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Digitalization and sustainable development

Digitalization is often understood as the introduction of digital technologies into various spheres of life to improve the quality of life and development. Digitalization is also a tool that can facilitate the implementation of the Sustainable Development Goals (SDGs) in three main directions: the transition to a closed resource cycle, reduction of inequality of opportunities and reduction of the anthropogenic impact on the environment.

Digitalization is the most important tool for achieving the SDGs, but so far, positive and truly large-scale effects of the digital transition have manifested in a limited number of countries and spheres of activity. To transform digital services into benefits that allow for launching new business models that can put the global economy on the path of inclusive economic growth, it is important to harmonize the transformations associated with digitalization and sustainable development.

In the first issue of the 2022 Sustainable Development and Engineering Economics journal, the authors examine how digitalization affects the sustainable development of enterprises and regions.

The first section, Economics of engineering and innovation decisions as a part of sustainable development, presents the article “Digital transformation of the information and analytical system of crisis management in the procedures of rehabilitation of enterprises” by L. Narkevich. The author shares practical experience of the results of an industrial enterprise’s digital transformation.

The Enterprises and sustainable development of regions section presents the article “Formation of effective organizational management systems” by S. Dianov and B. Isroilov. This article is devoted to adapting the mechanism for evaluating the effectiveness of organizational management systems to an agent-oriented approach and assessing the adequacy of such models and determining the boundaries of their capabilities.

In the Sustainable development of regional infrastructure section, authors M. Balog, S. Demidova and N. Lesnevskaya contribute to solving related problems with the article “Risks and factors of human capital development in the digital economy”. The authors consider the issues of access to information technologies in obtaining new knowledge, professional development and comprehensive personal development throughout life, and they identify the specifics of human capital development in the digital economy and trends in its development, use and limitations. According to the authors, promoting sustainable development, reducing inequality, maintaining a balance of supply and demand in the labour market and striving for responsible consumption are governments’ current priorities.

In the final section, Management of knowledge and innovation for sustainable development, the article “Development of innovative industrial cluster strategy using compound real options” by K. Anguelov focuses on achieving sustainable development by evaluating the effectiveness of the implementation of European funds in the member states, with a special focus on Bulgaria. The author analyses the added value of European funds and their effectiveness and efficiency for national economies to understand their contribution to the sustainable development of specific member states.

The second article in this section is “Digital inequality of Russian regions” by O. Yanovskaya, N. Kulagina and N. Logacheva. The authors have developed an author’s approach to assessing the effectiveness of digital transformation processes at the regional level. A distinctive feature of the proposed methodology is the accounting of indicators reflecting the development of digital infrastructure and the use of digital technologies, staffing and innovation activity, which are integrated into three indices and eventually form an additive model for conducting a comprehensive assessment of the digitalization processes of the region.

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SECTION 1

**ECONOMICS OF ENGINEERING
AND INNOVATION DECISIONS
AS A PART OF SUSTANABLE DEVELOPMENT**

РАЗДЕЛ 1

**ЭКОНОМИКА ИНЖЕНЕРНЫХ
И ИННОВАЦИОННЫХ РЕШЕНИЙ
КАК ЧАСТЬ УСТОЙЧИВОГО РАЗВИТИЯ**

Research article

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DIGITAL TRANSFORMATION OF THE INFORMATION-ANALYTICAL SYSTEM FOR CRISIS MANAGEMENT IN ENTERPRISE REHABILITATION PROCEDURES

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Abstract

The problem considered in this article is relevant owing to the inevitable digital transformation of the crisis management of enterprises in bailout procedures, which is associated with a new technological shift and the growing competition between countries for the markets of Industry 4.0 technologies. The introduction of high-tech solutions has led to changes in the format and content of crisis management, with a focus on solving the optimisation tasks of operational management in bailout procedures and rethinking approaches to develop digital development strategy scenarios that include mobile and cloud-based analytical solutions. The digital transformation of the formats of system and comprehensive analyses in bankruptcy institutions has become a natural step in the development of crisis management. This article considers the problem of developing an effective information and analytical system for crisis management in bailout procedures for domestic enterprises in the new economic conditions. The study demonstrates the need to introduce digital tools in building an effective information system for crisis management. Actively developing the market for information products and services offers many opportunities for enterprises to solve problems in the transition to automated and digital technology crisis management.

Keywords: crisis management, analysis, digital transformation, bailout, efficiency, resource

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ЦИФРОВАЯ ТРАНСФОРМАЦИЯ ИНФОРМАЦИОННО-АНАЛИТИЧЕСКОЙ СИСТЕМЫ АНТИКРИЗИСНОГО УПРАВЛЕНИЯ В ПРОЦЕДУРАХ САНАЦИИ ПРЕДПРИЯТИЙ

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Аннотация

Проблема, рассматриваемая в данной статье, актуальна в связи с неизбежной цифровой трансформацией антикризисного управления предприятиями в процедурах спасения, что связано с новым технологическим сдвигом и растущей конкуренцией между странами за рынки технологий Индустрии 4.0. Внедрение высокотехнологичных решений привело к изменениям в формате и содержании антикризисного управления с акцентом на решение задач оптимизации оперативного управления в процедурах санации и переосмысление подходов к разработке сценариев стратегии цифрового развития, которые включают мобильные и облачные аналитические решения. Цифровая трансформация форматов системного и комплексного анализа в институтах банкротства стала естественным шагом в развитии антикризисного управления. В данной статье рассматривается проблема разработки эффективной информационно-аналитической системы антикризисного управления в процедурах санации отечественных предприятий в новых экономических условиях. Исследование демонстрирует необходимость внедрения цифровых инструментов при построении эффективной информационной системы для управления кризисными ситуациями. Активно развивающийся рынок информационных продуктов и услуг открывает перед предприятиями множество возможностей для решения проблем при переходе на автоматизированные и цифровые технологии антикризисного управления.

Ключевые слова: антикризисное управление, анализ, цифровая трансформация, санация, эффективность, ресурсы

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1. Introduction

Transitioning to a digital economy entails a large-scale restructuring of socio-economic institutions and causes changes in the way social and economic relations are organised in society (Avdeeva et al., 2019). Today, anti-crisis management in enterprises undergoing bailout procedures cannot keep up with technological progress. The business processes of bankruptcy institutions lag behind the pace of technological development. The adaptation of anti-crisis management to new conditions and environmental factors implies the need to meet the key criteria for the strategic and operational plans for enterprise bailout, the emergence of new business areas, and opportunities for communication (Shakhmametova, 2012). Within the subprogram “Information Analytical, Organizational and Technical Support of Digital Development” of the 2021–2025 State Program for Digital Development of Belarus, it seems relevant to transform the analytical processes of anti-crisis management. The prerequisite for this research study is the negative growth dynamics in the number and proportion of unprofitable industrial enterprises in the Republic of Belarus. The share of unprofitable industrial organisations in 2015 significantly increased but showed a downward trend by 2018.

In the structure of unprofitable organisations by type of economic activity, the mining and manufacturing enterprises had the largest shares (24.3% and 22.3% in 2018 and 12.5% and 20.9% in 2020, respectively). In addition, a significantly growing share of unprofitable industrial organisations was observed in 2015, with a downward trend achieved by 2020 (profile of the indicator for 2015–2020: 23.5%, 20.6%, 16.7%, 17.3%, 14.7%, and 16.4%, respectively). The proportion of unprofitable organisations in the production of automobiles and equipment was 10.0% in 2020, which is 14.8 percentage points lower than that in 2018 and corresponds to the trend common for industrial enterprises¹.

The digital transformation strategy for the analytical systems of anti-crisis management of enterprises in bankruptcy proceedings implies that the existing economic potential is effectively and proactively managed using a system of prescriptive analytics (Abdullaev et al., 2019). Analytical processes on a digital platform can improve the use of the economic potential of an enterprise in bailout procedures, cut costs, reduce unplanned standstills, and ensure that all resources are applied in the best way possible in space and time. The goal of predictive and prescriptive analytics as digital transformation tools is effective anti-crisis management of all blocks of the economic potential of the debtor’s enterprise.

The aim of this study was to develop an efficient information and analytical system (IAS) for restoring debtors’ solvency based on digital transformation tools and given the potential of the infrastructure of the business processes in the enterprise. The main objective of this research was to form the theoretical foundation and put into practice the analytical justification of anti-crisis management in the bailout procedures of industrial enterprises, taking into account the architecture of the IT services it uses.

2. Literature Review

Researchers such as I.L. Avdeeva et al. (2019), G.R. Shakhmametova (2012), N.S. Abdullaev and E.S. Sabina (2019), L.S. Lapidus et al. (2019), A.V. Kostikova et al. (2021) pay much attention to the issues relevant to the digital economy that is developing in the economic environment.

I.L. Avdeeva et al. consider the need for digital transformation in the manufacturing industry and emphasise the importance of sustainable development. The authors identified the fundamental factors of this process, highlighting that digital transformation mechanisms play the central role because they create the image of an organisation and call for significant resources. At the same time, the macro-level of digital transformation is considered without specifying or adapting it to the level of industrial organisations, particularly in bankruptcy proceedings.

In her paper, G.R. Shakhmametova considered individual tools for information support in anti-crisis management (information modules of anti-crisis management) given the life cycle of an enterprise. The study lacks mechanisms for building an information and analytical environment that would support anti-crisis management and help develop measures for debtor bailout.

The article by N.S. Abdullaev and E.S. Savzikhanova contains materials on the results of digital transformation in Russia according to the international digital competitiveness rankings. The authors focused on the regional imbalance in the advancement of digital technologies and highlighted an acute shortage of IT industry specialists. The paper does not consider the issues of how digital potential is used by enterprises in a crisis. It lacks information on one of the most important problems of digital transformation that is related to business processes in the systems of product distribution logistics.

In their research article, L.V. Lapidus et al. discussed the ‘minimal digital basket of Russian regions’, which, if monitored systematically, can be useful for the prompt building of an effective platform for the sustainable development of regions and for reducing the digital divide between them. This paper takes into account the existing approaches to the study of digital transformation to develop an effective IAS for restoring debtor solvency using digital transformation tools and given the potential of the infrastructure for business processes in the enterprise.

Many scholars, particularly O.I. Dolganova, E.A. Deeva (2019), M.P. Galimova (2019), I.A. Brusakova (2019), and D.V. Kuzin (2019), have studied the prerequisites and readiness of industrial enterprises for digital transformation. Their studies relied on the methods suggested by foreign authors as evaluation criteria, with the foreign experiences being summarised when digital platforms for the development of business processes are formed.

A group of scholars from the Analytical Center and Financial University of the Government of the Russian Federation and the National Research University Higher School of Economics, including E.P. Kochetkov, A.A. Zabavina, and M.G. Gafarov (2019), conducted research on forming a theoretical basis for the assessment of efficiency.

The conceptual approaches to anti-crisis management were considered by E.A. Buranova (2019). According to the researcher, these approaches include measures of adaptation to the changing conditions of the external and internal institutional environments, and an increase in the level of corporate social responsibility as part of a company’s sustainable development strategy.

According to I.V. Ilyin et al. (2019), the IT architecture of an enterprise should be designed in accordance with the level of digital transformation of production and management processes.

The macro-level aspects of developing a strategy and models of digital transformation were discussed by M.K. Tsenzharik et al. (2020), N. Zhargalsaikhan (2021), B.M. Garifullin, V.V. Zyabrikov (2018), and I.V. Tarasov (2019).

T.V. Aleksandrova (2019) considers digital technologies as a tool for improving the efficiency of management in production enterprises.

Matters related to the increase in the efficiency of accounting operations based on digital transformation are discussed in the papers of I.N. Dmitrieva, A.F. Chernenko (2018), A.L. Fedorishina and K. Popovich-Zubchinskaya (2020).

By using the methods of accounting, probability theory, financial management, and financial analysis, authors such as T. Mulyk and Y.V. Mulyk (2016) proposed a critical analysis of the essence of risks in financial statements and accounting.

Foreign researchers such as V.L. Da Silva, J.K. Kovaleski, R. Negri Pagani, J. De Matos Silva, and A. Corsi (2020) have discussed technological and scientific achievements that provide new opportunities for smart industries. The concept of Industry 4.0 is considered by expert groups as an important approach to industrial configuration. The researchers highlighted that this study is especially relevant to developing countries. Empirical studies on Industry 4.0, company cases, and other materials were considered. However, the data presented were not related to specific enterprises or anti-crisis management systems. Thus, our study is relevant in this respect.

The abovementioned scientific works discuss the theoretical aspects and need for developing and applying digital transformation tools, the prerequisites and readiness of industrial enterprises for digital transformation, and the assessment of the effectiveness of digital transformation procedures. However, these research studies do not present any mechanisms for developing an information and analytical environment to support anti-crisis management and elaborate measures for debtor bailout, given the industry affiliation of a specific organisation.

3. Materials and Methods

The effectiveness of anti-crisis management in the bankruptcy proceedings of industrial enterprises is largely determined by the quality of the financial and economic IT-based analysis, which simplifies operations, relationships, and exchange of information. The IAS, built in the format of modern digital platforms, can be used by those involved in the trial to objectively assess the causes of the debtor's bankruptcy and the debtor's potential for restoring solvency. The present authors believe that the digital analytical platform for anti-crisis management is a business model of analytical procedures integrated into a single digital space at all levels of the management hierarchy that actively works in the system of the debtor's enterprise stakeholders.

The basic configuration of the digital analytical platform for anti-crisis management includes all blocks of analytical research on narrow regulatory and legislative state diagnoses of a crisis situation and an extended field of bailout and restoration of the debtor's enterprise solvency. Anti-crisis financial and economic analysis (FEA) is a tool for anti-crisis management in bankruptcy proceedings that is useful in resolving conflicts of interest between stakeholders during bankruptcy proceedings. The use of analytical software in the anti-crisis management system increases the likelihood of saving the business from destruction, while digital transformation tools act as drivers of efficiency, consistency, complexity, and objectivity, and are useful for setting company goals to recover solvency.

This study applied analytical methods for studying production systems, particularly analysis, synthesis, abstraction, generalisation, induction, deduction, analogy, and modelling.

With regard to an industrial enterprise involved in a bankruptcy procedure, the proposed concept of anti-crisis FEA based on a digital platform includes analytical calculations for the following blocks of analytical procedures:

- economic substantiation of the parameters and criteria for system and comprehensive analyses in separate blocks of decomposition of the economic potential in the procedures for the bailout of the debtor's enterprise;
- economic analysis of the main indicators for the use and development of resource potential in the blocks, including analysis of the technical state and efficiency of the fixed assets, analysis of the quantitative and qualitative indicators of workforce planning, and analysis of the material resources used;
- analysis of the dynamics, factors, and reserves in the system of costs for the production and sale of products, profits, and profitability of the debtor's enterprise;
- prospective analysis of the possibility of loss-free production and measures aimed at restoring the enterprise's solvency.

Given this concept, an information-analytical platform was built for monitoring and controlling the anti-crisis management system of an enterprise involved in bankruptcy proceedings based on a digital platform. The research involved several sequential analytical blocks that allow for the following:

- express analysis of the solvency of the enterprise involved in bankruptcy proceedings that is aimed at substantiating the gravity of the crisis, including financial analysis of the economic activity of the enterprise, such as analysis of a series of financial and economic indicators;

- analysis of the structure and dynamics of the assets and liabilities in the balance sheet, including the monitoring of structural dynamics as a factor in the sustainable financial status of the enterprise;
- analysis of the financial stability and solvency of the enterprise, including a coefficient analysis of financial stability and solvency according to the bankruptcy criteria;
- analysis of the production capacity;
- analysis of the technical condition and efficiency of the fixed assets;
- analysis of human resources.

The abovementioned research methods were chosen to solve the problem in the context of a systematic and integrated approach towards forming the information and analytical platform for anti-crisis management of the enterprise in the process of bailout. The methodological tools for FEA were used for the standard analysis to provide analytical support for management decision-making. The initial analytical material was arranged in accordance with the database of the enterprise used in the course of the study.

The empirical, statistical, financial, and operational information of JSC 'Pinsk Shipyard', which was studied in this research, was processed using qualitative and quantitative analyses and a correlation analysis. The results were synthesised in the plan for the rehabilitation of the debtor's enterprise, as elaborated by the present authors.

At present, a two-level system of legal regulation exists, according to which the FEA of organisations involved in bankruptcy proceedings is performed: at the state level, the Law of the Republic of Belarus 'On Economic Insolvency (Bankruptcy)', dated 13 July 2012 (No. 415-Z), with amendments and additions dated 24 October 2016, and at the level of by-laws adopted for implementing the provisions of the above document. The Resolutions of the Council of Ministers of the Republic of Belarus Nos. 140/206 and 1672 provide the guidelines for calculating the indicators and criteria for recognising an organisation as insolvent and the structure of the balance sheet as unsatisfactory. Proactive anti-crisis management implies performing a detailed analysis of the production activities of the debtor's enterprise in terms of the decomposition blocks of the economic potential, that is, objects of retrospective and prospective analytical processes, namely production capacity, production and human resources, costs, profits, profitability, and turnover. The research subject is the formation of an effective IAS for anti-crisis management of the fixed assets of the debtor's enterprise.

This paper presents the results of the IAS built using a block of methods for managing the financial stability, solvency, and resource potential of the debtor's enterprise.

4. Results

The results of the relevant analytical procedures based on digital platforms are presented in the IAS format and subsequently used for introducing measures for the financial recovery of Pinsk Shipyard. The material used in the study was based on the information support of this plant, which is currently in the process of reorganisation. Pinsk Shipyard is located in the centre of the city of Pinsk, in the coastal zone of River Pina. It has a floor area of 6.4 Ha; the plant grounds include buildings, essential and auxiliary facilities, and engineering infrastructures. Road and river transport is used for cargo turnover, and the plant has a railway line.

Since 2017, the plant has had no orders for the construction of motor ships. Today, the key problem of the plant is the lack of demand and funding for shipbuilding and repairing the water transport facilities owned by water transport enterprises. Hence, to meet other types of demand, the enterprise produces and sells a wide range of non-core products (services). Principally, it is about the repair of the internal combustion engines of D6 and D12, and V-46 diesel engines, which are used in military machines, fuel pumps, starters, generators, structural steel, and so forth. Starting from 2018 and throughout 2019–2020, the plant experienced a significant decrease in output in the context of individual types of production (down to 50%), while the share of give-and-take raw materials processed at production sites was capa-

cious. The main reason for the decline in production is the decreasing demand from the river transport organisations operating in the republic.

In 2017–2019, the output of current prices showed a steady downward trend, which was also consistent with the decreasing volume indicators in comparable prices. The base rates of the decline in 2018 and 2019 were respectively 48.15% and 43.18% in the current assessment and 43.86% and 35.36% in comparable prices.

The relative growth in 2019 compared with 2018 was 10.33%, which, provided that the inflationary factor is excluded, corresponds to a decrease of 19.36%. At the moment, the plant is closely cooperating with JSC “Kuzlitmash” in Pinsk to produce metal brackets and stands used in the production of JSC “Belaz” under a 1-year contract. For 8 months, marketable products were produced under this contract in the amount of 151.1 thousand rubles, which is 22.9% of the total output. Within the period of January to August 2020, the plant facilities were used for minor scopes of ship repair work performed for some water transport organisations in the amount of 88.0 thousand rubles, which is 13.3% of the total output. In recent years, the water levels were low during the navigation period, which stopped water transport organisations from conducting cargo transportation with maximum draft. Hence, there is need to design and build new types of transport vessels that consider the hydrological conditions that have been common in recent years for the inland waterways of the Republic of Belarus.

