labour potential management is an important aspect for ensuring effective adaptation to changes in the system of digitalization of financial and economic security in the context of a smart economy. As the speed of technological and economic changes in the digital

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environment is significantly accelerating, effective labour resource management becomes critically important for maintaining the stability and competitiveness of enterprises and national economies. Using a model that can adapt to changes contributes not only to accurate forecasting but also to ensuring resilience to economic and social challenges. In particular, in the context of a smart economy dominated by automation, digitalization and new approaches to labour organization, accurate forecasting helps to shape strategic directions for the development of labour potential, in particular through the analysis of various aspects of employment, labour mobility, time worked, real wages and collective agreements. The application of this approach is especially important in crisis situations, such as economic or military conflicts, which require a quick response to minimize negative consequences. Thus, the importance of our research is due to the need for adaptive forecasting to maintain financial and economic security in the face of rapid and unpredictable changes in the smart economy.

LITERATURE REVIEW

The first group of researchers covers research in the field of the digital economy, including the impact of digital technologies on entrepreneurial development, innovation and sustainable development in the context of Industry 4.0. Particular attention is paid to researching the impact of digital transformations on the efficiency and competitiveness of enterprises, in particular in the agricultural and industrial sectors. The author (Williams, 2021) described the concepts of the digital economy and Industry 4.0, which are the basis for intelligent information systems, which makes it possible to optimize labour potential management in a digital environment. Scientists (Pan et al., 2022) investigate the impact of the digital economy as an innovative driver of productivity. Its results can be used to improve labour resource management mechanisms in a smart economy. The scientific paper (Zhang, 2023) examines the impact of artificial intelligence on the structure of employment, which is a key aspect for understanding changes in workforce management in a digitalized environment. The scientific work (Kurniawan et al., 2022) analyzes the use of digital technologies in the field of waste processing in the era of Industry 4.0, emphasizing the role of digitalization in building a circular economy. The scientific article (Deng et al., 2021) explores the concept of digital twins of cities as a new approach to the management of urban systems. This approach can be adapted for the management of labour resources in the smart economy. The consideration of the digital economy, blockchain technologies and cryptocurrencies emphasizes the opportunities for increasing the efficiency of labour resources in the sharing economy (Ertz and Boily, 2019).

The second block of scientific works focuses on issues of innovation management, entrepreneurial efficiency and resource optimization in various sectors of the economy. Research within this block concerns the development of startup ecosystems, management of economic security and the use of innovation models to achieve competitive advantages. The scientific work (Fatimah et al., 2020) reveals the concept of a circular economy based on Industry 4.0 for sustainable waste management. This methodology can be applied to improve workforce management through the integration of sustainable practices. The authors (Gryshchenko et al., 2021) analyze the competitive advantages of an innovation cluster in university education. This is related to the development of workforce competencies in the digital economy. Research (Balanovska et al., 2022) is devoted to the development of agrarian entrepreneurship in Ukraine and shows how digital technologies can increase the productivity of industries, in particular through innovative labour resource management. The authors (Ma and Zhu, 2022) explore the role of the digital economy in stimulating high-quality green development, which can be adapted to labour resource management through the implementation of environmentally friendly digital technologies. The study (Velychko, 2014) is devoted to the development of logistics infrastructure for the storage of crop products. The ideas of logistics optimization can be applied to the management of labour potential in digitalized logistics systems.

The third block focuses on research covering the impact of digital technologies on environmental aspects and sustainable development. Publications analyze the role of the digital economy and innovation in contributing to the achievement of sustainable development goals, in particular in the areas of waste management and carbon reduction. The scientific work (Dmytryshyn and Blahun, 2016) examines the efficiency of credit resource allocation in the banking system of Ukraine, which is important for financial support of projects related to the digitalization of labour potential. The scientific work (Dymchenko et al., 2022) considers modelling the impact of startup ecosystem components, which provides innovative approaches to the development of labour potential through the support of entrepreneurial activity. The scientific paper (Khodakivska et al., 2022) concerns issues of sustainable development of regions and management of economic security in the context of innovative entrepreneurship, which is an important aspect of ensuring sustainable development. The authors (Furman et al., 2023) investigate the issue of motivation and incentive of employees, where a key aspect of innovative management of labour potential in a digitalized environment is indicated. The study (Kubitskyi et al., 2024) assesses the impact of innovative technologies on global competitiveness through modelling, which concerns the use of new technologies for the development of labour potential. The study (Rayets et al., 2023) focuses on the role of leadership

in stimulating innovation and the creative potential of the team, which directly affects the management of labour resources in the conditions of digitalization. The scientific article (Voznyuk et al., 2021) is devoted to the use of interdisciplinary educational technologies, which contribute to the development of labour competencies in the digital age.

The next block covers digitalization and innovation in labour management, where there is a study of the impact of digital technologies and innovations on the optimization of management processes in the field of labour resources. It includes an analysis of financing digital innovations, the integration of economic security, as well as the impact of digitalization on increasing the efficiency of labour resources. The scientific work (Mazur et al., 2021) focuses on improving the financial management of enterprises, which is the basis for ensuring the stability of labour potential in the conditions of digitalization. The scientific article (Porfirenko et al., 2022) analyzes ways to optimize the mobility of passenger transportation in megacities and demonstrates how digital technologies contribute to increasing the efficiency of operational processes, which can be adapted to labour potential management. The methodological approach to assessing the creditworthiness of enterprises concerns the provision of financial resources for the implementation of digitalization innovations aimed at effective management of labour potential, as noted by scientists (Dmytryshyn and Blahun, 2014). Scientists (Kyryliuk et al., 2021) investigate organizational and economic drivers for ensuring safety and improving product quality, which is related to the integration of economic security into labour potential management strategies. The scientific article (Wen et al., 2022) analyzes the relationship between digitalization, competitive strategy and corporate innovation, which provides the basis for improving labour management. The scientific paper (Stolyarov et al., 2022) analyzes the optimization of the management of material and technical support of industrial enterprises, which is important for the effective use of labour resources. The scientific article (Bubenko et al., 2021) examines the territorial organization of innovative development, which emphasizes the importance of the regional aspect in labour management. The study (Blahun et al., 2022) analyzes stock indices as indicators of market efficiency, which is important for assessing economic stability in labour potential management.