Express analysis of the solvency of JSC “Pinsk Shipyard” in the context of understanding the gravity of the crisis. The financial statements of the plant were studied and used to analyse the financial coefficients of solvency and financial stability according to the current legal regulation of bankruptcy institution. The results of the calculations are shown in Table 1.

Table 1. Analysis of unsatisfactory balance sheet structure

Indicator	30.09. 2019	31.12. 2019	31.03. 2020	30.06. 2020	30.09. 2020	Standard values
Current liquidity ratio (K_1)	0.44	0.37	0.38	0.34	0.31	≥ 1.3
Working capital ratio (K_2)	-1.25	-1.72	-1.62	-1.97	-2.20	≥ 0.20
Debt-to-asset ratio (K_3)	0.77	0.89	0.92	1.01	1.12	≤ 0.85

The dynamics shows a negative trend towards a decrease in the current liquidity ratio and the increasing deficit of the company’s own working capital and the level of coverage of the working capital with the company’s own working assets. The ratio K_2 characterises the lack of working capital, which is formed with the enterprise’s own funds and essential for ensuring its financial stability. Since the second quarter of 2020, the enterprise’s liabilities exceeded the value of its assets. In the third quarter of 2020, liabilities kept reinforcing this negative trend: as of September 30, 2020, the long- and short-term liabilities of Pinsk Shipyard exceeded the currency level of the balance sheet by the negative amount of its equity or by 12.3%.

The balance sheet of the plant has an unsatisfactory structure. The company is insolvent and is classified as a permanently insolvent enterprise.

Analysis of the structure and dynamics of the balance sheet assets and liabilities. The total fund of the enterprise as of 31 December 2019 amounted to 781 thousand rubles and was reduced compared with that at the beginning of the year by 120 thousand rubles or 13.32%. The absolute decrease in the value of long-term assets as of 31 December 2019 was 9 thousand rubles or 1.66%; the decrease in the value of short-term assets amounted to 111 thousand rubles or 31.01%. At the beginning of the period, long-term assets accounted for 55.05% in the balance structure, while at the end of the period,

this figure was 62.74%. The structural dynamics was defined in the amount of 7.69%, which indicates a rather ‘rigid’, non-mobile structure of the balance sheet assets. The distribution of funds between long- and short-term assets as of 31 December 2019 was 62.74% and 36.27%, respectively (Figure 1).

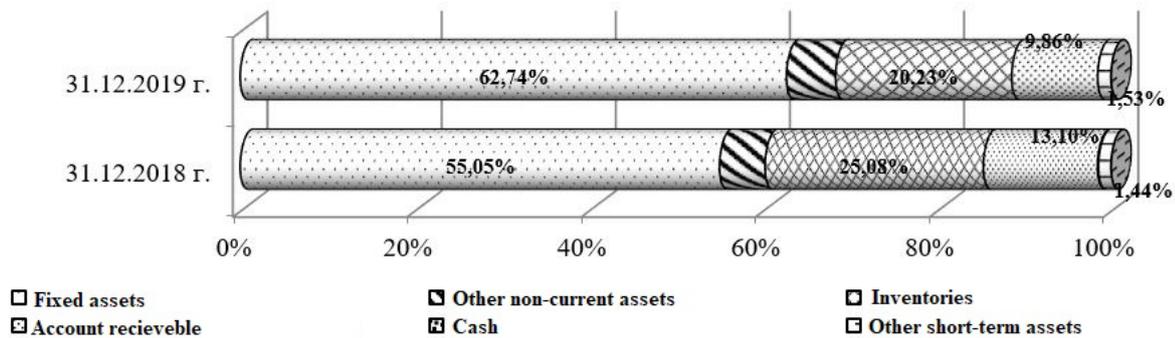
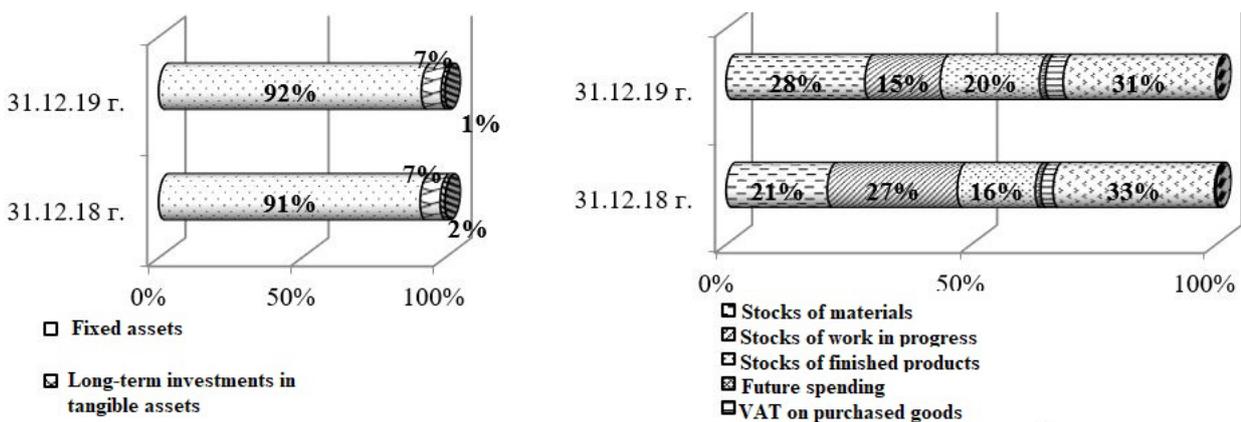


Figure 1. Dynamics of the asset structure of the balance sheet

In 2019, the redistribution of funds was in favour of the long-term assets (with an increase in the asset structure of 7.69 percentage points). The share of tangible short-term assets (stocks) decreased by 4.85 percentage points, including 5.68 percentage points for work in progress. The following elements of the short-term assets illustrate negative structural dynamics: the share of accounts receivable decreased by 3.24 percentage points, and that of cash decreased by 0.11 percentage points. The share of deferred expenses was 0.38% as of 31 December 2019, which corresponds to a structural decrease in dynamics by 0.06 percentage points. The share of taxes on purchased goods increased by 0.15 percentage points. As of 31 December 2019, the value of the long-term assets decreased by 9 thousand rubles, which was due to a decrease in the value of the fixed assets by 6 thousand rubles, or 1.21%, compared with the level at the beginning of 2019.

In the structure of long-term assets, the fixed assets had the largest share (91.34% and 91.76% in 2018 and 2019, respectively). In 2019, the share of this item in the long-term assets increased by 0.42 percentage points (Figure 2).



a) structure of long-term assets

b) structure of short-term assets

Figure 2. Structural dynamics of the property complex

The following conclusions can be made for the block of short-term assets: the plant had the largest share of short-term assets in the period under consideration in terms of stocks and accounts receivable, which were 63.97% and 31.17%, respectively, which corresponds to an increase in the structural dy-

namics of stocks by 0.84 percentage points and a decrease in the accounts receivable by 1.79 percentage points. The increase in the reserves was the result of the growing share of raw materials and finished products, by 7.67 and 4.32 percentage points, respectively. Significant funds of the enterprise were diverted to accounts receivable. As of 31 December 2019, these funds reached are 77 thousand rubles or 31.17% of the total working capital, which corresponds to a decrease in the amount and proportion of short-term receivables by 41 thousand rubles or 1.79 percentage points.

The factors that reduced the sources of property financing include a significant decrease in the equity of the enterprise, which, as of 31 December 2019, declined by 428 thousand rubles or 83.76%. The long-term liabilities reduced by 12 thousand rubles or 31.58%, whereas the short-term liabilities increased by 320 thousand rubles or 90.91%. The equity decreased as a result of significant accumulated losses amounting to 553 thousand rubles, which led to the losses increasing in dynamics by 417 thousand rubles or exceeding the losses at the beginning of 2019 by 3.1 times. The share of the short-term liabilities in the structure of the balance sheet liabilities increased by 46.98 percentage points (Figure 3), which is 320 thousand rubles in absolute terms. This was due to the increase in short-term credits and loans by 12 thousand rubles (80.0%), while accounts payable increased by 328 thousand rubles (113.89%).

The high debt in taxes and duties observed was the result of the accumulated land tax debt (calculated given the high values of regionalised local coefficients and the size of the occupied area [6.4 Ha in the centre of Pinsk]) and real estate tax. The increasing share of borrowed funds reduced the financial stability of Pinsk Shipyard, which was aggravated by its lack of profit and equity.

The ratio of the accounts receivable to the accounts payable as of 30 June 2020 was 0.132 (with optimal values ranging from 0.9 to 1.0, which implies that the accounts payable should not exceed the accounts receivable by more than 10%).

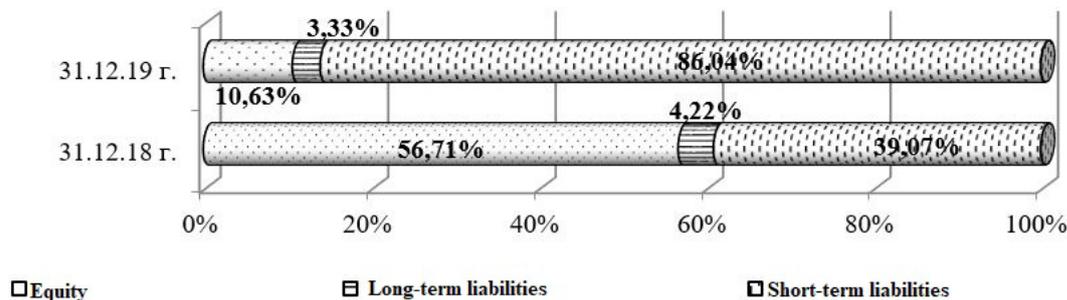


Figure 3. Structure of property financing sources

As of 30 June 2020, the net assets of the enterprise amounted to –6 thousand rubles and decreased by 89 thousand rubles relative to the beginning of 2020, which reflects the grave financial crisis of the plant. The overdue credit debt was incurred by Pinsk Shipyard because of the lack of financial resources, which was caused primarily by declining production volumes and shrinking sales markets. The fact that the short-term liabilities were bigger than the working capital means that the company could not pay off its short-term liabilities and had no reserves for expanding its activities.

Analysis of the financial stability and solvency of the enterprise. According to the analytical calculations, Pinsk Shipyard lacked its own working capital in 2019: as of 31 December 2018, the working capital of the plant amounted to 6 thousand rubles. As of 31 December 2019, the deficit was 425 thousand rubles, and as of 30 June 2020, it was 243 thousand rubles (42.82% reduction). As of 30 June 2020, the plant lacked its own working capital, with a deficit in working capital amounting to 510 thousand rubles, which corresponds to its growth in dynamics by 85 thousand rubles (20% growth). These data correspond to the structural imbalance and low financial stability of the enterprise, with the company remaining highly dependent on external creditors.

The financial dependence ratio increased by 7.646 points, which corresponds to an increasing proportion of the borrowed capital in the property complex of the enterprise. As of 31 December 2019, the equity concentration ratio was 10.6%. It decreased by 46.1 percentage points, while the concentration ratio of the borrowed capital increased by the same amount. These figures indicate a growing dependence of Pinsk Shipyard on the borrowed capital market. As of 31 December 2018, the enterprise borrowed funds equivalent to 0.763 rubles for each ruble of its own assets, and as of 31 December 2019, this figure was 8.410 rubles, with the increase amounting to 7.646 rubles. The current debt ratio increased by 0.470 points. The equity flexibility ratio at the end of 2019 was -5.120 and decreased in dynamics by 5.132 points. The equity ratio (the ratio of the company's own short-term assets to short-term assets) also decreased by 1.737 points, which confirms the conclusion about the falling financial stability of the plant. The irrational structure of the assets and liabilities in the balance sheet provoked an imbalance in the financial stability indicators and criteria and their negative dynamics.

Analysis of production capacity. The level of production capacity used in the ferrous structural steel manufacturing section in the current period of 2020 decreased by 49.50 percentage points relative to the level observed in 2019 (Table 2).

In the engine repair section, the level of production capacity used for 9 months in 2020 was reduced to 33.33%, which is 10.0 percentage points lower than that in 2019. The lack of demand and orders for manufacturing special vehicle bodies for transportation of gas cylinders in 2019–2020 resulted in the exclusion of this stock item from production. The percentage of the production capacity used for the conversion and reconstruction of ships and other watercrafts and services in ship building for 9 months in 2020 was 44.0%, which is significantly lower than the level observed in 2011–2017 but higher than the utilisation rate of the production capacity in 2018–2019.

Table 2. Analysis of capacity utilisation in dynamics

Indicator	2011	2016	2017	2018	2019	6 months 2020	9 months 2020
Production capacity utilisation, %							
Ferrous structural steel manufacturing	58.40	40.91	13.00	19.50	54.00	4.50	4.50
Production of special vehicle bodies for transportation of gas cylinders	27.27	80.00	91.11	24.44	0.00	0.00	0.00
Engine repair	88.00	26.67	43.33	36.67	43.33	23.33	33.33
Services on converting and reconstructing ships and other watercraft and services in the shipbuilding industry	63.82	57.45	93.45	3.82	3.82	43.45	44.00

In dynamics, a decreasing level of production capacity utilisation is observed for all the items of the production plan of Pinsk Shipyard (with a low workload in 2018–2019). In 2017–2018, the production declined in all production departments of the plant.

As of September 30, 2020, the percentage of the production capacity used for ferrous structural steel was 4.50%, having decreased by 53.90 percentage points compared with that in the base year

(2011); that used for the production of special vehicle bodies for the transportation of gas cylinders was 0%, having decreased by 27.27 percentage points; and that used for engine repair amounted to 33.33%, having decreased by 54.67 percentage points. For 9 months in 2020, the output and production capacity used for providing services for converting and reconstructing ships and other watercrafts and ship-building services increased.

Regarding the data as of 30 September 2020, the levels of production capacity utilisation for the stock items under consideration were as follows: for ferrous structural steel, 4.50%; for engine repair, 33.33%; for services on converting, reconstructing ships and other watercrafts and ship-building services, 44.00%.

In this study, a negative trend was observed in the declining output of products, services and work of Pinsk Shipyard. This can be explained by the lack of orders for the core activity and the fulfilment of orders for non-traditional types of products, work, and services. Given the abovementioned results and to preserve the specifics of the enterprise, it is advisable to load the production capacity of the plant according to its main area of specialisation to meet the growing demand from water transport organisations. The 2018–2021 State Program for the Development of the Transport Complex of the Republic of Belarus envisages measures that could be partially implemented at the facilities of the plant. In this way, ship repair work planning and implementation could be improved in the long term.

Analysis of the technical condition and efficiency of the fixed assets. The production activity of the plant is concentrated in three main sections: case welding, mechanical, and power-mechanical sections.

The production capacity of the sections is determined by the available complex of equipment. The initial (replacement) cost of the company's fixed assets as of 30 June 2020 was 2,094.4 thousand rubles (Table 3).

Table 3. Analysis of the structural dynamics of fixed assets

Fixed assets	1 January 2020		30 June 2020		Change	
	amount, thousand rubles	share, %	amount, thousand rubles	share, %	amount, thousand rubles	share, %
Buildings	1 058	49.91	1058.4	50.53	0	0.63
Structures	465	21.93	464.9	22.20	0	0.26
Transfer devices	11.0	0.52	11.3	0.54	0	0.02
Machines and equipment	477	22.50	448.7	21.42	–28	–1.08
Vehicles	89	4.20	67.8	3.24	–21	–0.96
Tools, inventory and accessories	17	0.80	16.6	0.79	0	–0.01
Other types	3	0.14	26.7	1.27	24	1.13
Total fixed assets	2 120	100.00	2094.4	100.00	–26	0.00
Fixed assets	01.01.2020		30.09.2020		Change	
	amount, thousand rub.	share, %	amount, thousand rub.	share, %	amount, thousand rub.	share, %
Buildings	1 058	49.91	1058.4	50.57	0	0.66
Structures	465	21.93	464.9	22.21	0	0.28
Transfer devices	11.0	0.52	11.3	0.54	0	0.02

Machines and equipment	477	22.50	447.4	21.37	-30	-1.13
Vehicles	89	4.20	67.8	3.24	-21	-0.96
Tools, inventory and accessories	17	0.80	16.6	0.79	0	-0.01
Other types	3	0.14	26.7	1.28	24	1.13
Total fixed assets	2 120	100.00	2093.1	100.00	-27	0.00

In the first half of 2020, the value of the fixed assets decreased by 26 thousand rubles or 1.21% owing to a decrease for items such as machines and equipment, and vehicles by 28 and 21 thousand rubles, respectively (5.93% and 23.82%, respectively). At the same time, a 24-thousand ruble increase in the assets for other types was found. In 9 months in 2020, the volume and structural changes also accounted for the decline in machines and equipment, and vehicles. The negative structural dynamics of the decline amounted to -1.13 percentage points and -0.96 percentage points.

According to the decision made by Pinsk Shipyard for 2020, to reduce the expenses included in the cost of products (work and services) and to strengthen the financial condition of the company, depreciation was not accrued for all items of the fixed assets, with the exception of computer equipment and vehicles.

As of 30 September 2020, the value of the fixed assets of Pinsk Shipyard amounted to 2,093.1 thousand rubles, having decreased relative to the beginning of the year by 27 thousand rubles or 1.27%. In 9 months in 2020, minor structural shifts in the composition of the production assets occurred.

Negative structural dynamics were observed for the items machines and equipment, vehicles, and tools: decrease of 1.13, 0.96, and 0.01 percentage points, respectively. Positive dynamics were shown for buildings, structures, and other types of fixed assets. Their shares increase by 0.66, 0.28, and 1.13 percentage points, respectively.

In the time interval considered, a critical level of wear of the active part of the fixed assets was observed, including machines and equipment. Thus, according to the control points, the profiles of the indicators were as follows: 88.52%, 88.26%, 88.86%, and 88.85% (Table 4). A significant degree of wear in 2019 accounted for machines and equipment (88.52% and 88.26%, respectively), which corresponds to the critical technical condition of the equipment (according to international standards, >60%).

Table 4. Analysis of the movement and technical conditions of machines and equipment

Indicator	Indicator level				Change in periods		
	31.12. 2018	31.12. 2019	30.06. 2020	30.09. 2020	2018–2019	6 months 2020	9 months 2020
Growth rate	0.0000	-0.0225	-0.0119	-0.0125	-0.0225	0.0106	0.0100
Wear factor	0.8852	0.8826	0.8886	0.8885	-0.0026	0.0060	0.0059
Acceptance factor	0.1148	0.1174	0.1114	0.1115	0.0026	-0.0060	-0.0059

The degree of validity of the active part of the assets decreased by 0.93 percentage points in 2019 compared with 2018. For the first 6 and 9 months of 2020, the wear of the item under consideration increased slightly, by 0.60 and 0.59 percentage points, respectively, which corresponds to the accrued depreciation of computer equipment and vehicles. In 2019, the wear coefficient for the machines and equipment amounted to 0.8826, having slightly decreased by 0.0026 points, which corresponds to the growing serviceability of the machines and equipment by the same amount. The retirement rate increased by 0.0205 points. The enterprise had assets in operation whose useful lives had expired (fully depreciated fixed assets). The period for renewing the machines and equipment was infinite. The average

age of the equipment was >20 years, which is considered to a critical level in the practice of analysis and marks high levels of physical wear and obsolescence of the equipment.

There is an absolute decrease in the value of the fixed assets, while their wear during operation also decreased, but it is because depreciation was not charged. The pattern of the indicators measuring depreciation and the serviceability of the fixed assets in the considered time interval indicate the need for anti-crisis management based on investments in innovative high-tech projects of Pinsk Shipyard. The technical characteristics of the fixed assets, including the machines and equipment, have deteriorated as a result of increased wear, and the production potential of the plant has to be managed in an investment-oriented way. The financial difficulties and lack of renewal of the machines and equipment determined a significantly growing period of renewal, increasing retirement and depreciation rates. Critical depreciation growth in dynamics is noted.

The intensity and efficiency of the fixed assets of Pinsk Shipyard were analysed. In 2019, compared with 2018, the return on assets decreased for all the items under consideration. The return on fixed assets was reduced by 0.028 rubles, the return on the active part of fixed assets decreased by 0.098 rubles, and the return on machines and equipment decreased by 0.114 rubles. In 2018–2019, a loss on sales of goods was incurred, amounting to 192 to 392 thousand rubles. It corresponds to the calculated loss ratios, whose value increased in dynamics for the module. The actual loss ratio of the fixed production assets for 2019 was –18.443%, which corresponds to an increase in the loss ratio of fixed assets in the considered time interval by 9.437 percentage points (>2 times). Similarly, the loss ratio of sales in 2019 relative to the loss ratio of sales in 2018 increased by 36.499 percentage points (with a twofold increase). In 6 and 9 months of 2020, the return on assets for all items under consideration increased (Table 5).

Table 5. Analysis of the efficiency of fixed assets of the plant

Indicator	6 months		9 months		Change	
	2019	2020	2019	2020	6 months	9 months
Return on production assets (loss ratio), %	-7.90	-2.61	-14.44	-6.08	5.29	8.37
Return on fixed assets r , rubles	0.10	0.26	0.16	0.36	0.16	0.20
Return on active part of assets, rubles	0.37	1.06	0.59	1.44	0.68	0.85
Return on machines and equipment, rubles	0.44	1.24	0.70	1.69	0.80	0.99

The largest increase was observed in the return on machines and equipment. In the first 6 months of 2020, it increased by 0.80 rubles or 179.92%, and in 9 months, it increased by 0.99 rubles or 141.99%. The loss ratio of fixed assets in the abovementioned time interval in 2020 was –2.610 and –6.076%, which corresponds to the decreasing loss ratio of the indicator (positive dynamics to decreasing loss ratio) relative to the loss ratio in 6 months in 2019 (–7.899%) by 5.289 percentage points and 9 months in 2019 (–14.444%) by 8.368 percentage points. The initial intangible assets as of 1 January 2020 amounted to 973.64 rubles. According to the accounting policy adopted by the company for 2020, the depreciation of intangible assets was calculated using the straight-line method. The accumulated depreciation as of 30 June 2020 amounted to 792.24 rubles, and the accrued depreciation for January to June 2020 was 37.32 rubles.

The state of the fixed assets, including machines and equipment, is characterised by a critical degree of wear, lack of renewal, and inefficient use. There was an increase in the utilisation of fixed assets, and the parameters of their efficient use (return on assets, return on capital) in 9 months in 2020. The following were identified as growth factors and reserves: reduction in all-day and intra-shift standstill of equipment due to the loading of the production capacity to the design values and increase in the average

hourly performance of equipment on the platform of active innovation and investment activities.

Analysis of the labour resources used. The average number of employees in the enterprise was 77 people in 2019. It decreased by 18.09% from that in 2017 and by 7.23% from that in 2018. The headcount was reduced because the plant adopted a policy aimed at optimising the headcount. The company's human resources are constant, and their turnover is low. The structure of human resources is characterised by the largest proportion of labour workers: 72.29% and 74.03%, respectively, by years. In dynamics, there is an increase in the share of this category of workers. Similar changes were observed in the category of managers and specialists. Their share in 2019 decreased from that in 2018, from 1.28 percentage points to 0.45 percentage points. The decreasing numbers of managers and specialists were the result of the intensification measures: expanding service areas for line personnel; that is, the manageability factor intensified owing to a growth in official salaries and rates, with new methods of economic leadership being introduced and new managerial competencies being formed by middle managers. In 2019, the total headcount of the enterprise slightly decreased (by 6 people or 7.23%); the structure was redistributed in favour of the direct labour workers (1.91 percentage points), while the share of indirect labour workers decreased by 0.17 percentage points, and those of managers and specialists decreased by 1.28 and 0.45 percentage points, respectively. Analysis of the structure of the plant's personnel by type of economic activity for 2018–2019 shows that the largest share of labour workers were engaged in the following production areas: production of structural steel and its components, 32.53 and 36.36%, respectively (positive structural dynamics of 3.83 percentage points), and repair, maintenance of ships, 36.14 and 44.16%, respectively (positive structural dynamics of 8.01 percentage points). In the shipbuilding section, the number of labour workers decreased by 10 people (by 83.33%), with a simultaneous reduction of 11.86 percentage points in the share in the structure of the enterprise's workers.

The average headcount of the enterprise in dynamics decreased in 2017–2019 (according to the final line, by 94, 83, and 77 people, respectively) with a simultaneous increase in wages. According to the human resources department, in general, the enterprise is dominated by labour workers with 10 to 15 years' work experience. Their share was 35.18 in 2019 and 33.25% in 2018, with the growth amounting to 1.93 percentage points. In addition, the percentage of those who have worked at the enterprise for more than 15 years was fairly high (15.37% in 2019), which corresponds to a 1.87-percentage point decrease relative to the level in 2018. This indicator can be the evidence of stability of the human resource activity of the enterprise, as people with extensive work experience prefer to work in this particular organisation. It should be noted that the company does not attract young professionals: the share of employees with <1 year of experience was only 2.34% in 2019, while in 2018, this figure was 2.75%. The average annual output of the enterprise's employees in 2019 was lower than that in 2018 by 0.242 thousand rubles or by 3.35% (Table 6).

Table 6. Analysis of the dynamics of efficiency of human resources of the enterprise

Indicator	2018	2019	Deviation	Change rate, %
Average annual output of an employee, thous. rub.	7.23	6.99	-0.24	96.65
Average annual output of a labour worker, thous. rub.	10.00	9.44	-0.56	94.39
Average daily output of a labour worker, thous. rub.	0.07	0.05	-0.02	74.44
Average hourly output of a labour worker, thous. Rub.	0.01	0.01	0.00	74.44
Average annual wages, rub.	4 109.64	5 328.57	1 218.93	129.66

The indicator under consideration decreased owing to the decreasing average hourly output of a labour worker, given the offset of the positive influence resulting from the growth factors in the labour workers' share in the structure of the company personnel and the increasing working time fund. In 2019,

the average hourly output per worker decreased in the current estimate by 0.002 thousand rubles (or 25.56%) compared with the output in 2018, which was 0.008 thousand rubles. Taking into account the headcount factor, in 2018–2019, the enterprise’s all-day standstill amounted to 2,492 or 581 man-days, which corresponds to the decreasing loss of working time in the reporting year.

The average annual output of a worker engaged in the core activity in dynamics decreased by 0.242 thousand rubles; in 2019, the average annual output of a worker amounted to 9.439 thousand rubles and decreased in dynamics by 0.561 thousand rubles or 5.61%. The decreasing average annual output was due to the influence of the intensive factor of average hourly output, and the presence of standstill and loss of working time caused by not utilising the production capacity to a full extent (the negative influence of extensive factors relative to the pre-crisis period). These dynamics are consistent with the increasing nominal wages of company employees in 2019 relative to those in 2017–2018: the base growth rate was 114.98, and the chain growth rate was 129.66%. These figures show an increase in real wages.

Table 7 shows that the average annual output of a worker of Pinsk Shipyard in 2019 was 0.24 thousand rubles lower than the level in 2018. It decreased by 2.40 thousand rubles owing to a reduction in the average hourly output of a worker by 25.56%; the influence of this factor amounted to –2.40 thousand rubles.

Table 7. Factor analysis of the average annual output of the enterprise labour worker

Factor	Amount of influence, thous. rub.
Share of labour workers in total headcount	0.17
Number of days worked by a labour worker per year	1.98
Working hours	0.00
Average hourly output of a labour worker	–2.40
Total	–0.24

The increase in the resulting indicator is determined by the following parameters: reduced all-day losses of working time ensured an increase in the average annual output of a labour worker engaged in the core activity by 1.98 thousand rubles, and an increasing share of labour workers in the personnel structure contributed to a growth in the average annual output of a labour worker engaged in the main activity by 0.17 thousand rubles. The length of the working day remained the same and did not affect the resulting indicator.

The decreasing average annual output of the enterprise is determined by the intensive factor of reduction in the average daily and average hourly output of workers, which is due to the production from give-and-take raw materials and does not correspond to the strategic development concept of Pinsk Shipyard. The dynamics of labour productivity was studied without adjusting for the inflation index, while the measured indices of decline in labour productivity in real terms take into account the price indices for industrial products in the republic and illustrate an even deeper downward trend in the effective indicator in comparable prices. The index of decline in labour productivity and the index of wage growth show an imbalance in the expanded reproduction indicators at crisis conditions, which determines the overspending in labour costs. The overspending in the dynamics of the wage fund in 2019 was determined in the amount of 1174.13 thousand rubles and considered as a production reserve for increasing production and output efficiency. The qualitative composition of employees in Pinsk Shipyard was characterised by an irrational structure of the plant’s personnel: according to the final line, each manager had 6 subordinates (78/13), while the recommendation is 7–9 people.

5. Discussion

This paper presents the adaptation of digital transformation tools in the system of anti-crisis management and the strategies of sustainable development of an enterprise, developed by several scholars. Anti-crisis management conceptual approaches, methods, and models were implemented in Pinsk Shipyard. Given the level of digitisation of the individual business processes at the plant, the author proposes an original model of a bailout plan, which proves to be successful on external examination. The financial plan to restore the solvency of Pinsk Shipyard was devised given the analysis of the current financial condition of the enterprise, the analysis of efficient use of the production potential, and a marginal analysis of costs, profits, and profitability. On the basis of the results of the study, the following areas of anti-crisis management were considered: taking measures to restore solvency, providing the entry of a foreign investor (according to the Pilot List of Belarusian Organizations with preconditions for the entry of Chinese investors into their share capital), and selling Pinsk Shipyard as a unified property complex. Anti-crisis measures that rely on the investment and innovation activities of new owners will ensure economic growth for the plant. The source of repayment of creditors' claims is the sale of the Unified Property Complex of Pinsk Shipyard. In accordance with the analytical data as of 6 January 2021, all creditor claims submitted as of 22 August 2020 can be upheld, and highly profitable operating activities can be ensured.

The proposed vectors of development were devised by the author in a real plan for the bailout of Pinsk Shipyard with access to the projected balance, cash flows, and parameters of financial stability and solvency.

The results obtained for resolving the problem are also presented by several scholars from different countries who showed that digital transformation is an important factor and foundation for economic growth of a country, region, and enterprise.

The study by I.L. Avdeeva, A.V. Polyandin, and T.A. Golovina projects digital transformation in the manufacturing industry as a factor in the sustainable development of economic systems (Avdeeva, 2019). The regional aspects of development of the digital economy are presented in the research materials by N.S. Abdullaev, S.E. Savzikhanova, and L.V. Lapidus, L.S. Leontieva, and A.O. Gostilovich. These authors conclude that there is an imbalance in the level of regional development of digital transformation (Abdullaev, 2019).

Strategic modelling of digital transformation with the prospect of increasing efficiency was studied in the work by M.K. Tsenzharik, Y.V. Krylova, and V.I. Steshenko (Tsenzharik, 2020). This study adopted the conceptual approaches to anti-crisis management, summarised by E.A. Buranova (Buranova, 2019).

G.R. Shakhmametova highlighted information modules of anti-crisis management at various stages of the enterprise life cycle, which is considered as a basis for automated collection and storage of data (Shakhmametova, 2012).

The fact that many enterprises are falling behind in terms of the digital potential they use was investigated in the research study by I.V. Ilyin, A.I. Levina, and A.S. Dubgorn, who came to a conclusion about the constraints on building the IT architecture of bankrupt enterprises (Ilyin, 2019).

The methodological aspects related to the evaluation of the efficiency of digitalisation are discussed in the study by E.P. Kochetkova, A.A. Zabavina, and M.G. Gafarova (Kochetkov, 2019). However, it is reasonable to conclude that the reporting system functioning in domestic enterprises does not reflect digital effects and their impact on the parameters of sustainable development of an enterprise, including those in the system of anti-crisis management of the debtor enterprise.

Foreign scholars V.L. Da Silva, J.K. Kovaleski, R. Negri Pagani, J. De Matos Silva, and A. Corsi obtained some important results on the introduction of digitalisation tools in production processes to

ensure efficiency and flexibility of the information space in the management system, which is relevant in the context of bailout of insolvent enterprises (Da Silva, 2020). Thus, the studied base in the chosen research area is adapted to building the information and analytical environment for anti-crisis management of Pinsk Shipyard.

6. Conclusion

According to the first vector of development, the following developments are identified as priority measures aimed at restoring solvency and supporting the efficient economic activity of Pinsk Shipyard: enhancing production processes related to certain types of products, industries, workshops, and sections, including improving technological processes; applying reusable materials; energy and resource saving; cost reduction; improving production areas and premises, including the best use of rental and leasing opportunities; selling production-intended property that is not used or used inefficiently; improving the marketing policy with marketing mix tools; increasing the production volumes and using the production capacity of the enterprise up to 80%; liquidating accounts receivable; and optimising the personnel structure with a focus on increasing sales and improving technological services of the plant, including organisation of labour and material incentives for human resources. In the bailout procedure, the emphasis should be placed on monitoring and searching for new markets, new consumers of shipbuilding and ship repair work, new types of products, and new areas for the application of traditional products that can provide the enterprise with the highest profits. It is suggested that marketing tools should be used in production and sales management so that the production activities of the enterprise and its structural policy could be organised in the best way possible to meet the demand of the market. The success of Pinsk Shipyard was ensured by its full cycle of shipbuilding and ship repair work, better quality of products and services, their constant improvement and updating, scientifically based pricing, commitment to customers, and suppliers and consumers of work and products. It is expected that the real estate and equipment used inefficiently will be sold at an auction, under direct contracts. The process of implementing the bailout plan of the enterprise is supplemented by recommendations for production and economic activities, actions aimed at reducing the costs of production and sale of products, work and services with simultaneous use of operational and financial leverage tools (currently Pinsk Shipyard is totally unbalanced in terms of these market criteria). Marginal profits should be increased with simultaneous reduction in fixed costs in the unit cost of production in accordance with the guidelines for cutting the most capacious material and labour costs. In this context, it is suggested that the technical capabilities of the plant were used to the maximum extent.

According to the second vector of development, if a foreign investor is not included in the “Pilot List of Belarusian Organizations with preconditions for the entry of Chinese investors into their share capital and if there is an agreement on selling Pinsk Shipyard as a unified property complex approved by the Ministry of Transport and Communications of the Republic of Belarus (Article 100), Pinsk Shipyard can be sold as a unified property complex in accordance with the norms of articles 127, 128, and 130 of the Law of the Republic of Belarus ‘On Economic Insolvency (Bankruptcy)’.

The barrier to the digital transformation of analytical anti-crisis management procedures with a preventive emphasis is the low level of IT architecture of industrial enterprises in bankruptcy proceedings, the difficulty in financing expensive software, and outsourcing services. Another obstacle is the issue of data security and integrity.

References

- Abdullaev, N.S., Sabina, E.S., 2019. Modern trends of digitalization and the effects it generates. *UEPS* 4, 32–38. <https://cyberleninka.ru/article/n/sovremennye-tendentsii-tsifrovizatsii-i-eflekty-kotorye-ona-porozhdaet>
- Aleksandrova, T.V., 2019. Cifrovizacija kak sovremennyj trend razvitija menedzhmenta proizvodstvennyh organizacij. *Seriya: Jekonomika i menedzhment* 3, 137–144.
- Avdeeva, I.L., Polyanin, A.V., Golovina, T.A., 2019. Digitalization of industrial economic systems: problems and consequences of modern technology. *Proc. Sarat. Ser. Econ. Manage. Law* 3, 238–245.
- Brusakova, I.A., 2019. Metody i modeli ocenki zrelosti innovacionnoj struktury. *Upravlencheskie nauki* 3, 56–62.

- Buranova, E.A., 2019. Konceptual'naja model' processa reabilitacionnogo institucional'nogo antikrizisnogo upravljenja predpriyatijami. Aktual'nye problemy jekonomiki i prava. T. 13(1), 948–965.
- Da Silva, V.L., Kovaleski, J.K., Negri Pagani, R., De Matos Silva, J., Corsi, A., 2020. Implementation of Industry 4.0 concept in companies: empirical evidences. *Int. J. Comput. Integr. Manuf.* 33(4), 325–342.
- Dmitrieva, I.N., Chernenko, A.F., 2018. Research methodology for lease financing receivables and payables. *Seriya: Jekonomika i menedzhment* 3, 92–98.
- Dolganova, O.I., Deeva, E.A., 2019. Gotovnost' kompanii k cifrovym preobrazovanijam: problemy i diagnostika. *Biznes-informatika* 2, 59–72.
- Fedoryshyna, L., Popovych Zubchynska, K., 2020. Accounting and analysis of settlements with suppliers and contractors. *Magyar Tudományos Journal* 41-2, 6–19.
- Galimova, M.P., 2019. Gotovnost' rossijskih predpriyatij k cifrovoj transformacii: organizacionnye drayvery i bar'ery. *Nauka, obrazovanie, jekonomika. Seriya: Jekonomika.* 1(27), 27–37.
- Garifullin, B.M., Zjabrikov, V.V., 2018. Cifrovaja transformacija biznesa: modeli i algoritmy. *KJe* 9, 1345–1358.
- Il'in, I.V., Ljovina, A.I., Dubgorn, A.S., 2019. Cifrovaja transformacija kak actor formirovanija arhitektury I IT-arhitektury predpriyatija. *Jekonomika i jekologicheskij menedzhment* 3, 50–55.
- Kochetkov, E.P., 2019. Cifrovaja transformacija jekonomiki i tehnologicheskie revoljucii: vyzovy dlja tekushhej paradigmy menedzhmenta i antikrizisnogo upravljenja. *Strategicheskie reshenija i risk-menedzhment.* T. 4, 330–341.
- Kochetkov, E.P., Zabavina, A.A., Gafarov, M.G., 2021. Cifrovaja transformacija kompanij kak instrument antikrizisnogo upravljenja: jempiricheskaja ocenka vlijanija na jeffektivnost'. *Strategicheskie reshenija i risk-menedzhment.* T. 12. 1, 68–81.
- Kostikova, A.V., Skeeter, N.N., Tarasova, I.A., 2021. Modeling of information system of personnel management in the conditions of digital transformation. *Fund. Res.* 4, 48–52. <http://fundamental-research.ru/ru/article/view?id=42437>
- Kuzin, D.V., 2019. Problemy cifrovoj zrelosti v sovremennom biznese. *Mir novoj jekonomiki* 3, 89–99.
- Lapidus, L.V., Leontieva, L.S., Gostilovich, A.O., 2019. Minimum digital basket of Russian regions for industry transformation. *Public Adm. Electron. Bull.* 77, 212–228. <https://cyberleninka.ru/article/n/minimalnaya-tsifrovaya-korzi-na-rossijskih-regionov-dlya-transformatsii-promyshlennosti>
- Mulyk, T., Mulyk, Y., 2020. Debts of the enterprise in the conditions of anti-crisis management: analytical and control aspects. *Nor. J. Dev. Int. Sci.* 48-2, 3–11.
- Mulyk, T.O., 2019. Organization of diagnostics of the enterprise and its business processes: theoretical and methodological approaches. *Mod. Econ.* 17, 158–164.
- Mulyk, T.O., Hordienko, M.I., 2017. Methodical approaches to management analysis in terms of integration processes. *Economy, Finances, Management: Current Issues of Science and Practice* 7(23), 7–19.21.
- Mulyk, T.O., Mulyk, Y.I., 2016. Classification of financial risks in the system of analytical and control support. *Collection of scientific works. Econ. Account. Finance.* 13(49), 107–118.
- Pylnova, V.P., 2020. Compliance with the balance of receivables and payables as an indicator of stable financial condition of the enterprise. *Investments: Practice and Experience* 1, 33–38.
- Shakhmametova, G.R., 2012. Information support for crisis management taking into account the life cycle by the example of bankruptcy monitoring. *Bulletin of UGATU = Vestnik UGATU* 6(51), 211–219.
- Tarasov, I.V., 2019. Podhody k formirovaniju strategicheskoy programmy cifrovoj transformacii predpriyatija. *SRRM* 2, 182–191.
- Tsenzharik, M.K., Krylova, J.V., Steshenko, V.I., 2020. Cifrovaja transformacija kompanij: strategicheskij analiz, faktory vlijanija i modeli. *Vestnik Sankt-Peterburgskogo universiteta. Jekonomika* 3, 390–420.
- Zhargalsajhan, N., 2021. Osobennosti cifrovoj transformacii zarubezhnyh kompanij: analiz opyta kompanii General Electric. *Strategii biznesa* 2, 42–48.