The fourth block focuses on the implementation of innovative approaches to ensure the stability and sustainable development of labour resources. Particular attention is paid to the use of the latest technologies and models to optimize the use of labour potential in the context of globalization and economic challenges. The study (Tang et al., 2023) shows how digital transformation affects green innovation in enterprises, which is relevant for developing strategies for optimizing labour potential in the context of digitalization. The authors (Kyzym et al., 2023) analyze the use of cluster analysis for the development of startup ecosystems, which emphasizes the role of innovation in increasing the efficiency of labour potential through digital technologies. The scientific work (Xing et al., 2023) examines the relationship between the low-carbon digital economy and socio-economic development, which provides the basis for environmentally oriented labour potential management. Modelling of personnel innovation development management systems under the influence of the COVID-19 pandemic is described in the paper (Kompanets et al., 2022), which focuses on the adaptation of labour potential to crisis situations through digitalization. Scientists (Ovcharenko et al., 2022) propose modelling the functioning of eco-clusters, which contributes to the sustainable development of labour resources in the context of globalization. Analysis of the consequences of military conflicts for the socio-economic development of Ukraine in the scientific article (Pysar et al., 2020), indicates the need to adapt labour potential to changing conditions through digital technologies. Research (Li and Zhou, 2024) demonstrates how the development of the digital economy can contribute to the reduction of carbon emissions, which is important for sustainable labour potential management.

The next block analyzes approaches to the effective use of labour and material resources in the context of sustainable development. Particular attention is paid to the integration of environmental and economic aspects into labour management strategies to ensure the long-term sustainability of enterprises and regions. The development of a marketing and logistics business model for the vegetable market emphasizes the importance of digital technologies for optimizing labour resource management in specialized areas (Pysarenko et al., 2020). Research on genetic systems for determining animal productivity highlights the importance of innovations in genetic research for the agricultural sector, which may impact labour potential (Saienko et al., 2023). Scientists (Cao et al., 2023) analyzed the impact of smart city construction on corporate employment, which is important for the development of labour potential in urban systems. The work of scientists focuses on theoretical approaches to online marketing, which contributes to the improvement of labour resource skills in the digital economy (Vynogradova et al., 2020). A scientific article (Zhyvko et al., 2022) considers the security aspects of digitalization in management accounting, which ensures sustainable labour resource management in the context of globalization. The management of higher education institutions as a tool for developing the educational environment in the scientific work of scientists demonstrates the importance of innovations in the formation of qualified labour potential (Kubitskyi et al., 2023). Research on the management assessment of the value of agricultural land through fuzzy logic is reflected in the scientific work (Ostapchuk et al., 2021), which identifies innovative methods that can support the development of labour resources in the industry.

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The sixth block focuses on the implementation of digital technologies and innovative methods to optimize management processes in the context of labour resources, which allows to increase the efficiency and adapt enterprises to modern changes. In this context, key are studies that analyze new approaches to the development of qualified personnel, the implementation of distance learning and the use of smart technologies to develop entrepreneurial potential. Innovative management of labour potential in the system of digitalization of financial and economic security of the smart economy is related to the article (Balanovska et al., 2020) since both topics focus on the implementation of digital technologies to optimize processes. The article considers the profitability of digitalization of precision agriculture, which is an example of the transformation of traditional sectors of the economy using digital solutions. Such an approach requires new approaches to labour resource management, including the development of employee competencies, adaptation to technologies and ensuring their effective use. In the scientific article (Oseredchuk et al., 2022), new approaches to monitoring the quality of education in the process of distance learning, which contributes to the development of qualified labour resources, are considered. The scientific paper (Dankevych et al., 2021) considers the ecological and economic management of innovative activities of enterprises, which supports the sustainable development of labour potential through the integration of innovative technologies. The scientific paper (Shtuler et al., 2024) investigates innovative management of eco-projects aimed at the development of entrepreneurial potential in smart technologies, which enhances the efficiency of labour resource management.

The authors of the last block focus on the application of innovative approaches to resource management in the agro-industrial sector and the development of effective models for the sustainable use of labour potential within territorial communities. Research in this area emphasizes the importance of environmentally oriented strategies, resource optimization in agriculture, and the integration of digital technologies to support the development of enterprises and local economies. The study (Vashchenko et al., 2023) examines the impact of feeding levels on pig growth depending on the genotype, which demonstrates the possibilities of resource optimization in the agricultural sector. Important for our analysis is the analysis of state regulation of employment in the context of innovative entrepreneurship, which shows the importance of managing labour potential at the level of territorial communities (Vasylchak et al., 2022). Research on animal genetic polymorphisms highlights the importance of innovative methods of labour resource management in agriculture (Vashchenko et al., 2022).

Thus, digitalization as an element of the smart economy creates new demands on labour potential, which links these studies in the general context of ensuring financial and economic security. The disadvantages of these works are that most of them only partially touch on aspects directly related to innovative management of labour potential in the context of digitalization. For example, many studies focus on general issues of digital transformation, green innovations or resource efficiency, but do not consider the integration of these processes into the labour sphere. Some works place excessive emphasis on specific industries, such as agriculture or education, which may narrow their application to the broader context of the smart economy.