СПИСОК ИСТОЧНИКОВ

- Abdullaev, N.S., Sabina, E.S., 2019. Modern trends of digitalization and the effects it generates. *UEPS* 4, 32–38. <https://cyberleninka.ru/article/n/sovremennye-tendentsii-tsifrovizatsii-i-effekty-kotorye-ona-porozhdaet>
- Aleksandrova, T.V., 2019. Cifrovizacija kak sovremennyj trend razvitija menedzhmenta proizvodstvennyh organizacij. *Seriya: Jekonomika i menedzhment* 3, 137–144.
- Avdeeva, I.L., Polyanin, A.V., Golovina, T.A., 2019. Digitalization of industrial economic systems: problems and consequences of modern technology. *Proc. Sarat. Ser. Econ. Manage. Law* 3, 238–245.
- Brusakova, I.A., 2019. Metody i modeli ocenki zrelosti innovacionnoj struktury. *Upravlencheskie nauki* 3, 56–62.
- Buranova, E.A., 2019. Konceptual'naja model' processa reabilitacionnogo institucional'nogo antikrizisnogo upravljenja predpriyatijami. Aktual'nye problemy jekonomiki i prava. T. 13(1), 948–965.
- Da Silva, V.L., Kovaleski, J.K., Negri Pagani, R., De Matos Silva, J., Corsi, A., 2020. Implementation of Industry 4.0 concept in companies: empirical evidences. *Int. J. Comput. Integr. Manuf.* 33(4), 325–342.
- Dmitrieva, I.N., Chernenko, A.F., 2018. Research methodology for lease financing receivables and payables. *Seriya: Jekonomika i menedzhment* 3, 92–98.
- Dolganova, O.I., Deeva, E.A., 2019. Gotovnost' kompanii k cifrovym preobrazovanijam: problemy i diagnostika. *Biznes-informatika* 2, 59–72.

- Fedoryshyna, L., Popovych Zubchynska, K., 2020. Accounting and analysis of settlements with suppliers and contractors. *Magyar Tudományos Journal* 41-2, 6–19.
- Galimova, M.P., 2019. Gotovnost' rossijskih predpriyatij k cifrovoj transformacii: organizacionnye drajvery i bar'ery. *Nauka, obrazovanie, jekonomika. Serija: Jekonomika.* 1(27), 27–37.
- Garifullin, B.M., Zjabrikov, V.V., 2018. Cifrovaja transformacija biznesa: modeli i algoritmy. *KJe* 9, 1345–1358.
- Il'in, I.V., Ljovina, A.I., Dubgorn, A.S., 2019. Cifrovaja transformacija kak actor formirovanija arhitektury I IT-arhitektury predpriyatija. *Jekonomika i jekologicheskij menedzhment* 3, 50–55.
- Kochetkov, E.P., 2019. Cifrovaja transformacija jekonomiki i tehnologicheskie revoljucii: vyzovy dlja tekushhej paradigmy menedzhmenta i antikrizisnogo upravlenija. *Strategicheskie reshenija i risk-menedzhment.* T. 4, 330–341.
- Kochetkov, E.P., Zabavina, A.A., Gafarov, M.G., 2021. Cifrovaja transformacija kompanij kak instrument antikrizisnogo upravlenija: jempiricheskaja ocenka vlijanija na jeffektivnost'. *Strategicheskie reshenija i risk-menedzhment.* T. 12. 1, 68–81.
- Kostikova, A.V., Skeeter, N.N., Tarasova, I.A., 2021. Modeling of information system of personnel management in the conditions of digital transformation. *Fund. Res.* 4, 48–52. <http://fundamental-research.ru/ru/article/view?id=42437>
- Kuzin, D.V., 2019. Problemy cifrovoj zrelosti v sovremennom biznese. *Mir novoj jekonomiki* 3, 89–99.
- Lapidus, L.V., Leontieva, L.S., Gostilovich, A.O., 2019. Minimum digital basket of Russian regions for industry transformation. *Public Adm. Electron. Bull.* 77, 212–228. <https://cyberleninka.ru/article/n/minimalnaya-tsifrovaya-korzi-na-rossijskih-regionov-dlya-transformatsii-promyshlennosti>
- Mulyk, T., Mulyk, Y., 2020. Debts of the enterprise in the conditions of anti-crisis management: analytical and control aspects. *Nor. J. Dev. Int. Sci.* 48-2, 3–11.
- Mulyk, T.O., 2019. Organization of diagnostics of the enterprise and its business processes: theoretical and methodological approaches. *Mod. Econ.* 17, 158–164.
- Mulyk, T.O., Hordienko, M.I., 2017. Methodical approaches to management analysis in terms of integration processes. *Economy, Finances, Management: Current Issues of Science and Practice* 7(23), 7–19.21.
- Mulyk, T.O., Mulyk, Y.I., 2016. Classification of financial risks in the system of analytical and control support. *Collection of scientific works. Econ. Account. Finance.* 13(49), 107–118.
- Pylnova, V.P., 2020. Compliance with the balance of receivables and payables as an indicator of stable financial condition of the enterprise. *Investments: Practice and Experience* 1, 33–38.
- Shakhmametova, G.R., 2012. Information support for crisis management taking into account the life cycle by the example of bankruptcy monitoring. *Bulletin of UGATU = Vestnik UGATU* 6(51), 211–219.
- Tarasov, I.V., 2019. Podhody k formirovaniju strategicheskoy programmy cifrovoj transformacii predpriyatija. *SRRM* 2, 182–191.
- Tsenzharik, M.K., Krylova, J.V., Steshenko, V.I., 2020. Cifrovaja transformacija kompanij: strategicheskij analiz, faktory vlijanija i modeli. *Vestnik Sankt-Peterburgskogo universiteta. Jekonomika* 3, 390–420.
- Zhargalsajhan, N., 2021. Osobennosti cifrovoj transformacii zarubezhnyh kompanij: analiz opyta kompanii General Electric. *Strategii biznesa* 2, 42–48.

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SECTION 2

**ENTERPRISES AND SUSTAINABLE
DEVELOPMENT OF REGIONS**

РАЗДЕЛ 2

**ПРЕДПРИЯТИЕ И УСТОЙЧИВОЕ
РАЗВИТИЕ РЕГИОНОВ**

Research articleDOI: <https://doi.org/10.48554/SDEE.2022.1.2>**FORMATION OF EFFECTIVE ORGANISATIONAL MANAGEMENT SYSTEMS**Sergey Dianov^{1*} , Bokhodir Isroilov² ¹Vologda State University, Vologda, Russia, dianov.sv@mail.ru.²Tashkent State University of Economics, Tashkent, Uzbekistan, isbokhodir@gmail.com*Corresponding author: dianov.sv@mail.ru**Abstract**

The success of modern enterprises is largely determined by the organisation of their management systems. In such systems, the elements have unique behavioural characteristics and form complex connections within the framework of the redistribution of powers. This research is aimed to identify such a structure of relations between the elements of the system that would most effectively ensure the fulfilment of the goals set for the organisation's goals under conditions of interaction with a changing external environment. In this work, we examine the existing methods for assessing the effectiveness of organisational management systems, noting that a set of quantitative performance evaluations can be obtained using organisational modelling. For this, we propose that the processes involved in the systems of organisational management are considered in the context of queuing theory. At the same time, the assumption is formulated that the use of an agent-based approach will allow for obtaining the best results. Based on this, the main goal of the study presented in this article was to adapt the mechanism for assessing the effectiveness of the functioning of organisational management systems toward an agent-based approach, assess the adequacy of such models, and determine the boundaries of their capabilities. In this study, an organisational system constructed for processing citizens' appeals was chosen as the modeling subject. The following developed models are presented: analytical, discrete-event in the GPSS World environment, and agent-based in the AnyLogic environment. The results of a computational experiment using these models allow us to conclude about the adequacy of using an agent-based approach within the framework of the author's concept of assessing the effectiveness of the functioning of organisational management systems. At the same time, when using an agent-based approach, to a certain extent, it is possible to eliminate the limitations of other approaches related to both the complexity of modelling systems consisting of many organisational elements and performing a variety of tasks as well as the inability to display the individual characteristics of the system elements. The scientific novelty of the presented work lies in the development of an agent-based modelling of organisational management systems within the framework of the queuing theory to assess their efficiency.

Keywords: management innovation, performance indicators, organisational management system, organisational modelling, decision support

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ФОРМИРОВАНИЕ ЭФФЕКТИВНЫХ СИСТЕМ ОРГАНИЗАЦИОННОГО УПРАВЛЕНИЯ

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Аннотация

Успех функционирования современных предприятий, их конкурентоспособность, во многом определяется эффективностью организации их систем управления. В таких системах элементы имеют индивидуальный характер поведения и формируют сложные связи в рамках перераспределения полномочий. Задача заключается в нахождении такой структуры отношений между элементами системы, которая бы наиболее эффективным образом обеспечивала выполнение целей, поставленных перед организационной структурой в условиях взаимодействия с изменяющейся внешней средой. Инновации по адаптации системы управления должны быть неотъемлемой чертой любой организационной системы. Автором рассматриваются существующие методы оценки эффективности систем организационного управления. Отмечается, что набор количественных оценок эффективности можно получить с использованием организационного моделирования. Для этого процессы в системах организационного управления предлагается рассматривать в нотации теории систем массового обслуживания. При этом формулируется предположение о том, что использование агент-ориентированного подхода позволит получать наиболее адекватные результаты. Исходя из этого, основной целью исследования, представленного в статье, являлась адаптация механизма оценки эффективности функционирования систем организационного управления под агент-ориентированный подход, оценка адекватности таких моделей и определение границ их возможностей. В качестве опытного объекта моделирования была выбрана организационная система, осуществляющая процесс обработки обращений граждан. Представлены разработанные модели: аналитическая, дискретно-событийная в среде GPSS World и агент-ориентированная в среде AnyLogic. Результаты вычислительного эксперимента с использованием данных моделей позволяют сделать вывод об адекватности использования агент-ориентированного подхода в рамках авторской концепции оценки эффективности функционирования систем организационного управления. При этом при использовании агент-ориентированного подхода в определенной степени можно снять имеющиеся у остальных подходов ограничения, связанные как со сложностью моделирования систем, состоящих из множества организационных элементов и выполняющих множество разнообразных задач, так и с возможностью отображения индивидуальных особенностей элементов системы.

Ключевые слова: управленческие инновации, показатели эффективности, система организационного управления, организационное моделирование, поддержка принятия решений

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1. Introduction

An organisational management system (OMS) is understood as groups of people united by common goals who operate together under certain regulations (Koshkin, 2014). Such systems are complex, encompassing many heterogeneous elements that can situationally form a certain connection structure (Burkov and Novikov, 2019). This explains why the state of the system can hardly be predicted in advance in terms of its temporal and spatial changes.

The processes that occur in organisational management systems depend on planning as well as the meaningful, controlled transformation of resources into specific results (Pisariuk, 2019). In this case, both material objects and services can be considered results. A specific feature of management processes is their continuous, cyclic nature (Kolesnichenko et al., 2018); they break down into a number of consecutive phases. The composition of these phases can vary by case, but, as a rule, there are objective, descriptive, prescriptive implementation and retrospective phases. During the objective phase, the management goal is formed based on an analysis of the current situation, while the descriptive phase is the time to determine the sequence of actions necessary for reaching the goal. The prescriptive phase is necessary for forming management procedures that would lead to certain actions (Rodionov et al., 2021). The implementation phase is the time to take action, specifically actions planned in accordance with the adopted management procedures. Last, the results obtained are analysed during the retrospective phase. The analysis may be related to several processes. Overall, based on the analysis, it is possible to set new objectives, which in turn trigger new processes. This is the essence of the continuity and cyclicity of management processes.

The efficiency of the processes within an organisational management system should be assessed in a comprehensive way, taking into account all phases of the management cycle. The assessment should measure the speed at which the system responds to significant changes in the controlled environment as well as the quality of the results obtained (Solovyeva, 2018). Determining degree to which the process complies with the requirements laid down for its organisation is essential (Savelyeva, 2014). The adequacy of the organisational structure ultimately determines the quality of the results obtained (and, in many cases, the possibility of achieving the objectives that have been set). The literature often references a concept of organizational efficiency, which is generally understood as the performance of the organisational management system (Bozhko, 2013). In practice, some relative characteristics are often used for measuring organisational efficiency, reflecting the degree to which the results obtained match the goals given the resources spent accordingly (e.g., material, labour, financial, time resources).

The more flexible and adaptive the system, the more variants of its possible architecture can be obtained. This is especially true for organisational management systems experiencing continuous changes in a controlled environment. Innovations designed for the better adaptation of the management system should be an inherent feature of any organisational system (Sharapov et al., 2012). Multi-variance increases the possibility of identifying the most effective structure. At the same time, the multifactorial content of management structures predetermines a variety of principles for their optimisation (Klimova and Smirnova, 2010). The main scientific challenge is developing tools that can ensure an optimal process for identifying the most efficient architecture of the organisational management system.

To address this challenge, it is necessary to define a set of criteria for evaluating the efficiency of the functioning organisational management system as well as mechanisms for determining which values of the criteria are calculated. Today, subjective assessments are most commonly used in this way, with standards for individual operations also widely used. This makes the assessments somewhat more objective, but only in terms of individual sub-processes. Any comprehensive assessment in this case is difficult. In addition, it is becoming increasingly popular to use indirect assessments based on a variety of indicators that characterise management processes in terms of the achieved goals. But in this case, the assessment of organisational efficiency will be indirect too. Therefore, it is quite important to form objective criteria for measuring the efficiency of the organisational management system. The author considers using the tools of the queuing theory as a methodological basis for tackling this problem (Ventzel,

2007). Previous research studies (Shvetsov and Dianov, 2015) have developed a set of criteria and tested a certain approach using a case study of a real organisational management system. There is a need to further develop questions related to the formal representation of the general concept that could be used to form the model as well as provide flexibility in setting its parameters. This would provide organisations operating in various fields with a tool for synthesising efficient organisational management systems.

An agent-oriented approach can be used as the main paradigm underlying is to implement the agent-oriented approach in measuring the efficiency of organizational management systems g this model. In this way, adaptive models can be built. In addition, the processes can be described more adequately, including in terms of their informal component that manifests itself during the interaction among the organisational elements of the management system. Thus, the main purpose of the this study is to adapt the mechanism for measuring the efficiency of organisational management systems (OMS) toward an agent-oriented approach as well as assess the adequacy of such models and determine their limits.

The scientific novelty of this work is the developed concept of an agent-based modelling of organisational management systems that relies on the queuing theory to assess their efficiency.

2. Literature Review

To properly assess the efficiency of an OMS, it is essential to establish a set of objective indicators. It should be sufficient for evaluating operating systems in an ongoing way and assess possible changes. Thus far, there is no generally accepted assessment methodology despite consistent research being done in this field. Yet, questions related to improving the functioning efficiency of the OMS are considered in various studies (Solovyeva, 2018; Savelyeva, 2014; Bozhko, 2013; Sharapov et al., 2012; Klimova and Smirnova, 2010; Asaul et al., 2009; Tarasov, 2012; Dezhkina and Potasheva, 2008). At the same time, this problem still remains one of the most acute problems in this particular field — both nationally and internationally (Tarasov, 2012). The solutions suggested in the literature basically rely on the following approaches (Dezhkina and Potasheva, 2008):

- Use comprehensive assessments that integrate various economic, production, and other indicators;
- Apply indicators that characterise the achievement of management goals with the best use of resources;
- Use an expert evaluation method to measure various aspects of OMS operation;
- Use transitive assessments with the aid of the enterprise's performance indicators;

Make assessments based on three interrelated groups of indicators: resource efficiency, qualitative parameters characterising the organisation and the content of the management process, parameters for measuring the rationality of the organisational structure as well as its technical and organisational level.

The last of the presented approaches is potentially the most accurate. A special role is assigned to the assessment of the adequacy of the organisational structure, given the forecasted changes in the external environment and adaptation to the market changes in the external environment (Burton and Obel, 2018). There are various methods for structuring the OMS, including the expert method, the method of analogies, the method of tasks, and the method of goal structuring. Their common weakness is a lack of quantitative estimates (Asaul et al., 2009). To obtain quantitative estimates of the efficiency of the organisational structure, organisational modelling methods are used; these are mathematical multifactor models. Some researchers highlight the following advantages of this method (Krivoruchko and Sukach, 2015): its capability of covering various aspects of the formation of the management structure (e.g., managerial, informational, socio-psychological); its potential application in the resolution of problems, the main parameters of which are the direct characteristics of the organisational structure; and its potential application in measuring changes in the organisational structures. However, for complex subjects, including the OMS, mathematical modelling methods can hardly be used (Burton and Obel, 2018). This

is due to the fact that the overall results of control systems are formed by the results of many interacting processes. Traditional approaches have a limited ability to analyse multiple interdependent processes that occur simultaneously. In these cases, a good alternative may be simulation modelling (Harrison et al., 2007).

Simulation models can enhance the processes in existing and persistent organisational mechanisms and systems as well as generate new approaches to organising and managing people's joint activities, such as the design of organisational systems with predefined properties. This can all be done in an environment with a large number of elements, complex connections between them, and courses of events (Parinov, 2007). The models built can be used to carry out computational experiments with various organisational configurations. In addition, new organisational structures can be synthesised to greatly differ from their traditional counterparts, with the capability of reacting promptly to changes in the external environment (Burton and Obel, 2018).

There are two opposite approaches to the simulation of an OMS (Gerasimov et al., 2005). The first uses an initially well-planned model architecture as a basis. All the elements and their interrelations are identified, and the guidelines for selecting the parameters of the organisational management system are described in the form of determinate patterns. Such models are used for studying the behaviour of the system under various control and input parameters. The outcome is the measured quality of the system as it functions under certain criteria. Regression and optimisation models can be highlighted among the methods used in this approach.

Regression models are developed for use in combination with standard structures. This method is applicable for determining the limits of the centralisation of management functions, staffing number standards; developing subdivision structures; and determining the number of rational hierarchy levels (Gerasimov et al., 2005). The use of the regression model was presented by Abrosimova (2015), who developed a multifactorial regression model for assessing the performance of the personnel management system within the organisation.

Optimisation models can be commonly formed using the queuing theory. The organisational elements of the system, which process the flows of various applications, are considered service channels. Chernyakhovskaya et al. (2016a, 2016b) and Galiullina (2015) consider the system for providing state and municipal services a queuing system. The structure of the service system is defined by the number and mutual arrangement of service channels. The system options are assessed according to the following criteria: technical characteristics (the length of time to service an application, service channel capacity, service channel downtime, probability of an application being serviced); economic characteristics (cost of the OMS, maintenance costs, system support costs); reliability characteristics of the OMS (system success probability, system operational state restoration probability). Examples of the practical use of models based on the queuing theory were presented by Okemiri (2018) and Amiens et al. (2020).

Li et al. (2015) suggested using genetic programming for optimising the organisational structure of multi-agent systems, as this method can be applied to a wide range of organisational forms and entails lower computational costs in comparison with exact methods. Khosraviani et al. (2004) described an optimal design model implemented at design organisations based on genetic programming methods. The model is an optimiser for the design simulator of organisational projects. During modelling, the decision-making policies and individual characteristics of subgroups vary, while the impact on the quality and duration of the project is compared using the fitness function. Then, the solutions obtained are compared to the best developments created by humans.

Another approach to modelling an OMS is based on its display as an open self-organising system. The ability of the system to adapt to changing conditions in the environment is modelled by taking into account the presence of a subjective element in the system: a person and their potential arbitrary behavior (Gerasimov et al., 2005). The model should include typical actors in the system along with their inherent behavioural attitudes and the environment in which they operate. Such models are studied under

various environmental configurations. The results of the modelling are identification of the most optimal structure for the organised interaction of the actors and their characteristics given the specified criteria of efficiency. Here, with attention given to microstructures, a large number of possible system states are achieved. With the various aggregations of many micro-level mechanisms, several macro-level organisational forms can be synthesised. At the same time, special attention is paid to the behavioural aspects of the system elements at various levels as well as the organisation of their interaction. These modelling methods have resulted in a new field of research in which several design options can be considered simultaneously. With these new tools, it has become possible to conduct systematic studies on a large number and variety of designs in terms of performance implications (Joseph et al., 2019).

This shift in theoretical focus is confirmed by a wider use of agent-oriented models in the literature (Dutta et al., 2015; Crowder et al., 2009; Quillinan et al., 2009; Chang and Harrington, 2006; Secchi and Neumann, 2016; Wall, 2016; Gomez-Cruz et al., 2017). The researchers highlight that such models are well-suited for a ‘bottom-up’ modelling of complex distributed systems and, especially, social systems, where we have to consider the specific behaviour of individuals interacting with each other to achieve their goals (Sayama, 2015). Such systems can hardly be modelled using other approaches. Given the challenge of forming an organisational structure, agent-oriented modelling allows us to flexibly define individual and team models as well as task workflows and simulate diverse variants of organisational structures to assess their performance (Dutta et al., 2015).

The work of Stanojevic et al. (2019) can be considered an example of approaches to organisational design based on agent-oriented modelling, with the authors presenting a methodology that relies on the following basic ideas:

1. Advanced software (simulation) technologies are used toward the object-oriented modelling of the behaviour of elements in the organisation (managers, technological resources, etc.).
2. The organisation is considered an information processing system. Managers in the organisation are modelled as interacting rational agents. The agents make decisions based on incoming messages and existing decision-making procedures and send messages to their organisational environment. Their resources for performing their functions are limited.
3. Various messages (information) are used to describe all the requirements of prospective consumers and all types of activities. Each message relates to a specific process in the organisation. The original message changes according to the process.
4. Modified organisational matrix-tables are introduced to link the processes and agents/objects. These help overcome the complexity of communication system modelling.
5. Important quantitative indicators are monitored to measure the efficiency of the model for a certain period of time.

The analysed agent-based models show that the weak application of even a randomly chosen formal bottom-up structure can be useful for guiding the emerging upward networks of intra-organisational interactions between agents (Clement and Puranam, 2017) (Levinthal and Workiewicz, 2018). If a formal structure is absent, interactions within the organisation tend to decline, since interactions require coordination to be maintained, while no coordination is required for stopping them. A formal structure restores a network of interactions between agents, who can then determine which interactions to keep and which to discard.

Along with the prospects of an agent-oriented approach to OMS modelling, researchers have highlighted a problem related to correlating the models with reality (Chang and Harrington, 2006). The reliability of a model depends on the assumptions made within it. Given the complexity of organisational systems, it is quite difficult to ensure an acceptable level of reliability of an agent-oriented domain model. Therefore, before they are used in practice, it is proposed they should be compared with the results of

the existing positive experience in the OMS simulation. This will not only foster a greater confidence in the model, but may also contribute to proposals for their useful modification.

Many researchers have emphasised the need for additional studies to coordinate two competing but complementary approaches to OMS modelling (Hunter et al., 2020). All approaches to designing organisational systems that exist today share several common characteristics: they simulate smaller, flexible and, consequently, more successful parts that are connected to the general network of the organisation. There has also been a constant shift in the form of structures from vertically tall and functionally aligned to horizontal and process-oriented networks. Under these conditions, it is difficult to choose an adequate methodology for organisational design. There are many possible solutions, yet all have some constraints or pose obvious implementation problems. This is why organisational design is still considered both an art and a science (Stanojevic et al., 2019).

3. Materials and Methods

Organisational systems aim to fulfil the flow of tasks coming to them. Depending on the size and complexity of the tasks, organisational structures are formed to determine the rights, powers, and responsibilities of their elements (Talanova and Alekseeva, 2015). The author proposed to evaluate the efficiency of such structures using the methods of the queuing theory (Ventzel, 2007; Shvetsov and Dianov, 2015). For clarity of this approach, let us consider an OMS dealing with citizens' applications (Valov et al., 2020). Most agencies, institutions, and enterprises must work with people's applications and complaints. Given the importance and scope of this work, organisational structures are created to ensure the efficient execution of processes related to the management of these applications. The articles solve the following problems: application registration; preliminary analysis for the competence of content consideration; controlling the time within which applications are considered; substantive analysis of the quality with which an application has been processed; and general analysis of the processes in which applications are considered.

This system interacts with both the external environment (citizens, agencies, enterprises) and internal environment. At the same time, it serves many information flows of messages coming from these two environments. These flows concern a certain list of the types of work carried out by employees of the OMS engaged in the organisation of procedures according to which citizens' applications are considered. In this context, the system can be regarded as an open multichannel system with an unlimited queue (Fig. 1).

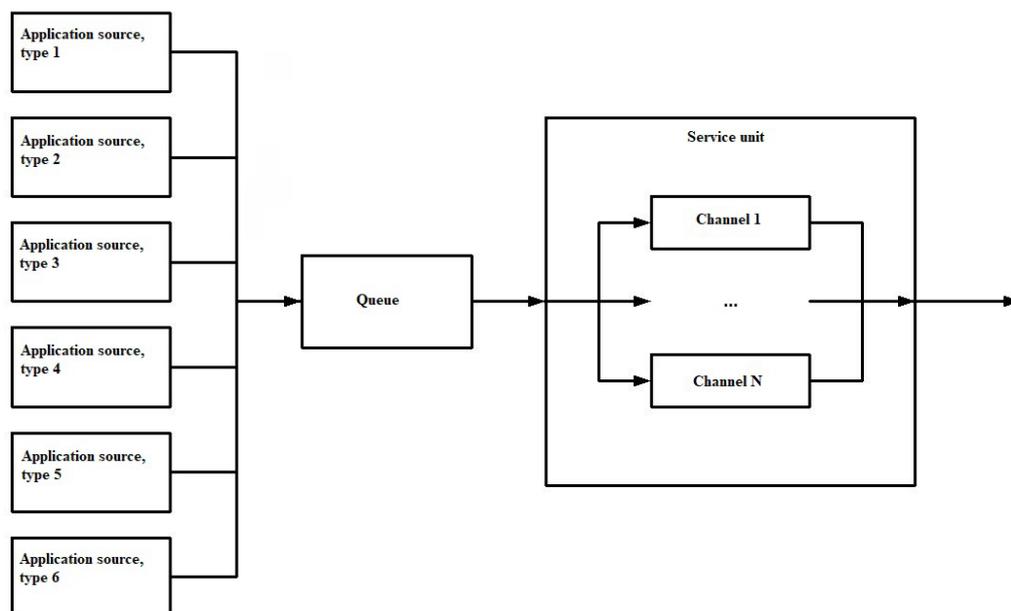


Figure 1. Queuing system structure

Typical operations carried out by employees are considered as applications, while employees are seen as service channels. The following sources of application types are considered: 1) registering and determining the procedure according to which the applications are considered; 2) changes in the control terms; 3) removal from control; 4) control of the execution course; 5) the generation of periodic reports; 6) reporting on applications.

The system is characterised by the following parameters (Shvetsov and Dianov, 2015): the number of service channels (N); the application receipt intensity λ ; the application service intensity (μ). The application receipt intensity is defined as the inverse of the average time between the receipt of two related applications (t_p): $\lambda = 1/t_p$. The application service intensity is defined as the inverse of the service time spent on one request (t_o): $\mu = 1/t_o$.

The following parameters can be defined for the existing operation mode of the system:

1) The overall intensity of the received applications:

$$\lambda_o = \sum_{i=1}^6 \lambda_i, \tag{1}$$

where λ_i is the receipt intensity of an application of the i -th type.

The total intensity of the application servicing is:

$$\mu_o = \sum_{i=1}^6 \mu_i \tag{2}$$

where μ_i is the servicing intensity of an application of the i -th type.

2) The load factor of the unit:

$$\psi = \lambda / \mu = t_o / t_p, \tag{3}$$

3) The total load factor of the system unit:

$$\psi_o = \sum_{i=1}^6 \psi_i, \tag{4}$$

where ψ_i is the unit load factor for servicing an application of the i -th type.

The system is presented as a labelled graph. The graph nodes define the possible states of the system:

P_0 – the system has no applications, and all the channels are at a standstill;

P_1 – there is one application in the system;

P_n – there are n applications in the system.

Two situations are defined for a multi-channel system:

1) The number of requests n arriving in the system is smaller than the number of service channels N (all applications are being serviced):

$$P'_n = P_0 \times (\psi_o)^n / n! \tag{5}$$

2) The number of requests n arriving in the system is larger or equal to the number of service channels N (N requests are being serviced, while the others are waiting in the queue):

$$P_n = P_0 \times (\psi_o)^n / (N! \times N^{n-N}) \tag{6}$$

The probability of no applications in the system:

$$P_0 = (1 + \sum_{n=1}^{N-1} \psi_o^n / n! + \sum_{n=N}^{\infty} \psi_o^n / (N! \times N^{n-N}))^{-1}. \tag{7}$$

The efficiency criteria of the system:

1) Average load of the system channels:

$$\gamma = \sum_{n=1}^N (1 - \sum_{k=0}^{n-1} P_k) / N. \quad (8)$$

2) Average length of the queue:

$$L_q = \psi^{N+1} P_0 / (N-1)!(N-\psi)^2. \quad (9)$$

3) Average number of applications in the system:

$$L_s = L_q + \psi. \quad (10)$$

4) Average length of time an application remains in the queue:

$$W_q = L_q / \lambda_o. \quad (11)$$

5) Average length of time an application remains in the system:

$$W_s = W_q + 1 / \mu_o. \quad (12)$$

The system can be considered optimally efficient if 1) the values of the average length of the queue, the average number of applications in the system, the average length of time an application stands in the queue, and the average length of time an application remains in the system are within the range of the desired values, and 2) the highest indicator of the average load of the device channels is observed.

Simulation modelling environments are often used to resolve problems presented in the form of queuing systems. One of the most popular queuing systems is GPSS World (Tomashevsky and Zhdanova, 2003). With the authors' participation, a discrete-event simulation model was built in this modelling environment to present the process of work organised to consider citizens' applications. A real entity existing at the time the model was created, the Department of Letters and Reception of Citizens of the Government of the Vologda Region (DLRC) was chosen as the object of modelling (Dianov and Shvetsov, 2004). The following parameters were set for the model:

- An exponential distribution of the time intervals for the receipt of neighbouring applications of the same type (each type of application comes from a large number of independent sources within a certain time interval);
- The length of time for servicing applications is subject to an indicative law (the amount of time for servicing applications in the system is random, with most spreading around average values);
- Each service channel can accept any application and has the same characteristics for servicing applications;
- There is a single queue in the system for applications of all types. The waiting method of the system is non-priority and organised according to the First In–First Out (FIFO) rule.

Table 1 shows the characteristics of the DLRC operation used in the model and obtained by the author as a result of experiments, surveys, statistical analysis of databases, and observations of the work of department employees:

- To determine the average service time, methods such as interviewing the employees in the DLRC and monitoring their work were used;
- The average interval for periodic reports was obtained based on an analysis of the organisational documentation (work regulations);
- The average intervals of registration and determining the procedure for considering applications, changes in the terms, and removal from control were obtained based on an analysis of the database of the automated system for recording citizens' applications;

The average intervals for monitoring the progress of executed resolutions following applications

and reports created on the requests of agencies, organisations, and citizens were obtained using surveys and observing the work of the DLRC employees.

Table 1. Characteristics of the work of the Department of Letters and Reception of Citizens

Application type	Average receiving time, min.	Average servicing time, min.
1. Registering and determining the consideration order	19	35
2. Change in the terms	96	5
3. Removal from control	40	7
4. Control of the execution process	480	60
5. Periodic reporting	9600	120
6. Reporting per requests	3200	25

Figure 2 presents the text of the simulation model program. The program consists of eight segments: segments 1–6 describe the order according to which applications of various types are created; segment 7 determines the order according to which an application enters or leaves the general queue and the order for servicing applications by a multi-channel unit; and segment 8 sets the simulation time.

```

.....
+ The Model
.....
+ 6 segments are created that simulate six types of service applications,
+ seventh segment - common blocks for the six previous segments,
+ the eighth segment is the timer segment responsible for the simulation time.

-T_1 TABLE M1,0,10,12 ; table for monitoring the time spent by applications in th
-T_4 TABLE Q1,0,1,12 ; table for monitoring queue length
-T_2 TABLE MP2,0,10,12 ; a table for monitoring the time of applications stay in t
-T_3 TABLE MP3,0,10,12 ; table for monitoring the time of applications stay under

F_A FUNCTION F1,D6 ; a function that, according to the type of applic
1,35/2,5/3,7/4,60/5,120/6,25 ; gives the average service time

USTR STORAGE 2 ; selecting the number of the device's channels

+ 1 section: Registration and consideration of applications
GENERATE 19, (EXPONENTIAL(1,0,1))
ASSIGN 1,1 ; remember the type of application in the parameter with the
TRANSFER ,L_1 ; click on the label L_1

+ 2 section: Changing the terms of appeals consideration
GENERATE 96, (EXPONENTIAL(1,0,1))
ASSIGN 1,2 ; remember the type of application in the parameter with the
TRANSFER ,L_1 ; click on the label L_1

+ 3 section: Withdrawal from control
GENERATE 40, (EXPONENTIAL(1,0,1))
ASSIGN 1,3 ; remember the type of application in the parameter with the
TRANSFER ,L_1 ; click on the label L_1

+ 4 section: Monitoring the progress of execution
GENERATE 480, (EXPONENTIAL(1,0,1))
ASSIGN 1,4 ; remember the type of application in the parameter with the
TRANSFER ,L_1 ; click on the label L_1

+ 5 section: Creating periodic reports
GENERATE 9600, (EXPONENTIAL(1,0,1))
ASSIGN 1,5 ; remember the type of application in the parameter with the
TRANSFER ,L_1 ; click on the label L_1

+ 6 section: Creating reports on queries
GENERATE 3200, (EXPONENTIAL(1,0,1))
ASSIGN 1,6 ; remember the type of application in the parameter with the
TRANSFER ,L 1 ; click on the label L 1

+ 7 section: The general part
L_1 QUEUE 1 ; the application is entered in the queue
+ MARK 2

```

Figure 2. Software implementation of the simulation model

The challenge with the formation of models of organisational systems is aggravated by the fact that their elements (people) behave actively (Koshkin et al., 2014). From the author's point of view, this feature can be taken into account if agent-oriented models are built. To assess the adequacy of the agent-oriented approach, the author built a model of the process of organising work based on the consideration of citizens' applications in the AnyLogic agent-oriented modelling environment (Borshchev, 2013), which is based on the approaches used for creating the respective model in the GPSS World environment. Figure 3 shows the main diagram of the model.