AIMS AND OBJECTIVES

The purpose of the article is to develop and test an analytical approach to forecasting the dynamics of innovative labour potential management in Ukraine in the context of digitalization of the financial and economic security of the smart economy, which includes identifying key trends or factors that affect the efficiency of labour resources use, as well as creating an integrated assessment for assessing the state of labour potential management.

Research objectives:

- to analyze statistical data on labour potential management indicators in Ukraine for the period 2008–2021;
- to deepen the methodology for forecasting key indicators of the state of labour potential management for 2022–2025;
- to develop a comprehensive integrated assessment of the state of labour potential management using methods of mathematical and economic modelling and determining weight coefficients;
- to identify the most significant factors that influence the integrated assessment of the state of labour potential management by analyzing the dependencies between indicators and building regression models;
- to offer recommendations for improving the efficiency of labour potential management in the context of the digital transformation of the smart economy.

METHODS

The article uses an approach that combines statistical analysis and mathematical and economic modelling to assess labour potential management. The collected statistical data were used to construct time series, assess trends, and forecast key indicators. To integrate heterogeneous data, a complex integral assessment was developed based on the modified principal component method, which allows for determining weighting coefficients for each indicator. The assessment of relationships between indicators was carried out by constructing a covariance matrix and determining eigenvectors and regression coefficients, which provided the possibility of analyzing the influence of individual factors. Forecasting the dynamics of innovative labour potential management in the system of digitalization of financial and economic security of the smart economy was carried out using an adaptive model using the Holt method, which takes into account changes in rates and fluctuations in data, providing a high level of accuracy. Such forecasting requires the use of a reliable analytical approach. One of these is a method that allows taking into account trends and adapting to changes over time. This approach makes it possible to provide effective data modelling, taking into account both stable and variable components, which are important for maintaining a balance between innovation processes and safety. The Holt method is used to forecast time series taking into account the trend component. In this model, the functions g(t) and r(t) are introduced, which correspond to the level of the smoothed series and the trend estimate, respectively. For the initial year of analysis, the function g(t) is defined as g(1) = X(1), where X(1) is the actual value of the indicator under study for a given year. X(t) in a given year, and the function r(t) for the first year takes the value r(t)=0. For subsequent years, the values of these functions are calculated using the following recurrent formulas and generally accepted methods of mathematical analysis:

$$g(t) = \alpha X(t) + (1-\alpha)(g(t-1) + r(t-1) \quad (1)$$

$$r(t) = \beta\big(g(t) - g(t-1)\big) + (1-\beta)r(t-1) \quad (2)$$

The predicted values for j years ahead are determined using the values of the functions g(t) and r(t) obtained for the last year of the retrospective period according to the formula:

$$X(T+j) = g(T) + jr(T) \quad (3)$$

where T is the number of years in the retrospective period.

To assess the accuracy of the forecast, the predicted value Q(t) is calculated for each year of the retrospective period. For the first year, the value $Q(1) = X(1)$, and for the other years we use the equality $Q(t) = g(t-1) + r(t-1)$. The absolute forecast error is calculated as $\Delta(t) = X(t) - Q(t)$. The accuracy of the model is estimated using the integral indicator:

$$\lambda = 1 - \frac{\sum_{t=2}^{T} \delta(t)}{T-1} \quad (4)$$

$$\delta(t) = \frac{\Delta^2(t)}{x^2(t)} \quad (5)$$

The obtained accuracy indicator λ indicates the suitability of the model for forecasting and making management decisions. Thus, the methodology allows you to calculate forecast values, focusing on trends and possible fluctuations arising from the dynamics of digital transformations. Its use is especially appropriate for analyzing systems where the speed of change and uncertainty are key characteristics. This approach contributes to the prompt adoption of management decisions aimed at increasing the efficiency of the use of labour potential in the conditions of the rapid development of the smart economy. Such forecasting provides a strategic vision and forms the basis for adaptive planning that takes into account the challenges of digitalization, the integration of new technologies and maintaining the stability of financial and economic security. This allows you to optimize management processes, increase competitiveness and ensure sustainable development.

RESULTS

It is advisable to assess the state of innovative labour potential management in the system of digitalization of financial and economic security of the smart economy on the basis of complex integral indicators. To create such indicators, we have used statistical data from the state service on labour potential. The complex integral assessment uses data on population employment, labour mobility, use of working hours, reasons for underemployment, dynamics of real wages of

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employees and the presence of collective agreements that regulate social and labour relations. To integrate these data in the complex assessment of labour potential management in the system of digitalization of financial and economic security of the smart economy, a toolkit of mathematical and economic modelling based on the modified principal component method was used. The list of indicators used is given in Table 1.

Table 1. Indicators for assessing labour potential management.

Designation	Indicator content
X1	Economically active population, thousands of people
X2	Employed population, thousands of people
X3	Registered number of full-time employees, thousands of people
X4	Dismissal of employees due to staff turnover, thousands of people
X5	Dismissal of employees due to downsizing, thousands of people
X6	Number of employees on unpaid leave (for the period of suspension of work), thousands of people
X7	Number of employees transferred to part-time work (week) for economic reasons, thousands of people
X8	Working hours worked per full-time employee as a % of the staff working hours fund
X9	Real wage in % to previous year
X10	Number of registered collective agreements

The indicators in Table 1 for assessing labour potential management reflect various aspects of economic activity, employment, labour efficiency and the stability of labour relations. They characterize the size of the economically active population, the level of employment, the number of full-time employees and the extent of staff turnover, as well as the impact of economic factors such as downsizing or transfer to part-time work. In addition, the indicators capture labour productivity by accounting for time worked and changes in real wages, which indicate the socio-economic conditions of workers. Aspects of collective work are also taken into account, in particular the number of concluded contracts, which is an indicator of the level of organization of labour relations. Such data provide a comprehensive approach to analyzing labour potential and allow us to assess the impact of digitalization on its effectiveness. Indicators for assessing labour potential management are key to understanding the state of the labour market and its dynamics in the context of digital transformation. They show how effectively the economically active population is involved, the employment rate, and the number of full-time employees. Analysis of staff turnover and layoffs helps identify problem areas in the stability of labour relations, which is critical for long-term planning. Additional aspects, such as transferring employees to part-time work or sending them on unpaid leave, indicate the level of adaptability of labour potential to economic challenges. The indicator of time worked demonstrates the efficiency of using labour resources, and the dynamics of real wages allow us to assess the level of material security of employees. In turn, the number of concluded collective agreements reflects the degree of organization and legal protection in the labour sphere. All these indicators together form a complete picture of the effectiveness of labour resource management in the modern smart economy. Indicators X1, X2, X3, X8, X9 and X10 are stimulants, their growth reflects an improvement in the state of labour potential management, and indicators X4, X5, X6 and X7 are destimulants. To study the dynamics of labour potential management indicators, we will select the period 2008-2021. Next, through t, we will determine the serial number of the year in the period involved in the analysis, and through $X_i(t)$ – the value of the indicator X_i for a separate period of time. The values of $X_i(t)$ are taken from the collections "Labour of Ukraine", published by the State Statistics Service of Ukraine, and are given in Table 2.

Table 2. The value of indicators of the state of labour potential management in Ukraine in 2008-2021. (*Source: systematized by the authors using the State Statistics Service of Ukraine https://ukrstat.gov.ua)*

Years	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10
2008	22397.4	20972.3	11310.6	3285.5	88.6	179.5	1205.8	86.8	106.3	95656
2009	22150.3	20191.5	10766.3	2544.9	169.5	275.9	2063.3	83.4	90.8	94964
2010	22051.6	20266	10993.4	2652.4	152.2	363.3	1466.8	85.5	110.2	105014
2011	22056.9	20324.2	10779.3	2788	215.9	189.5	908.9	87.1	108.7	98514
2012	22011.5	20354.3	10123	2787.6	196.5	137.9	736.8	87.4	114.4	101712
2013	21980.6	20404.1	9720	2647.8	223.9	94.4	758.9	87.2	114.4	84401
2014	19920.9	18073.3	8959	2376	146.7	90.5	888.1	86.2	93.5	76017
2015	18097.9	16443.2	8065	2092.4	175.1	62.6	742.1	86.7	79.8	69602
2016	17955.1	16276.9	7868	1993	124.5	163.6	464.2	84.1	109	64158
2017	17589.5	16156.4	7679	2120.4	151.5	149.3	685.7	84.8	119.1	63359
2018	17854.4	16360.9	7661.5	2113.5	116.4	90.227	559.0	85.0	112.5	59622
2019	17939.5	16578.3	7443	2129.1	122.7	72.8	491.8	85.2	109.8	51408
2020	18066	15915.3	7345.2	1866.8	140.2	212.7	684.8	81.3	107.4	51125
2021	17321.6	15610	7096	1873.1	172.2	86.9	466.1	84.1	110.5	43154

Table 2 shows changes in indicators characterizing labour potential management in Ukraine from 2008 to 2021. During this period, there has been a gradual decrease in the economically active population (X_1) and the employed population (X_2), which is evidence of a decrease in the total labour force in the country. In particular, the number of economically active persons has decreased by several thousand people annually. At the same time, there is a decrease in the number of full-time employees (X_3), which may be due to job cuts or changing employment structures. The staff turnover indicator (X_4) shows uneven fluctuations, in particular, sharp jumps in dismissals were observed in 2009 and 2014, which may be due to economic difficulties. On the other hand, indicators related to employees on unpaid leave or transferred to part-time work for economic reasons (X_6 and X_7) indicate the adaptation of the workforce to changing economic conditions, in particular, a reduction in working hours during periods of economic crises. In 2020 and 2021, part-time work rates peaked, which may have been related to the COVID-19 pandemic and economic hardship. Working hours (X_8) per full-time employee fluctuated, but remained generally stable, indicating a maintained level of labour productivity. The real wage indicator (X_9) also fluctuated, but in most years, it was above 100%, indicating a gradual increase in real wages compared to the previous year, although it decreased significantly in 2015. Overall, there has been a decrease in the number of collective agreements (X_{10}) in the period 2014–2021, which may indicate a decrease in the level of social protection of employees or changes in organizational forms of labour resource management. Thus, Table 2 demonstrates the general trends in the reduction of the number of employed persons, changes in working conditions and levels of social guarantees, reflecting the difficult economic situation in the country.

Using statistical data for 2008-2021, we will make forecasts of the indicators of the state of labour potential management in Ukraine for 2022-2025. Comparing the obtained forecasts with real data, we can estimate the magnitude of the reduction in labour resources as a result of Russian aggression. Calculation of the predicted values for the indicator of the number of economically active population is given in Table 3. The values of the Holt model parameters are $\alpha = 0{,}9,\ \beta = 0{,}9$. The accuracy of the obtained forecast is λ =99,81%.