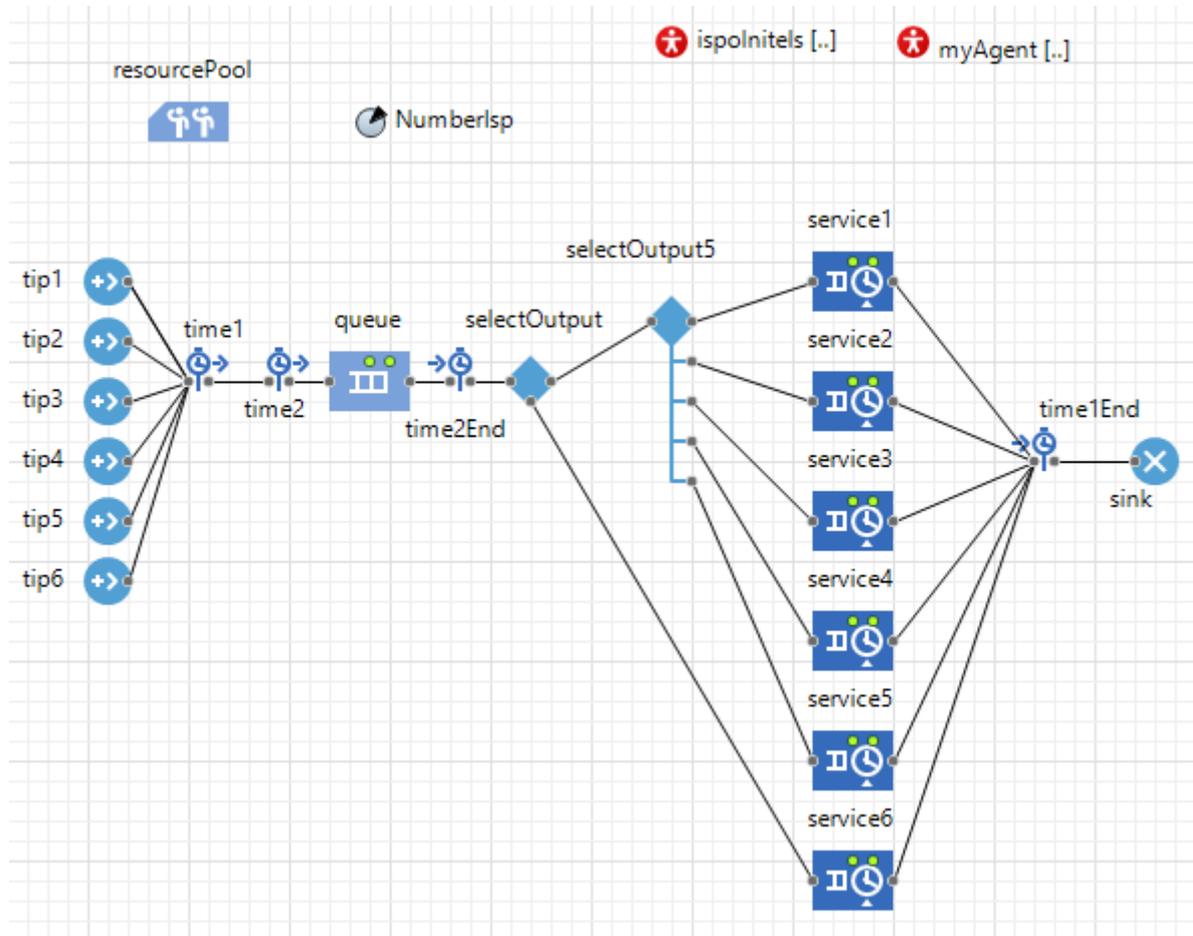


Figure 3. Main diagram of the model of the process of organising work on the consideration of citizens' applications in the AnyLogic environment

There are two types of agents in the model: myAgent, applications (Application Agent), and ispolnitels, employees of the DLRC (Executor Agent). Executor Agents represent the servicing channels. At the level of an Application Agent, a variable is determined, the value of which indicates the type of application. Six elements of the 'Source' type (tip1–tip6) generate Application Agents of the relevant type. Application Agents arrive at the common queue, which is organised according to FIFO rule. The applications are served by 'Service' type blocks (service1–service6). Each block serves only its own type of applications. The appropriate redistribution is made by two SelectOutput elements (selectOutput and selectOutput5). The Executor Agents are determined as the consumed resources during servicing (resourcePool element). The NumberIsr parameter sets the number of Executor Agents to be created. At the end of the service, the Application Agents are destroyed by the 'Sink' type block (sink). The TimeMeasureStart (time1 and time2) and TimeMeasureEnd (time1End and time2End) elements are used to determine the timers that set the time during which an application can remain in the queue and in the system.

In order to visually display the simulation results, five elements of the 'Bar Chart' type are created.

These can be used to track the average number of applications in the system, average length of the queue, average load of the channel, average amount of time an application stands in the queue, and average amount of time an application remains in the system.

4. Results

The simulation environments allowed us to conduct the necessary experiments using fairly simple means and, ultimately, obtain results that can be applied for assessing the efficiency of the DLRC. Figure 4 shows an example of the results obtained in the GPSS World simulation environment.

START TIME	END TIME	BLOCKS	FACILITIES	STORAGES
0.000	121440.000	27	0	1

QUEUE	MAX CONT.	ENTRY	ENTRY (0)	AVE. CONT.	AVE. TIME	AVE. (-0)	RETRY
1	1173	1173	10995	8 592.286	6541.809	6546.572	0

STORAGE	CAP.	REM.	MIN.	MAX.	ENTRIES	AVL.	AVE.C.	UTIL.	RETRY	DELAY
USTR	2	0	0	2	9822	1	1.999	1.000	0	1173

TABLE	MEAN	STD.DEV.	RANGE	RETRY FREQUENCY	SUM. %	
T_1	6572.726	3822.693		0		
			0.000 -	10.000	5	0.05
			10.000 -	20.000	2	0.07
			20.000 -	30.000	1	0.08
			30.000 -	40.000	2	0.10
			40.000 -	50.000	2	0.12
			50.000 -	60.000	5	0.17
			60.000 -	70.000	2	0.19
			70.000 -	80.000	3	0.22
			80.000 -	90.000	4	0.26
			90.000 -	100.000	6	0.33
			100.000 -	-	9788	100.00

Figure 4. An example of the output of the results from the simulation modelling of the process of organising work on the consideration of citizens’ applications in the GPSS World environment

Figure 5 shows an example of the model execution in the AnyLogic environment.

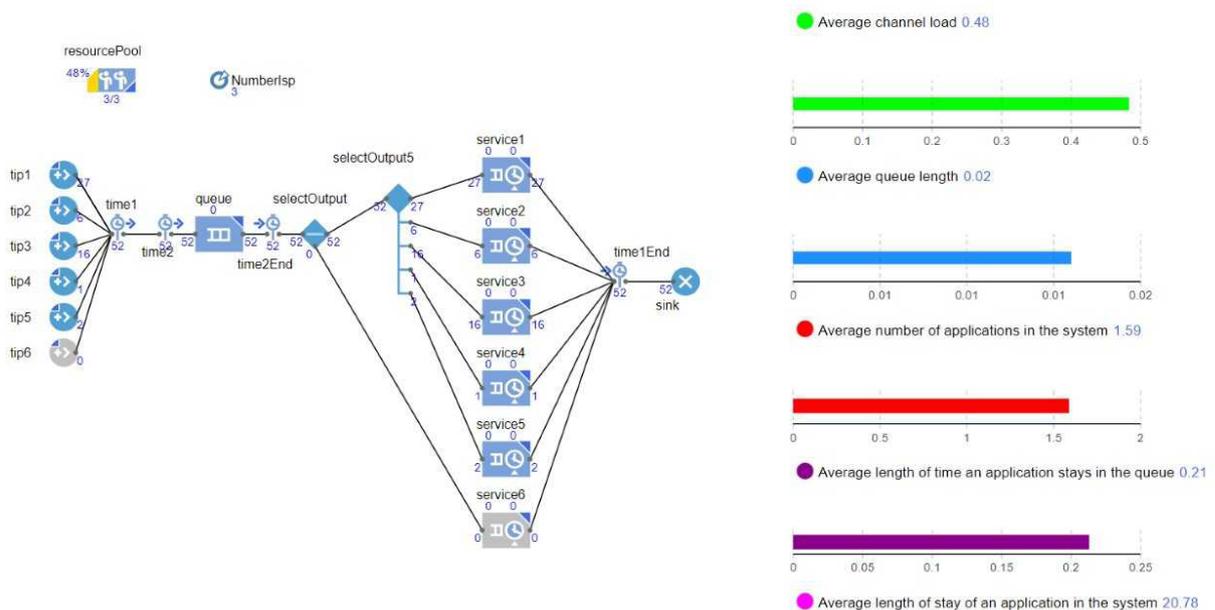


Figure 5. An example of the model of the work organised for considering citizens’ applications in the AnyLogic environment

To determine the adequacy of the agent-oriented model of the process of work organised around considering citizens' applications, a computational experiment was carried out. Using an analytical model, a simulation model in the GPSS World environment and a simulation model in the AnyLogic environment, efficiency indicators of the DLRC were obtained for different numbers of channels. The simulation time of the system operation was set as the working time for one year: $253 \times 8 \times 60 = 121,440$ minutes. Table 2 shows the results obtained.

Table 2. The results of the efficiency indicator calculation

Number of channels	Indicator	Analytical model	Simulation model	
			GPSS World	AnyLogic
2	Average load of channels	-	1	1
	Average length of the queue	-	592.286	370
	Average number of applications in the system	-	594.859	373.73
	Average time an application stands in the queue, min.	-	6541.809	4296.62
	Average time an application remains in the system, min.	-	6572.726	4341
3	Average load of channels	0.738	0.747	0.71
	Average length of the queue	1.464	0.854	1.09
	Average number of applications in the system	3.644	3.095	3.82
	Average time an application stands in the queue, min.	16.2	9.435	12.52
	Average time an application remains in the system, min.	41.2	34.194	43.65
4	Average load of channels	0.5425	0.561	0.53
	Average length of the queue	0.28	0.134	0.13
	Average number of applications in the system	2.48	2.377	2.43
	Average time an application stands in the queue, min.	3.1	1.48	1.53
	Average time an application remains in the system, min.	28.1	26.25	27.86

The indicators of both simulation modelling types imply a low efficiency of the system. The values of all indicators—except that of the average load—are quite different. However, it should be noted that the ratios of the parameters are proportional: the ratio between the indicator of the average load of the channels and the average number of applications in the system is 1.6; the ratio between the indicator of the average time an application stands in the queue and the average time an application remains in the system is 1.5.

In general, comparable indicators were obtained for all models for systems with three and four channels. First, this refers to the indicators' values regarding the average load of the channels. As for the remaining indicators, in most cases, the values obtained using the agent-oriented model were between the values obtained using the analytical model and those obtained from the simulation model implemented in the GPSS World environment.

Based on the results obtained, it can be concluded that the agent-oriented approach can be ad-

equately used within the author's concept of assessing the efficiency of organisational management systems.

5. Discussion

The concept described in this paper propels the integration of two approaches in the model simulation of an efficient OMS: one focused on the initial use of a clear model architecture and another defining an OMS as an open self-organising system in which many active elements interact. Some foreign authors believe that research in this area is promising (Hunter et al., 2020). This is due to the fact that none of the above-mentioned approaches alone can adequately display and evaluate the totality of the processes occurring in OMS. The author is interested in combining the queuing theory and agent-oriented modelling. The separate application of these methods is considered in the works of various authors. Specifically, the use of the queuing theory for measuring the efficiency of an OMS is presented by Chernyakhovskaya et al. (2016a, 2016b), Galiullina (2015), Okemiri (2018), and Amiens et al. (2020), while agent-oriented modelling is discussed by Dutta et al. (2015), Crowder et al. (2009), Quillinan et al. (2009), Chang and Harrington (2006), Secchi and Neumann (2016), Wall (2016, 2021), Gomez-Cruz et al. (2017), Reinwald et al. (2021), Adomavicius et al. (2021), Wall and Leitner (2021). According to the results of these studies, we can assert that the chosen area of research has considerable prospects.

The author considers the results obtained in the course of this research as the first step towards enhancing the tools used for evaluating the efficiency of organisational management systems. It should be noted that the very concept of efficiency—defined with the queuing theory—should be preserved, as it is useful for assessing organisational structures in an adequate way. The original tools developed previously have limitations, as it is difficult to model large systems (i.e., those consisting of many organisational elements and requiring the performance of a variety of tasks) and display the individual traits of employees. The author believes these challenges can be addressed to a certain extent with the implementation of an agent-oriented approach. The subsequent steps for its implementation should consist of the following:

- Creating a flexible mechanism for Application Agents (a large number of Application Agents with various parameters can be created);
- Forming the structure of the parameters of Executor Agents to determine the possible range of Application Agents they serve;
- Creating a flexible mechanism to facilitate the Application Agents' redistribution for being serviced between Executor Agents.

If implemented, this functionality can help not only in achieving better results in determining the efficiency of organisational management systems but also in choosing their most effective structure under specific conditions.

In addition, there is a need for tackling the methodological aspects related to the construction of agent-oriented models for assessing the efficiency of the functioning of organisational management systems.

6. Conclusion

Within this research, some work was done to adapt the queuing theory-based mechanism for assessing the efficiency of the functioning of the OMS within the framework of an agent-oriented approach. The aim was to build an agent-oriented model for assessing the efficiency of the OMS and to evaluate the adequacy of such models.

The following are the main conclusions of the study:

- One of the urgent challenges to be resolved by various institutions is developing a mechanism for adapting to changing environmental conditions, which is possible only through implementation of rational and timely organisational changes of management subsystems;
- To tackle this problem, it is necessary to establish a set of criteria for evaluating the efficiency of the functioning organisational management system as well as mechanisms for ensuring the process in which the values of the criteria are calculated;

- Simulation modelling is the most effective method that provides ample opportunities for studying and designing organisational management systems;
- In terms of the challenge related to the formation of an organisational structure, agent-oriented modelling can be used to flexibly define individual and team models as well as task workflows, and simulate many variants of organisational structures to assess their performance;
- Agent-based modelling is an adequate tool for measuring the efficiency of organisational management systems.

The practical significance of the results obtained in this study revolves around their potential use among enterprises, organisations, and institutions in various fields as a tool for forming the organisational structure of the management subsystem.

References

- Abrosimova, E.B., 2015. Applying multifactorial regression analysis for improving human resource management efficiency. *Technological Audit and Production Reserves* 6 (5), 26. 53-58.
- Adomavicius, G., Jannach, D., Leitner, S., Zhang, J., 2021. Understanding longitudinal dynamics of recommender systems with agent-based modelling and simulation. <https://doi.org/10.48550/arXiv.2108.11068>
- Amiens, E., Adedoyin, O., Adeyemi, S., 2020. Optimising service delivery using queueing theory. *Afr J Manage* 5, 73-88.
- Asaul, A.N., Asaul, N.A., Simonov, A.V., 2009. Forming and assessing the efficiency of an organisational management structure of companies in investment and construction business. Saint-Petersburg: GASU, 258.
- Borshchev, A., 2013. *The Big Book of Simulation Modelling: Multimethod Modelling with Anylogic 6*. AnyLogic North America.
- Bozhko, L.M., 2013. On the essence of management efficiency in the context of organisational changes based on the marketing approach. *The Bulletin of the Astrakhan State Technical University. Series: Economics* 1, 37-40.
- Burkov, V.N., Novikov, D.A., 2019. The theory of active systems is 50 years old: the history of development. In: V.N., Burkov (Ed.), *Proceedings of the International Scientific and Practical Conference*, November 18-19, 2019. IPU RAS, pp. 10-54.
- Burton, R.M., Obel, B., 2018. The science of organisational design: fit between structure and coordination. *J. Org. Design* 7 (5). <https://doi.org/10.1186/s41469-018-0029-2>.
- Chang, M.-H., Harrington, J.E., 2006. Chapter 26: Agent-based models of organizations. In: Tesfatsion, L., Judd, K.L. (Eds.), *Handbook of Computational Economics*, vol. 2. Elsevier, pp. 1273-1337.
- Chernyakhovskaya, L.R., Galiullina, A.F., Sabitov I.I., 2016. Assessing the efficiency of public services using a fuzzy logic system. *Information Technologies* 22 (8), 563-568.
- Chernyakhovskaya, L.R., Gvozdev, V.E., Galiullina, A.F., 2016. Decision support for assessing the quality of public services using ontological analysis. *Design Ontology* 6 (2), 20, 193-204.
- Clement, J., Puranam, P., 2017. Searching for structure: formal organisation design as a guide to network evolution. *Management Science* 64 (8), 3879-3895. <https://doi.org/10.1287/mnsc.2017.2807>
- Crowder, R., Hughes, H., Sim, Y.W., Robinson, M., 2009. An agent based approach to modelling design teams. In: 17th International Conference on Engineering Design, September 3-4, 2015. Stanford, pp. 91-102.
- Dezhkina, I.P., Potasheva, G.A., 2008. Assessing the efficiency of organisational management structures. *Problems of the Theory and Practice of Management* 5, 80-86.
- Dianov, S.V., Shvetsov, A.N., 2004. Enhancing the organised work with citizens' appeals in organisational management systems using a multi-agent technology. *Algorithms, Methods and Data Processing Systems* 9-2, 97-101.
- Dutta, P., Pepe, C., Xi, H., 2015. Analyzing organisation structures and performance through agent-based socio-technical modelling. In: Handa, H., Ishibuchi, H., Ong, Y.S., Tan, K.C. (Eds.), *Proceedings of the 18th Asia Pacific Symposium on Intelligent and Evolutionary Systems*, vol. 2, pp. 39-53.
- Galiullina, A.F., 2015. Modeling the process of public services provision. *Scientific Review* 22, 253-263.
- Gerasimov, B.I., Shubin, A.V., Romanov, A.P., 2005. *Modeling the Organisational Structure of an Industrial Enterprise [Monograph]*. Publishing House of the TSTU, Tambov, 86.
- Gómez-Cruz, N.A., Saa, I.L., Hurtado, F.F.O., 2017. Agent-based simulation in management and organisational studies: a survey. *European Journal of Management and Business Economics* 26 (3), 313-328. <https://doi.org/10.1108/EJM-BE-10-2017-018>.
- Harrison, J.R., Lin, Z., Carroll, G.R., Carley, K.M., 2007 [Forthcoming]. Simulation modelling in organisational and management research. *Academy of Management Review* 32 (4), 1229-1245.
- Hunter, S.D., Bentzen, H., Taug, J. 2020. On the 'missing link' between formal organisation and informal social structure. *J. Org. Design* 9 (13). <https://doi.org/10.1186/s41469-020-00076-x>.
- Joseph, J., Baumann, O., Burton, R., Srikanth, K., 2019. Reviewing, revisiting, and renewing the foundations of organisation design. *Organisation Design. Advances in Strategic Management* 40, 1-23. 10.1108/S0742-332220180000040012
- Khosraviani, B., Levitt, R., Koza, J., 2004. *Organisation design optimization using genetic programming*. Working Paper 2004-85, Stanford University.