Table 3. Determination of the expected number of economically active population in Ukraine using the Holt method. *(Source: calculated by the authors using the source https://ukrstat.gov.ua)*

Year	T	X1(t)	g(t)	r(t)	j	X(T+j)	g(t)+r(t)	Δ(t)	δ(t)	λ
Retrospective period										
008	1	22397.4	2.8	0.00			22397.4			
009	2	22175.0	2.98	-200.15			22397.4	-247.1	0.00012	
010	3	22043.9	3.10	-137.99			21974.9	76.7	0.00001	
011	4	22041.8	3.29	-15.71			21905.9	151.0	0.00005	
2012	5	22013.0	3.32	-27.53			22026.1	-14.6	0.00000	
2013	6	21981.1	3.22	-31.44			21985.4	-4.8	0.00000	
2014	7	20123.8	2.92	-1674.72			21949.6	-2028.7	0.01037	
2015	8	18133.0	2.61	-1959.16			18449.1	-351.2	0.00038	
2016	9	17777.0	2.39	-516.35			16173.9	1781.2	0.00984	99.81%
2017	10	17556.6	2.29	-249.96			17260.6	328.9	0.00035	
2018	11	17799.6	2.20	193.72			17306.7	547.7	0.00094	
2019	12	17944.9	2.01	150.10			17993.3	-53.8	0.00001	
2020	13	18068.9	1.80	126.62			18095.0	-29.0	0.00000	
2021	14	17409.0	1.60	-581.25			18195.5	-873.9	0.00255	
Forecast period										
2022					1	16827.7				
2023					2	16246.5				
2024					3	15665.2				
2025					4	15084.0				

The table shows the dynamics of calculating the expected number of economically active population in Ukraine using the Holt method. In the retrospective period, data on population size, growth rates and forecast errors for each year are

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presented. The values of forecast indicators are based on an analysis of trends in previous years, taking into account changes in rates and the level of fluctuations. The method takes into account factors of population change, estimation errors, as well as weighting factors that refine the calculations for each year. The forecast for the period 2022–2025 indicates a gradual reduction in the number of economically active population, which reflects the general trend of demographic and socio-economic changes. The calculation data indicate a high level of accuracy of the model, confirmed by minimal deviation indicators in the retrospective period. The forecast obtained shows that in addition to Russian aggression, other factors that also operated during the retrospective period influenced the decrease in the number of economically active population. Similar forecasts have been made for other indicators reflecting the state of labour potential management in Ukraine. The forecast results are presented in Table 4.

Table 4. Projected values of indicators reflecting the state of labour potential management in Ukraine.

Indicator	Predicted values				Forecast accuracy
	2022	2023	2024	2025	
Economically active population, thousands of people	16827.7	16246.5	15665.2	15084.0	99.81%
Employed population, thousands of people	15188.1	14775.5	14362.9	13950.3	99.73%
Registered number of full-time employees, thousands of people	6886.5	6675.2	6443.8	6222.5	99.84%
Dismissal of employees due to staff turnover, thousands of people	1796.3	1738.6	1680.8	1623.1	98.25%
Dismissal of employees due to staff reduction, thousands of people	186.9	214.4	241.9	269.3	92.56%
Working hours worked per full-time employee as a % of the staff working hours fund	84.9	86.2	87.6	88.9	99.89%
Real wages as a % of the previous year	112.0	114.1	116.2	118.3	96.96%
Number of registered collective agreements	37358	31037	24715	18394	98.99%

Thus, using the Holt adaptive model, it was expected that in 2021 the number of economically active population, employed population, number of full-time employees and number of registered collective agreements would decrease. Improvement in the use of working time, growth in real wages and reduction in staff turnover were forecast, although some increase in the number of dismissed employees due to downsizing was expected. Table 4 shows the dynamics of key indicators characterizing labour potential management in the context of the digitalization of financial and economic security of the smart economy. The predicted values indicate a gradual decrease in the number of economically active and employed population, which may be a consequence of demographic changes, structural transformations or other economic factors. A similar trend is observed in the number of full-time employees, reflecting the general reduction of jobs in traditional sectors. Working hours of full-time employees demonstrate positive dynamics, growing relative to the staffing fund, which indicates an increase in the efficiency of working time use. Real wages are also growing, although with somewhat less forecast accuracy, reflecting stable income growth. At the same time, the reduction in the number of collective agreements indicates a change in approaches to organizing labour relations in the digital economy. Dismissals due to employee turnover are gradually decreasing, while downsizing is showing a reverse trend, which may indicate a reorganization of labour resources. Overall, the data in Table 4 provide an idea of the transformational processes in the labour sector that are taking place under the influence of digital technologies and economic challenges. To obtain a comprehensive integrated assessment of labour potential management, data for the period 2008-2023 were analyzed. Since in 2022 and 2023, there was a significant decrease in the number of full-time employees, to obtain an objective assessment, the absolute indicators X_4 (dismissal of employees due to staff turnover), X_5 (dismissal of employees due to staff reduction), X_6 (number of employees who were on unpaid leave for the period of cessation of work), and X_7 (number of employees transferred for economic reasons to part-time work or a week) should be replaced by relative indicators xi, determined by the equality:

$$x_i = \frac{X_i}{X_3} \quad (6)$$

In this case, other indicators X_i will be considered $x_i = X_i$.

To obtain a comprehensive integral assessment of labour potential management, the indicators xi need to be brought into a comparative form. To do this, we will replace these indicators with dimensionless indicators Y_i, which vary on the interval

from 0 to 1, and for stimulants the value Y_i=1 corresponds to the maximum, and the value Y_i=0 to the minimum value of the indicator x_i; and for destimulants – vice versa.

We define a comprehensive integral assessment of the management of the country's labour potential as a linear combination of indicators Y_i:

$$W(t) = \sum_{i=1}^{10} \varepsilon_i Y_i(t). \quad (7)$$

To determine ε_i we find the covariance coefficients between the indicators Y_i. These coefficients form the covariance matrix Λ, which has the following form:

0.093	0.089	0.088	0.012	0.024	-0.011	-0.033	0.040	0.013	0.095
0.089	0.085	0.083	0.008	0.023	-0.007	-0.028	0.039	0.013	0.087
0.088	0.083	0.085	0.013	0.029	-0.015	-0.035	0.039	0.007	0.094
0.012	0.008	0.013	0.069	-0.007	-0.048	-0.037	-0.028	-0.024	0.020
0.024	0.023	0.029	-0.007	0.055	-0.020	-0.021	0.004	0.000	0.033
-0.011	-0.007	-0.015	-0.048	-0.020	0.078	0.036	0.041	-0.010	-0.023
-0.033	-0.028	-0.035	-0.037	-0.021	0.036	0.057	0.009	0.024	-0.044
0.040	0.039	0.039	-0.028	0.004	0.041	0.009	0.070	0.003	0.056
0.013	0.013	0.007	-0.024	0.000	-0.010	0.024	0.003	0.075	0.003
0.095	0.087	0.094	0.020	0.033	-0.023	-0.044	0.056	0.003	0.124

We determine the eigenvalues of this matrix, which are the roots of the equation $\det(\Lambda - \gamma E) = 0$, where E – is the identity matrix, and $\det(\Lambda - \gamma E)$ – is the determinant of the matrix $\Lambda - \gamma E$. The maximum root of this equation $\gamma_0 = 0{,}4164$. The obtained maximum value of the matrix Λ corresponds to the eigenvector $L = \{l_1, l_2, l_3, l_4, l_5, l_6, l_7, l_8, l_9, l_{10}\}$, the coordinates l_i of which are a non-zero solution of the system of linear equations $\Lambda L = \gamma_0 L$. The weight coefficients ε_i in the complex integral estimate W(t) are determined from the equality:

$$\varepsilon_i = \frac{l_i^2}{\sum_{i=1}^{10} l_i^2} \quad (8)$$

The coordinates of the eigenvector L and the weight coefficients ε_i determined by this method are given in Table 5.

Table 5. Coordinates of the eigenvector L and weight coefficients of the complex integral assessment of the management of the labour potential of Ukraine.

i	Coordinates l_i of the eigenvector L	Weighting factors ε_i
1	0.4591	0.2108
2	0.4315	0.1862
3	0.4467	0.1995
4	0.0844	0.0071
5	0.1582	0.0250
6	-0.0956	0.0091
7	-0.2036	0.0415
8	0.2135	0.0456
9	0.0325	0.0011
10	0.5237	0.2743

Thus, a comprehensive integrated assessment of Ukraine's labour potential management looks like this:

$$W(t) = 0{,}2108Y_1(t) + 0{,}1862Y_2(t) + 0{,}1995Y_3(t) + 0{,}0071Y_4(t) + 0{,}0250Y_5(t) + +0{,}0091Y_6(t) + 0{,}0415Y_7(t) + 0{,}0456Y_8(t) + 0{,}0011Y_9(t) + 0{,}2743Y_{10}(t)$$

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The dynamics of this assessment are shown in Figure 1.

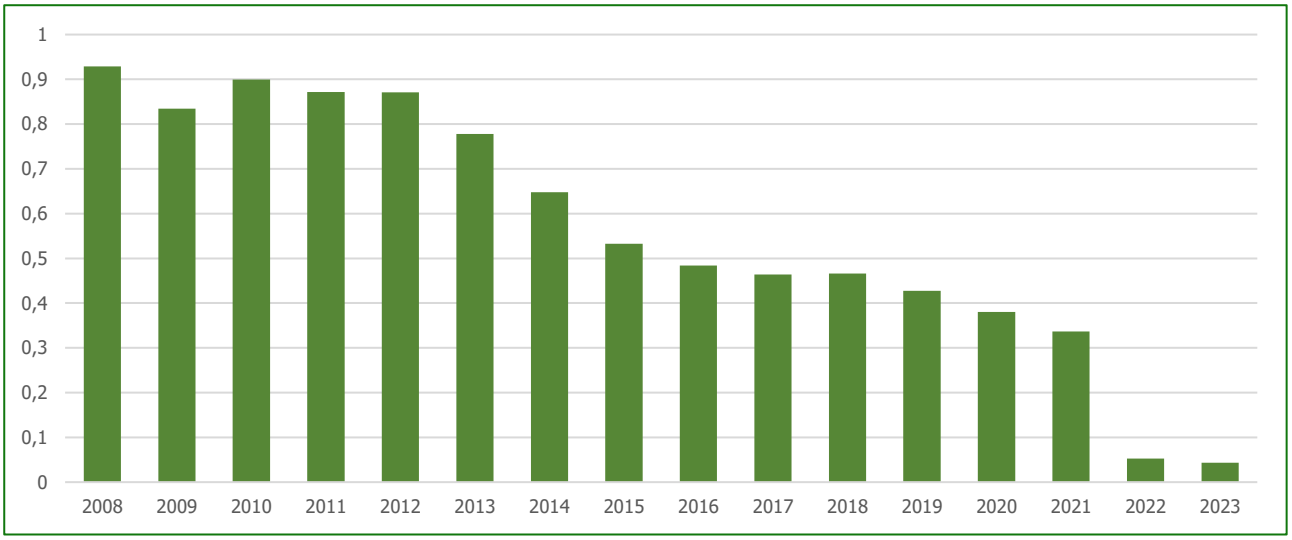

Figure 1. Dynamics of the comprehensive integrated assessment of labour potential management in Ukraine.

Figure 1 shows a gradual decline in the comprehensive integrated assessment of labour potential management over the period from 2008 to 2023. In the beginning, a consistently high level of assessment is observed, which gradually begins to decrease after 2012. A particularly noticeable decline occurred in 2014–2016, which may be due to the influence of socio-economic and political factors. In subsequent years, the dynamics become less rapid, but the downward trend persists. By 2023, the indicators reach a minimum level, which may indicate significant challenges in the field of labour potential management in the context of digitalization and economic transformations. The graph clearly reflects changes and makes it possible to assess both short-term fluctuations and long-term trends. Let us estimate the influence of factors determined by indicators x_i, on the complex integral estimate $W(t)$. Let us define the pairwise linear regression equation $W = a_i x_i + b_i$ for each indicator x_i. The coefficients a_i and b_i of these equations are determined by the least squares method. Their values are solutions to the system of equations:

$$\begin{cases} a_i \sum_{t=1}^{T} x_i^2(t) + b_i \sum_{t=1}^{T} x_i(t) = \sum_{t=1}^{T} x_i(t) W(t) \\ a_i \sum_{t=1}^{T} x_i(t) + b_i T = \sum_{t=1}^{T} W(t) \end{cases} \quad (9)$$

where T is the number of years in the retrospective period.