- Klimova, N.S., Smirnova, G.A., 2010. Organisational audit as a tool for improving the efficiency of an enterprise. *The Bulletin of INGECON–SPB: RIO INGECON*, 339-342.
- Kolesnichenko, E.A., Rudakova, O.V., Plakhov, A.V., 2018. Efficiency in public administration: Russia and the world trends. *Srednerussky Bulletin of Social Sciences* 13 (2), 161-175.
- Koshkin, K.V., 2014. Simulating organisational project and program management systems. *Project Management and Production Development* 2 (50), 6-14.
- Krivoruchko, O.N., Sukach, Y.A., 2015. Organisational modelling of a process-oriented enterprise management structure. *Economics of the Transport Complex* 25, 50-66.
- Levinthal, D., Workiewicz, M., 2018. When two bosses are better than one: nearly decomposable systems and organisational adaptation. *Organisation Science* 29. <https://doi.org/10.1287/orsc.2017.1177>.
- Li, B., Yu, H., Shen, Z., Cui, L., Lesser, V.R., 2015. An evolutionary framework for multi-agent organisations. In: 2015 IEEE/WIC/ACM International Conference on Web Intelligence and Intelligent Agent Technology (WI-IAT), pp. 35-38. <https://doi.org/10.1109/WI-IAT.2015.45>.
- Mikhnenko, P.A., 2015. *Mathematical Modelling of the Processes Related to the Development and Management of Changes in Economic Organisations [Monograph]*. Synergy University, Moscow, 214.
- Okemiri, H., 2018. Analysis of queuing model: a case study of Madonna Model Secondary School, Owerri. *Discovery* 54(269), 189-194.
- Parinov, S.I., 2007. New possibilities for simulation modelling of socio-economic systems. *Artificial Societies* 2 (3-4), III-IV quarters of 2007, 26-61.
- Pisariuk, S.N., 2019. Applying the methods of program-targeted management in enterprises. *Economics: Yesterday, Today, Tomorrow* 9 (3A), 112-118. <https://doi.org/10.34670/AR.2019.89.3.011>.
- Quillinan, T.B., Brazier, F., Aldewereld, H., Dignum, F., Dignum, V., Penserini, L., Wijngaards, N., 2009. Developing agent-based organisational models for crisis management. In: 8th International Conference on Autonomous Agents and Multiagent Systems, Budapest, pp. 45-52.
- Reinwald, P., Leitner, S., Wall, F., 2021. Limited intelligence and performance-based compensation: An agent-based model of the hidden action problem. <https://doi.org/10.48550/arXiv.2107.03764>
- Rodionov, D., Zaytsev, A., Konnikov, E., Dmitriev, N., Dubolazova, Y., 2021. Modeling changes in the enterprise information capital in the digital economy. *JOItmC* 7(3), 166.
- Savelyeva, E.N.N., 2014. Scientific and practical approaches to assessing the effectiveness of enterprise management systems. *Economics, Management, Finance*. Perm: Mercury, 142-146.
- Sayama, H., 2015. *Introduction to the Modeling and Analysis of Complex Systems* Open SUNY Textbooks. Milne Library, State University of New York at Geneseo. <https://doi.org/10.1186/s40294-016-0015-x>.
- Secchi, D., Neumann, M. (Eds.), 2016. *Agent-Based Simulation of Organizational Behavior*, Cham: Springer International Publishing. <https://doi.org/10.1007/978-3-319-18153-0>.
- Sharapov, A.R., Gilyazova, A.A., Morozov, A.V., 2012. Comparative analysis of the methods used for assessing the efficiency of innovation. *The Bulletin of the Kazan Technological University* 15 (17), 305-311.
- Shvetsov, A.N., Dianov, S.V., 2015. Efficiency criteria of a multi-agent organisational management system. *Bulletin of the Cherepovets State University* 6 (67), 50-54.
- Solovyeva, M.V., 2018. Management efficiency and enterprise management system. *Regional Problems of Economic Transformation* 11 (97), 265-272.
- Stanojevic, P., Misita, M., Zoran, J., Mladen, M., Vasilije, M. Bukvic, V., 2019. Organisational design based on simulation modelling. *The International Journal of Advanced Manufacturing Technology* 104. <https://doi.org/10.1007/s00170-017-1453-0>.
- Talanova, N.V., Alekseeva, N.V., 2015. The interrelation between organisation management strategy and personnel management strategy. *The Bulletin of the Russian University of Cooperation* 3 (21), 73-77.
- Tarasov, A.A., 2012. Developing a method for integral assessment of the efficiency of an organisational structure. In: *Proceedings of the Tula State University: Economics and Law*, no. 3-1, 149-155.
- Tomashevsky, V.N., Zhdanova, E.G., 2003. *Simulation modelling in the GPSS environment*. Moscow, Bestseller, 416.
- Valov, S.V., Buryinin, S.S., Cheremisina, T.V., Tsvetkov, Y.A., 2020. *Receiving Citizens and Considering Appeals in Investigation Agencies [Monograph]*, INFRA-M, Moscow, 380.
- Ventzel, E.S., 2007. *Researching Operations: Problems, Principles, Methodology*. The Higher School, Moscow, 208.
- Wall, F., 2016. Agent-based modelling in managerial: an illustrative survey and study. *Review of Managerial Science* 10 (1), 135-193.
- Wall, F., 2021. Workforce diversity in decision-making organisations: a perspective from agent-based computational economics. *New Mathematics and Natural Computation*, 1-25. [10.1142/S1793005722500181](https://doi.org/10.1142/S1793005722500181).
- Wall, F., Leitner, S., 2021. Agent-based computational economics in management accounting research: opportunities and difficulties. *Journal of Management Accounting Research* 33, 189-212. <https://doi.org/10.2308/JMAR-19-073>.

СПИСОК ИСТОЧНИКОВ

- Adomavicius, G., Jannach, D., Leitner, S., Zhang, J., 2021. Understanding longitudinal dynamics of recommender systems with agent-based modelling and simulation. <https://doi.org/10.48550/arXiv.2108.11068>.

- Amiens, E., Adedoyin, O., Adeyemi, S., 2020. Optimising service delivery using queueing theory. *Afr J Manage* 5, 73-88.
- Borshchev, A., 2013. *The Big Book of Simulation Modelling: Multimethod Modelling with Anylogic 6*. AnyLogic North America.
- Burton, R.M., Obel, B., 2018. The science of organisational design: fit between structure and coordination. *J. Org. Design* 7 (5). <https://doi.org/10.1186/s41469-018-0029-2>.
- Chang, M.-H., Harrington, J.E., 2006. Chapter 26: Agent-based models of organizations. In: Tesfatsion, L., Judd, K.L. (Eds.), *Handbook of Computational Economics*, vol. 2. Elsevier, pp. 1273-1337.
- Clement, J., Puranam, P., 2017. Searching for structure: formal organisation design as a guide to network evolution. *Management Science* 64 (8), 3879-3895. <https://doi.org/10.1287/mnsc.2017.2807>
- Crowder, R., Hughes, H., Sim, Y.W., Robinson, M., 2009. An agent based approach to modelling design teams. In: 17th International Conference on Engineering Design, September 3-4, 2015. Stanford, pp. 91-102.
- Dutta, P., Pepe, C., Xi, H., 2015. Analyzing organisation structures and performance through agent-based socio-technical modelling. In: Handa, H., Ishibuchi, H., Ong, Y.S., Tan, K.C. (Eds.), *Proceedings of the 18th Asia Pacific Symposium on Intelligent and Evolutionary Systems*, vol. 2, pp. 39-53.
- Gómez-Cruz, N.A., Saa, I.L., Hurtado, F.F.O., 2017. Agent-based simulation in management and organisational studies: a survey. *European Journal of Management and Business Economics* 26 (3), 313-328. <https://doi.org/10.1108/EJMBE-10-2017-018>.
- Harrison, J.R., Lin, Z., Carroll, G.R., Carley, K.M., 2007 [Forthcoming]. Simulation modelling in organisational and management research. *Academy of Management Review* 32 (4), 1229-1245.
- Hunter, S.D., Bentzen, H., Taug, J. 2020. On the 'missing link' between formal organisation and informal social structure. *J. Org. Design* 9 (13). <https://doi.org/10.1186/s41469-020-00076-x>.
- Joseph, J., Baumann, O., Burton, R., Srikanth, K., 2019. Reviewing, revisiting, and renewing the foundations of organisation design. *Organisation Design. Advances in Strategic Management* 40, 1-23. 10.1108/S0742-332220180000040012
- Khosraviani, B., Levitt, R., Koza, J., 2004. Organisation design optimization using genetic programming. Working Paper 2004-85, Stanford University.
- Levinthal, D., Workiewicz, M., 2018. When two bosses are better than one: nearly decomposable systems and organisational adaptation. *Organisation Science* 29. <https://doi.org/10.1287/orsc.2017.1177>.
- Li, B., Yu, H., Shen, Z., Cui, L., Lesser, V.R., 2015. An evolutionary framework for multi-agent organisations. In: 2015 IEEE/WIC/ACM International Conference on Web Intelligence and Intelligent Agent Technology (WI-IAT), pp. 35-38. <https://doi.org/10.1109/WI-IAT.2015.45>.
- Okemiri, H., 2018. Analysis of Queuing Model: A Case Study of Madonna Model Secondary School, Owerri. *Discovery* 54(269), 189-194.
- Quillinan, T.B., Brazier, F., Aldewereld, H., Dignum, F., Dignum, V., Penserini, L., Wijngaards, N., 2009. Developing agent-based organisational models for crisis management. In: 8th International Conference on Autonomous Agents and Multiagent Systems, Budapest, pp. 45-52.
- Reinwald, P., Leitner, S., Wall, F., 2021. Limited intelligence and performance-based compensation: An agent-based model of the hidden action problem. <https://doi.org/10.48550/arXiv.2107.03764>.
- Rodionov, D., Zaytsev, A., Konnikov, E., Dmitriev, N., & Dubolazova, Y., 2021. Modeling changes in the enterprise information capital in the digital economy. *JOITmC* 7(3), 166.
- Sayama, H., 2015. *Introduction to the Modeling and Analysis of Complex Systems* Open SUNY Textbooks. Milne Library, State University of New York at Geneseo. <https://doi.org/10.1186/s40294-016-0015-x>.
- Secchi, D., Neumann, M. (Eds.), 2016. *Agent-Based Simulation of Organizational Behavior*, Cham: Springer International Publishing. <https://doi.org/10.1007/978-3-319-18153-0>.
- Stanojevic, P., Misita, M., Zoran, J., Mladen, M., Vasilije, M. Bukvic, V., 2019. Organisational design based on simulation modelling. *The International Journal of Advanced Manufacturing Technology* 104. <https://doi.org/10.1007/s00170-017-1453-0>.
- Talanova, N.V., Alekseeva, N.V., 2015. The interrelation between organisation management strategy and personnel management strategy. *The Bulletin of the Russian University of Cooperation* 3 (21), 73-77.
- Wall, F., 2021. Workforce diversity in decision-making organisations: a perspective from agent-based computational economics. *New Mathematics and Natural Computation*, 1-25. 10.1142/S1793005722500181.
- Wall, F., Leitner, S., 2021. Agent-based computational economics in management accounting research: opportunities and difficulties. *Journal of Management Accounting Research* 33, 189-212. <https://doi.org/10.2308/JMAR-19-073>.
- Wall, F., Leitner, S., 2021. Agent-based computational economics in management accounting research: opportunities and difficulties. *Journal of Management Accounting Research* 33, 189-212. <https://doi.org/10.2308/JMAR-19-073>.
- Абросимова, Е.Б., 2015. Применение многофакторного регрессионного анализа для повышения эффективности управления человеческими ресурсами. *Технологический аудит и резервы производства* 6 (5), 26. 53-58.
- Асаул, А.Н., Асаул, Н.А., Симонов, А.В., 2009. Формирование и оценка эффективности организационной структуры управления в компаниях инвестиционно-строительной сферы. СПб.: ГАСУ, 258 с.
- Божко, Л.М., 2013. О сущности эффективности управления в контексте проведения организационных изменений на основе маркетингового подхода. *Вестник Астраханского государственного технического университета. Серия: Экономика* 1, 37-40.
- Бурков, В.Н., Новиков, Д.А., 2019. Теории активных систем 50 лет: история развития. Теория активных систем. Материалы международной научно-практической конференции, 18–19 ноября, 2019 г. Под общ. ред. В.Н. Буркова, ИПУ РАН. С. 10-54.
- Валов, С.В., Бурнин, С.С., Черемисина, Т.В., Цветков, Ю.А., 2020. Прием граждан и рассмотрение обращений в следственных органах [Монография]. Москва, ИНФРА-М. 380 с.
- Вентцель, Е.С., 2007. Исследование операций: задачи, принципы, методология. Москва, Высшая школа, 208 с.
- Галиуллина, А.Ф., 2015. Моделирование процесса предоставления государственных услуг. *Научное обозрение* 22, 253–263.

- Герасимов, Б.И., Шубин, А.В., Романов, А.П., 2005. Моделирование организационной структуры промышленного предприятия [Монография]. Тамбов, Издательство ТГТУ, 86 с.
- Дежкина, И.П., Поташева, Г.А., 2008. Оценка эффективности организационных структур управления // Проблемы теории и практики управления 5, 80-86.
- Дианов, С.В., Швецов, А.Н., 2004. Совершенствование организации работы с обращениями граждан в системах организационного управления с использованием мультиагентной технологии. Алгоритмы, методы и системы обработки данных 9-2, 97-101.
- Климова, Н.С., Смирнова, Г.А., 2010. Организационный аудит как инструмент повышения эффективности работы предприятия. Вестник ИНЖЭКОНА. С. 339-342.
- Колесниченко, Е.А., Рудакова, О.В., Плахов, А.В., 2018. Эффективность государственного управления: Россия на фоне мировых тенденций. Среднерусский вестник общественных наук, 13 (2), 161-175.
- Кошкин, К.В., 2014. Имитационное моделирование организационных систем управления проектами и программами. Управление проектами и развитие производства 2 (50), 6-14.
- Криворучко, О.Н., Сукач, Ю.А., 2015. Организационное моделирование процессно-ориентированной структуры управления предприятием. Экономика транспортного комплекса 25, 50-66.
- Михненко, П.А., 2015. Математическое моделирование процессов развития и управления изменениями хозяйственных организаций [Монография]. Университет «Синергия», 214 с.
- Паринов, С.И., 2007. Новые возможности имитационного моделирования социально-экономических систем. Искусственные общества 2 (3-4), III-IV кварталы 2007, 26-61.
- Писарюк, С.Н., 2019. Применение методов программно-целевого управления на предприятиях. Экономика: вчера, сегодня, завтра 9 (3А), 112-118. <https://doi.org/10.34670/AR.2019.89.3.011>.
- Савельева, Е.Н., 2014. Научно-практические подходы к оценке эффективности систем управления предприятием. Экономика, управление, финансы: материалы III Международной научной конференции, февраль 2014 г., Пермь. С. 142-146.
- Соловьева, М.В., 2018. Эффективность менеджмента и система управления организацией. Региональные проблемы преобразования экономики 11 (97), 265-272.
- Тарасов, А.А., 2012. Разработка метода интегральной оценки эффективности организационной структуры. Известия Тульского государственного университета. Экономические и юридические науки. 3-1, 149-155.
- Томашевский, В.Н., Жданова, Е.Г., 2003. Имитационное моделирование в среде GPSS. Москва, Бестселлер, 416 с.
- Черняховская, Л.Р., Галиуллина, А.Ф., Сабитов, И.И., 2016. Оценка эффективности предоставления государственных услуг с использованием системы нечеткого логического вывода. Информационные технологии 22 (8), 563-568.
- Черняховская, Л.Р., Гвоздев, В.Е., Галиуллина, А.Ф., 2016. Поддержка принятия решений для оценки качества предоставления государственных услуг с применением онтологического анализа. Онтология проектирования 6 (2), 20, 193-204.
- Шарапов, А.Р., Гилязова, А.А., Морозов, А.В., 2012. Сравнительный анализ методик оценки эффективности инноваций. Вестник Казанского технологического университета 15 (17), 305-311.
- Швецов, А.Н., Дианов, С.В., 2015. Критерии эффективности функционирования мультиагентной системы организационного управления. Вестник Череповецкого государственного университета 6 (67), 50-54.

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SECTION 3

**SUSTAINABLE DEVELOPMENT
OF REGIONAL INFRASTRUCTURE**

РАЗДЕЛ 3

**УСТОЙЧИВОЕ РАЗВИТИЕ
РЕГИОНАЛЬНОЙ ИНФРАСТРУКТУРЫ**

Research article

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HUMAN CAPITAL IN THE DIGITAL ECONOMY AS A FACTOR OF SUSTAINABLE DEVELOPMENT

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Abstract

Digital transformation balances the risks and opportunities related to the development of human capital, while asymmetries arise in economics field and social sustainability. There is a need for continuous improvement, especially in terms of new competency development, due to the growth of information and emotional load, information leakage, digital failures, and the reduction in the rights of employees working remotely. There are risks associated with job cuts, including a fall in the real income of the population, discrimination against various groups of the population, and the growth of socio-economic inequality. Under these conditions, issues related to the access to information technologies for comprehensive professional and personal development are especially relevant. At the present stage, sustainable development, reduced inequality, the appropriate balance of supply and demand in the labour market, and responsible consumption are the priorities of governments. The purpose of this study is to identify the specifics of human capital development in the digital economy, including its trends and limitations. The analysis is based on scientific publications and expert opinions considering statistical and empirical data reflecting problems related to human capital development in the digital economy, culminating in cross-country comparisons of this development. The results of the study include a description of the challenges faced by various groups of the population and a systematisation of the factors that stimulate or restrain employment. The study then ranks the countries in terms of their human capital development in the digital economy.

Keywords: human capital, digitalisation, sustainable development, education, employment, innovation, cyber security

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ЧЕЛОВЕЧЕСКИЙ КАПИТАЛ В ЦИФРОВОЙ ЭКОНОМИКЕ КАК ФАКТОР УСТОЙЧИВОГО РАЗВИТИЯ

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Аннотация

Цифровая трансформация балансирует риски и возможности для формирования и применения человеческого капитала, при этом возникают асимметрии в области экономической и социальной устойчивости. Необходимость или вынужденность постоянного совершенствования, приобретения новых компетенций, стрессы из-за роста информационной и эмоциональной нагрузки, утечки информации, цифровых сбоев, уменьшение прав наёмных работников, перешедших на дистанционную занятость. Возникают риски общего сокращения рабочих мест и падения реальных доходов населения, риски дискриминации различных групп населения и роста социально-экономического неравенства. В этих условиях актуальны вопросы доступа к информационным технологиям при получении новых знаний, повышении профессиональной квалификации и всестороннего личностного развития на протяжении всей своей жизни. Содействие устойчивому развитию, сокращение неравенства, поддержание баланса спроса и предложения на рынке труда, стремление к ответственному потреблению – приоритетные задачи правительств на современном этапе. Цель исследования – выявить специфику развития человеческого капитала в цифровой экономике, тенденции развития, использования и ограничения. Анализ проводился на основе научных публикаций, мнений экспертов, с учетом статистических и эмпирических данных, отражающих проблематику развития человеческого капитала в цифровой экономике. Представлены межстрановые сравнения готовности к развитию человеческого капитала в цифровой экономике. К конкретным результатам относятся системное представление вызовов, с которыми сталкиваются различные группы населения, группировке факторов, стимулирующих и сдерживающих занятость населения, ранжирование стран по критерию условий развития человеческого капитала в цифровой экономике.

Ключевые слова: человеческий капитал, цифровизация, устойчивое развитие, образование, занятость, инновации, кибербезопасность

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1. Introduction

Scientific and technological progress evolve on the basis of existing scientific achievements. At the same time, the development of scientific and technical knowledge is disrupted on occasion by breakthroughs that fundamentally diverge from previous ideas. These discoveries serve as a basis for revolutionary changes in technologies used in a wide variety of areas of public life. Industry 4.0 is based on artificial intelligence, the Internet of Things, wireless communication, and robotics, enabling us to count on the effective implementation of concepts such as the Smart Factory, the Smart Supply Chain, and the Smart City (Rymarczyk, 2020). The current stage of digitalisation fundamentally differs from previous technological breakthroughs due to the scale of transformational processes that blur the boundaries between the physical, digital, and biological spheres of human life¹. At the same time, the development of the digital world, with its potential for new challenges, should ensure the achievement of the sustainable development goals (UN SDGs) in conjunction with the economic, social, and environmental components of sustainability. The level of skill demanded in the labour market is rapidly changing, which creates both new opportunities and risks. Without investments in human capital, states will be unable to achieve sustainable economic growth and provide employment in the digital economy. Inaction in this area can be quite costly (WDR, 2019).