To check the adequacy of the obtained equation with the available statistical data, the coefficient of determination R_i^2 is determined by the formula:

$$R_i^2 = 1 - \frac{\sum_{t=1}^{T} (W(t) - a_i x_i(t) - b_i)^2}{\sum_{t=1}^{T} (W(t) - \overline{W})^2} \quad (10)$$

Based on the coefficient of determination, the obtained criterion indicator is determined according to the equation:

$$F_i = \frac{R_i^2}{1 - R_i^2} (T - 2) \quad (11)$$

If the obtained criterion indicator exceeds the critical value of this criterion, which corresponds to a confidence probability of 0.95 and degrees of freedom k_1=1 and k_2=T-2, then the regression equation is considered adequate, and the influence of the indicator x_i on the complex integral estimate $W(t)$ is considered significant. The critical value of the Fisher criterion for a confidence probability of 0.95 and degrees of freedom k_1=1 and k_2=T-2=14 is 4.6.

The results of the study of the influence of indicators x_i on the complex integral estimate W(t) are given in Table 6.

Table 6. Assessment of the influence of indicators on the complex integral estimate of the state of labour potential management in Ukraine.

	Regression equation coefficients		Determinant indicator	Real Fisher exact measure	Determining the depth and extent of impact
	`	bi			
x1	0.000083	-0.99446	0.95618	305.47353	affects
x2	0.000074	-0.6948	0.93455	199.91538	affects
x3	0.000125	-0.48024	0.98115	728.61983	affects
x4	-2.653724	1.267731	0.01855	0.26467	does not affect
x5	-28.936502	1.085116	0.16353	2.73697	does not affect
x6	5.532542	0.470175	0.01991	0.28442	does not affect
x7	4.212457	0.180753	0.23068	4.19782	does not affect
x8	0.099043	-7.874	0.33718	7.12191	affects
x9	0.002540	0.296031	0.00974	0.13773	does not affect
x10	0.000012	-0.30405	0.91059	142.57433	affects

Thus, it was found that the number of economically active population, the number of employed population, the registered number of full-time employees, the percentage of working hours worked by a full-time employee in relation to the staff working hours fund, and the number of registered collective agreements have a significant impact on the comprehensive integral assessment of labour potential management. The closest relationship was found between the comprehensive integrated assessment of labour potential management and the number of full-time employees. The relationship between these indicators is shown in Figure 2.

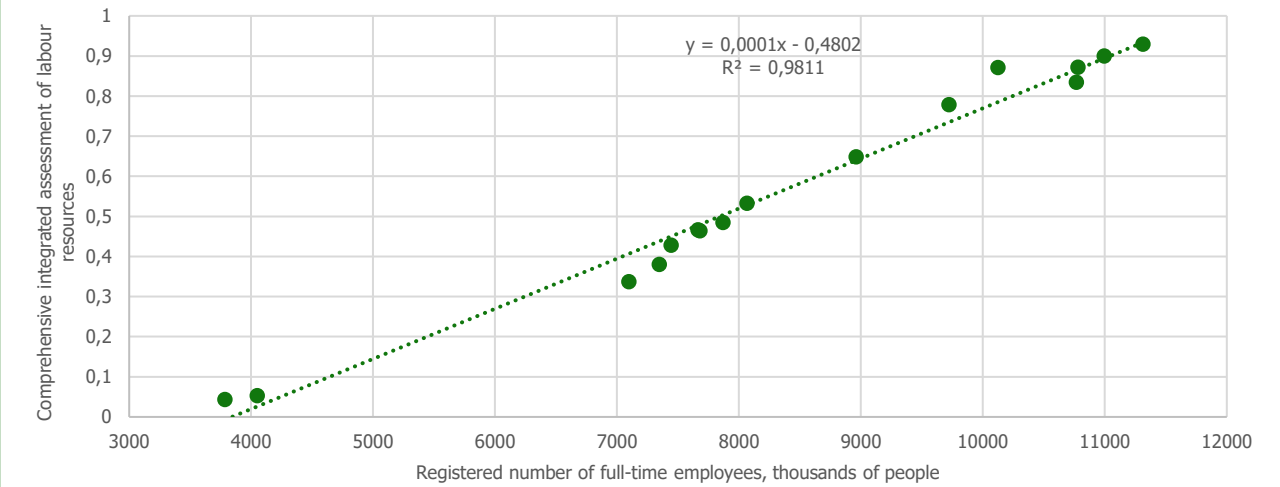

Figure 2. Relationship between the registered number of full-time employees and the comprehensive integral assessment of labour potential management. *(Source: calculated by the authors)*

Figure 2 illustrates the relationship between the number of full-time employees and the comprehensive integral assessment of labour potential management. The graph demonstrates a clear linear relationship, where the increase in the number of employees is accompanied by an increase in the integral assessment. The constructed regression line reflects a high degree of correlation between the indicators, which is confirmed by the coefficient of determination R2=0.9811. This relationship indicates that the effectiveness of labour potential management is largely determined by the number of employees, which affects the integral indicators in the digitalization system. The linear regression equation allows you to predict the management assessment for a certain number of employees, which can be useful for modelling strategic management decisions.

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DISCUSSION

Most scientific research only indirectly addresses human resource management. They focus on general aspects of the digital economy, green innovation, environmental safety, or smart technologies, but do not offer specific mechanisms for developing human capital in these conditions. For example, (Hao et al., 2023) consider the impact of digitalization on green economic development through the optimization of industrial structure and green innovation. The discussion could focus on how to integrate the proposed mechanisms into labour potential management since the authors do not sufficiently consider the human factor. The question remains: can these approaches take into account the socio-economic aspects of labour resource development? The scientist (Williams, 2021) considered the concept of the digital economy, but the author does not detail how these technologies can be applied to labour potential. The discussion could focus on the role of digital tools in improving the skills of employees and developing managerial competencies in the context of a smart economy. The scientific article (Shtuler et al., 2024), focuses on eco-projects in the bioeconomy but does not sufficiently highlight the connection with labour resources. The question remains: how will the application of these approaches to personnel management affect the stability and efficiency of labour potential? An important aspect is also the integration of smart technologies into the training and retraining of personnel. The authors (Kubitskyi et al., 2024), analyze the impact of innovative technologies on competitiveness, but the connection with labour resource management is only superficially mentioned. The discussion could cover the issue of how digital transformation creates new opportunities for the development of labour potential, especially in the field of small and medium-sized businesses. Further research into digital twins of cities is a revolutionary approach, but the emphasis is on urban management, not on human capital (Deng et al., 2021). It is worth investigating in the future how the implementation of digital twins can affect employee productivity in the smart economy. Is it possible to adapt these technologies for monitoring and optimizing labour resources? The work (Blahun et al., 2022), analyzes stock indices as indicators of market efficiency but does not consider the human factor. The discussion may revolve around how the use of these indicators can influence employment planning, especially in the financial and economic security of enterprises. Research on the impact of smart cities on employment opens up interesting perspectives but does not sufficiently consider the impact on the quality of work and social aspects (Cao et al., 2023). However, the discussion may focus on issues of social justice in job creation, as well as possible challenges for workers due to automation. In general, the debatability of these works emphasizes the need for a more comprehensive approach that combines technological, social and economic aspects of labour resource management in the context of digitalization.

CONCLUSIONS

The results of the article substantiate the importance of innovative labour potential management in the context of digitalization of the financial and economic security of the smart economy, as well as the application of the Holt method to forecast key indicators of this process. Forecasting is necessary for adapting to rapid changes arising from digital transformations and allows you to effectively model the dynamics of labour resources, taking into account trends and possible fluctuations. Using the Holt method to forecast the dynamics of labour potential in Ukraine allows you to obtain accurate forecasts of changes in the number of economically active and employed population, the number of full-time employees, staff turnover, the use of working time, real wages and collective agreements. The calculations show a high level of forecast accuracy, which is confirmed by minimal deviations in the retrospective period. The projected values for 2022-2025 indicate a decrease in the number of economically active population, as well as a reduction in the number of full-time employees and registered collective agreements, which indicates certain structural changes in the labour market. At the same time, the increase in the efficiency of working time use and the increase in real wages indicate positive trends in the use of labour potential. In general, it can be noted that labour potential forecasting is an important tool for planning adaptive management strategies in the context of rapid digitalization and changes in the financial and economic security of the smart economy. The use of such methods helps not only to increase the efficiency of management decisions but also to ensure the stable development of economic systems in the context of constant change. The prospects for research into innovative labour potential management in the context of digitalization reflect the need to adapt forecasting methods to the rapidly changing conditions of the digital economy. This includes improving forecasting models based on artificial intelligence, which allows for a more accurate assessment of changes in the labour market and the need for certain skills and professions. Also, one of the important problems is the integration of the latest digital tools for personnel management, which will ensure effective recruitment, training and monitoring of qualifications.

ADDITIONAL INFORMATION

AUTHOR CONTRIBUTIONS

All authors have contributed equally.

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CONFLICT OF INTEREST

The Authors declare that there is no conflict of interest.

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Пронько Л., Пузирьова П., Собчишин В., Варава Л., Захаров Д., Виноградова О.

ІННОВАЦІЙНЕ УПРАВЛІННЯ ТРУДОВИМ ПОТЕНЦІАЛОМ У СИСТЕМІ ДИДЖИТАЛІЗАЦІЇ ФІНАНСОВО-ЕКОНОМІЧНОЇ БЕЗПЕКИ СМАРТЕКОНОМІКИ

У роботі досліджено специфіку та особливості оцінювання інноваційного управління трудовим потенціалом у системі диджиталізації фінансово-економічної безпеки смартекономіки. Розроблено методику прогнозування динаміки інноваційного управління трудовим потенціалом, який дає змогу враховувати тенденції розвитку та адаптуватися до змін, що виникають у поточній діяльності суб'єктів підприємництва. Запропонована методика забезпечує ефективне моделювання даних, яке враховує й стабільні, і змінні фактори, що важливі для підтримання балансу між інноваціями та безпекою. Розроблена методика прогнозування не лише дозволяє оцінити зміни трудового потенціалу, а й допомагає ухваленню рішень при адаптивному управлінні в умовах стрімкої цифровізації економіки. Наведена комплексна оцінка стану трудового потенціалу з використанням математично-економічного моделювання й методів

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інтеграції даних на основі модифікованої головної компоненти. Результати прогнозування показали тенденції скорочення економічно активного населення, зайнятості й кількості штатних працівників в Україні через зовнішні економічні та соціальні фактори, включаючи російську агресію. Результати статті будуть корисні для широкого кола читачів, зокрема для керівників підприємств і організацій, які займаються управлінням трудовими ресурсами й економічною безпекою, а також для економістів та аналітиків, що займаються прогнозуванням змін в економіці.

Ключові слова: трудовий потенціал, заробітна плата, працівники, інноваційне управління, смартекономіка, диджиталізація, фінансово-економічна безпека, конкурентоспроможність

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