Modern economic and social reality as well as the environmental agenda have been determining the growing importance and new features of human capital, generating higher and constantly changing demands in the face of growing uncertainty (Koneva and Lisenkova, 2019). According to empirical research, the highest priority for companies in the field of information and communication when choosing a location is the presence of highly qualified specialists, which emphasises the high importance of human capital in the modern economy (Marinkovic et al., 2018).

The rapidly changing principles of workplace organisation are calling into question the previously highly valued role of work experience. The determinants of education and new competencies have become the priorities in studying the effectiveness of investments in human capital (Kelchevskaya and Shirinkina, 2019). Lifelong learning should become an unconditional imperative for every professional who desires to remain competitive under the conditions of digitalisation (Manakhova et al., 2019). Overall, states and individuals alike now recognise the need for the ongoing development of human capital.

Researchers have also recognised trends in the use of human capital at the stage of Industry 4.0, including the possibility of an overall reduction in the number of jobs, the flow of specialists to industries with the highest added value, and an increase in demand for job seekers with the necessary skills to work in the digital environment (Sima et al., 2020).

The fourth industrial revolution has given birth to technologies that improve the economic efficiency of business, the quality of public administration, and the level of comfort in everyday life. These positive effects stem from the automation and robotisation of production, wireless communication, and the development of artificial intelligence—which is devoid of human error and constantly striving for optimisation. As surveys in European countries have shown (WDR, 2019), new technologies improve the quality of citizens' life (67% of respondents), the state of the economy (75% of respondents), and public sentiment (64% of respondents).

The purpose of this study is to clarify the role and specifics of human capital development in the new digital reality, grouping factors that stimulate or constrain employment, trends in the use of human capital, and emerging risks in the field of inclusiveness, innovation, and security. Specifically, in the present study, the conditions for the development of human capital in the digital economy were analysed in different countries, with global indices presented by leading institutions used to then rank these countries accordingly the strength of these conditions for the development of human capital by country.

Schwab, K., 2016. The fourth industrial revolution. World Economic Forum, Geneva.

2. Literature Review

The concept of human capital has undergone changes in a way similar to its role's development in the economic life of society. The theory of human capital, which appeared in the 1960s, understood this concept as a set of knowledge, skills, competencies, health, and motivation accumulated by an individual. Within this theory, each person was seen as an investor, weighing the marginal rate of a return on an investment in their education or health care with the return on alternative investments. In recent decades, human capital has been understood by economists in a much broader way. The image of a rational egoist who invests resources in himself in order to maximise his income has been replaced by the image of a person who appreciates both work and leisure, political and cultural events (Demidova et al., 2019). In addition, the concepts of 'knowledge' and 'skills' have been replaced by the concept of 'competencies' in the field of education. The latter are more focused on practical achievements and also imply personal qualities that are significant in the professional sphere of the individual.

The digital economy—based on the rapid development of knowledge and the creative approach to its use—determines the exceptional role of high-quality human capital in economic progress. The paradigm of the economic success of any organisation in the modern world is the rival innovation enterprises (Alexankov et al., 2017). The key competencies necessary for the development of innovative products and technologies form the basis of the competitiveness of the individual, enterprise, and national economy as a whole. In addition, important task for enterprises is the fair distribution of benefits from digital transformation (Manakhova, 2018; Balynin, 2020).

The digital transformation of various aspects of human life has had a significant impact on the development of human capital. The increased availability of information has contributed to the cultivation of humanistic values in society, the effectiveness of social lifts, the development of creativity, and the acquisition of additional knowledge (Koneva and Lisenkova, 2019). The use of information technology makes it possible to intensify the learning process toward becoming more interesting and accessible. Artificial intelligence technologies will contribute to the individualisation of the learning process in accordance with the personal characteristics of each student (Frolova et al., 2020). Massive online courses act as an additional learning opportunity for students and a marketing strategy for well-resourced universities aiming to expand the market (Laaser, 2018). Moreover, digital hubs contribute to the dissemination of personal skills and knowledge as well as the development of digital literacy, e-commerce, and business mentoring, making them a powerful tool for the advancement of rural communities and businesses in Europe (Dyba, 2020). A high level of integration of individuals in social networks helps prevent depression and reduces the risk of death from cardiovascular diseases, drug overdose, and suicide (Bochaver, 2019). Social networks and Internet forums are convenient platforms where medical professionals or people with rare and chronic diseases can share knowledge and experience. Online interaction between medical organisations and patients increases the level of comfort and quality of services provided. Moreover, AI-enabled monitoring of Internet traffic and mobile device data can improve the prediction of infectious disease outbreaks (McKeeetal, 2019).

At the same time, digitalisation does not only create new opportunities and improve the quality of human capital being formed, but also generates negative effects in education and healthcare. For teachers, the digitalisation of the educational space is accompanied by an increase in workload and the displacement of experienced teachers who do not possess the required digital competency level. For students, information can be distorted in the process of its transmission, leading to an increase in overload, the simplification of interpersonal communications, and, consequently, elevated difficulties in the development of necessary competencies. Another significant disadvantage of digitalisation in the educational field is a decrease in the level of training of students who do not need to memorise information available online (Frolova et al., 2020). There is also a certain concern about the possibility of several large companies controlling the global educational market in providing the primary software and information platforms for the educational process (Laaser, 2018). The Internet search queries of the individual user create an information cocoon around him, which ultimately narrows his horizons and presents

a simplified view of reality (Koneva et al., 2019). Cyber attacks made on medical systems endanger the personal data of patients. Moreover, media companies' collection of information about user searches and purchases can lead to privacy violations, including those in relation to health issues. In some cases, this can seriously harm a person—for example, the leaking into the public domain of information about the disease status of an individual applying for a prestigious position or the pregnancy status previously kept hidden by a woman. Additionally, fake news and misinformation spread over the Internet, such as self-medication or anti-vaccine beliefs, can result in irrational patterns of behaviour (McKee, 2019).

The fourth industrial revolution has brought about significant changes to the process of human capital development. Nowadays, information technologies overcome territorial and temporal barriers, creating opportunities for flexible and non-standard forms of employment. Thanks to digitalisation tools, young people, women with children, and people with disabilities—previously considered the most vulnerable groups—now enjoy an increased competitiveness and new opportunities in the labour market. The availability of smartphones and mobile Internet as well as the development of electronic payment systems have created new income-generating mechanisms for young and enterprising African women (Bailur and Masiero, 2017). Overall, there is a steadily increasing demand in the labour market for professionals in the digital environment field as well as specialists with the competencies necessary to work with digital tools (Corejova and Al Kassiri, 2016). There is also a demand for specialists with the skills to build effective communication in management, education, and marketing (Chinoracký and Čorejová, 2019).

Some researchers also discuss certain negative impacts of digitalisation on human capital functioning. Vulnerabilities in cyberspace and digital dependency lead to an uncertain institutional landscape and disruptive decision-making that blocks collaboration, ultimately reducing the effective use of human potential (Knox, 2018). Specifically, interviewing job applicants using digital mediation technology leads to worse results than face-to-face interviews. Job candidates also perceive remote interviewing as unfair and limiting their chances of success (Basch and Melchers, 2020). Overall, the boundaries between the time devoted to work and rest are blurred. Many employees take advantage of working from home to complete their household affairs during their work hours, while others, on the contrary, work overtime in their free time (Rodríguez Fernández et al., 2018). In addition, there is a challenge related to the interaction between the man and information and communication technologies. The introduction of digital technologies in nuclear power plants can negatively affect the cognitive reliability of operators due to the peculiarities of interface management, an over-reliance on automation, and the complexity of information systems (Zhouetal, 2012). Automation and robotisation reduce the demand for low-skilled workers performing routine operations, with many employees involved in manual operations at a risk of losing their jobs (Chinoracký and Čorejová, 2019). These employees face the need to retrain to take into account the new demands of the labour market. In addition, almost all workers are forced to constantly improve their competencies also at the risk of looming unemployment (Rymarczyk, 2020). Workers employed in the digital technologies consistently earn less than their counterparts performing the same duties on the employer's premises. Remote work also implies unstable schedules, overwork, and high stress (Islam, 2018). The introduction of distance technologies into the economic system increases the risks of insecure employment. Remote work contributes to the transition from permanent employment to fixed-term employment and temporary contracts. This deprives workers of guaranteed rights to regular employment, regular wages, a safe working environment, social security, and holidays. The individualisation of employment not only highlights the necessity for an individual to acquire professional competencies, but also requires their ability to negotiate, analyse the situation on the labour market, and establish their own work–time balance².

3. Materials and Methods

This study is based on an analysis of conceptual approaches to measuring the impact of the digital transformation on the development of human capital. In accordance with the systematic method of

²Bobylev S.N., Grigoriev L.M. (Eds.), 2018. Report on human development in the Russian Federation for 2018, Analytical Center under the Government of the Russian Federation, 172.

studying trends in the field of education, health care, and employment, the processes that change the requirements for human capital with both a destructive and positive impact on its development are specifically analysed.

At the first stage of this study, a literature review was carried out considering the problems associated with human capital development in the digital economy. At the second stage, an analysis of the preparedness of different countries for this development of human capital was carried out. A cross-country analysis was carried out using global indices provided by leading institutions to obtain a summary indicator and rank the nations in terms of preparedness. At the third stage, the obtained results were analysed, and trends in the development of human capital in the digital economy—together with the associated risks—were identified.

The analysis was carried out on the basis of data from the scientific publications, expert opinions, and data from international institutions as well as statistical indicators.

4. Results and Discussion

The study found an extremely ambiguous assessment of the impact of digitalisation on overall employment in terms of whether digital transformation cause an increase in demand for workers or, on the contrary, an increase in unemployment. Theoretical factors that can cause both an increase and decrease in the level of employment as well as the results of empirical research in this area are systematised in Table 1.

Table 1. The impact of digitalisation on the level of employment

Factors of Decline in the Level of Employment	Factors of Growth (Preservation) in the Level of Employment
<ul style="list-style-type: none"> • A decrease in the price of capital motivates the replacement of labour with capital (Islam, 2018) • Importing innovative technologies to developing countries will reduce their demand for labour (Ugur and Mitra, 2017) • The development of robotics and artificial intelligence technologies make more professions open to automation (Islam, 2018) • There is a dismissal of low-skilled workers (i.e., staff selection effect) (Genz et al., 2019) • High unemployment (Chinoracký and Čorejová, 2019) and a high proportion of non-manufacturing workers (Gómez-Plana and Latorre, 2019) increase the risk of job automation and reduced labour demand 	<ul style="list-style-type: none"> • Income growth increases the demand for local products and, hence, the demand for labour, stimulating the creation of new professions and industries (Gregory et al., 2019) • ICT and related industries require new talent (Goos et al., 2015) • The lower capital intensity of firms and less wage flexibility contribute to the creation of new jobs (Gómez-Plana and Latorre, 2019) • National firms investing in ICT create more jobs than foreign firms (Gómez-Plana and Latorre, 2019) • Infrastructural constraints, older cultures, and union activity help keep jobs (Lloyd and Payne, 2021)
Effect of Reducing the Level of Employment	Effect of Increasing the Level of Employment
<ul style="list-style-type: none"> • One additional robot replaces 3 to 5.6 workers in the US (Acemoglu and Restrepo, 2020) • In the French manufacturing sector, hiring ICT professionals and using big data result in a 2.5% reduction in the workforce (Cette et al., 2021) • In the United States, 47% of jobs will be 70% automated over the next 20 years (Frey and Osborne, 2017) 	<ul style="list-style-type: none"> • EU countries created up to 11.6 million new jobs between 1999 and 2010 (Gregory et al., 2016) • In Spain, a 1% increase in ICT investment increases employment by 0.02% (Gómez-Plana and Latorre, 2019) • Using the example of the European Union, one high-tech job creates five new jobs in other, low-tech industries (Goos et al., 2015)

The results of studying the impact of digital transformation on the level of income of the population were also very ambiguous and this topic requires further study. A study on the importance of digital solutions in German companies from 2011 to 2016 showed an increase in wages by 0.8%. The largest increase of 3.6% occurred in the category of low-skilled workers (Genz et al., 2019). Another study found that one additional robot per 1,000 workers results in wage cuts ranging from 0.25% to 0.5% (Acemoglu and

Restrepo, 2020). To prevent a decline in employment and a fall in the real incomes of the population, politicians and scientists suggest using tools such as ‘helicopter money’ and an unconditional basic income to ensure social stability and maintain the effective demand of the population.

The development of human capital depends on factors related to both the traditional economy and the innovative economy, since they both determine the ability of different spheres to adapt to rapidly changing environmental conditions. Access to education, health care, environmental security, network resources, information security, and innovation determine the development of human capital in the digital economy.

Internationally, several indicators characterising the development of human capital in the digital economy are used: The Human Development Index³ (HDI) is a normalised indicator of the three conditions for personal development—education, a long healthy life, and income level—taking into account environmental efficiency factors; the Healthy Life Expectancy Index⁴ (HLEI) takes into account the activity and health of the lived years of an individual; the Networked Readiness Index⁵ (NRI) reflects innovation and manufacturability—i.e., the possibilities of the digital economy; the Global Innovation Index⁶ (GII) evaluates the resource base and practical results in the field of innovation; and the Global Cyber security Index⁷ (GCI) evaluates cyber security as a factor in the development of the digital economy. The COVID-19 pandemic has changed social interaction (e.g., with remote employment, distance learning). According to some estimates, Internet traffic grew by 30% in 2020, rapidly expanding ‘digital public services’ and thus strengthening the requirements for data security. Technologies of the digital age have begun to play a key role in maintaining socio-economic processes, and a reliable environment is needed to realise this potential.

To analyse the factors of human capital development in the digital economy, groups of countries from the whole world with a high HDI as well as the countries with an average HDI were selected, and all relevant indices were calculated. A summarised cross-country assessment of the global indices is presented in Table 1.

Table 2. Ranking of the analysed countries based on indices reflecting the development of human capital in the digital economy

Country	Ranking по ИЧП	HDI (2020)	HLEI (2018)	NRI (2020)	GII (2020)	GCI (2020)	Total score	Rank by total score
Sweden	7	0.945	0.724	0.8275	0.625	0.9455	4.067	1
Singapore	11	0.938	0.762	0.8139	0.566	0.9852	4.0651	2
Netherlands	8	0.944	0.721	0.8137	0.588	0.9705	4.0372	3
Switzerland	2	0.955	0.735	0.8041	0.661	0.8697	4.0248	4
Great Britain	13	0.932	0.719	0.7627	0.598	0.9954	4.0071	5
USA	17	0.926	0.685	0.7891	0.606	1.0	4.0061	6
Finland	11	0.938	0.717	0.8016	0.57	0.9578	3.9844	7
Denmark	10	0.94	0.718	0.8219	0.575	0.926	3.9809	8
Germany	6	0.947	0.716	0.7748	0.565	0.9741	3.9769	9
Norway	1	0.957	0.73	0.7939	0.493	0.9689	3.9428	10
South Korea	23	0.916	0.73	0.746	0.561	0.9852	3.9382	11
Canada	16	0.929	0.732	0.7492	0.523	0.9767	3.9099	12
Japan	19	0.919	0.748	0.7354	0.527	0.9782	3.9076	13

³Human Development Reports, 2020. <http://hdr.undp.org/en/content/download-data>

⁴World Health Statistics, 2018. Monitoring health for the SDGs, World Health Organization, Geneva. https://who.int/gho/publications/world_health_statistics/2018/en/

⁵Network Readiness Index, 2020. <https://networkreadinessindex.org>

⁶Global Innovation Index, 2020. <https://www.globalinnovationindex.org/Home>

⁷The Global Cyber security Index, 2020. <https://www.itu.int/epublications/publication/global-cybersecurity-index-2020/en/>

Australia	8	0.944	0.73	0.7509	0.484	0.9747	3.8836	14
France	26	0.901	0.734	0.7318	0.537	0.976	3.8798	15
Luxembourg	23	0.916	0.726	0.7527	0.508	0.9741	3.8768	16
Austria	18	0.922	0.724	0.7292	0.501	0.9389	3.8151	17
Belgium	14	0.931	0.716	0.7067	0.491	0.9625	3.8072	18
Israel	19	0.919	0.729	0.6981	0.535	0.9093	3.7904	19
Ireland	2	0.955	0.721	0.7213	0.53	0.8586	3.7859	20
Spain	25	0.904	0.738	0.6731	0.456	0.9852	3.7563	21
Estonia	29	0.892	0.682	0.7032	0.483	0.9948	3.755	22
New Zealand	14	0.931	0.728	0.7327	0.47	0.8404	3.7021	23
Italy	29	0.892	0.732	0.6339	0.457	0.9613	3.6762	24
Iceland	4	0.949	0.73	0.7055	0.492	0.7981	3.6746	25
Portugal	38	0.864	0.72	0.644	0.435	0.9732	3.6362	26
UAE	31	0.89	0.667	0.6442	0.418	0.9806	3.5998	27
Malta	28	0.895	0.722	0.6673	0.464	0.8365	3.5848	28
Cyprus	33	0.887	0.733	0.6067	0.457	0.8882	3.5719	29
Lithuania	34	0.882	0.661	0.647	0.392	0.9793	3.5613	30
Poland	35	0.88	0.685	0.618	0.4	0.9386	3.5216	31
Latvia	37	0.866	0.662	0.6047	0.411	0.9728	3.5165	32
Malaysia	62	0.81	0.666	0.6143	0.424	0.9806	3.4949	33
China	85	0.761	0.687	0.5844	0.533	0.9253	3.4907	34
Czech	27	0.9	0.693	0.6633	0.483	0.7437	3.483	35
Slovakia	39	0.86	0.683	0.6078	0.397	0.9236	3.4714	36
Greece	32	0.888	0.72	0.552	0.368	0.9398	3.4678	37
Slovenia	22	0.917	0.705	0.6658	0.429	0.7493	3.4661	38
Hungary	40	0.854	0.668	0.6005	0.415	0.9128	3.4503	39
Croatia	43	0.851	0.69	0.5594	0.373	0.9253	3.3987	40
Saudi Arabia	40	0.854	0.657	0.5797	0.309	0.9954	3.3951	41
Qatar	45	0.848	0.686	0.6026	0.308	0.945	3.3896	42
Russia	52	0.824	0.635	0.5423	0.356	0.9806	3.3379	43
Turkey	54	0.82	0.66	0.5124	0.349	0.9749	3.3163	44
Mauritius	66	0.804	0.658	0.4983	0.344	0.9689	3.2732	45
Serbia	64	0.806	0.675	0.5296	0.343	0.898	3.2516	46
Oman	60	0.813	0.656	0.5533	0.265	0.9604	3.2477	47
Brazil	84	0.765	0.66	0.5058	0.319	0.966	3.2158	48
Thailand	79	0.777	0.668	0.5345	0.367	0.865	3.2115	49
Kazakhstan	51	0.825	0.634	0.5138	0.286	0.9315	3.1903	50
Bahrain	42	0.852	0.681	0.5759	0.284	0.7786	3.1715	51
Macedonia	82	0.774	0.671	0.4828	0.334	0.8992	3.161	52
Romania	49	0.828	0.666	0.5416	0.36	0.7629	3.1585	53
Chile	43	0.851	0.697	0.5406	0.339	0.6883	3.1159	54
Uruguay	55	0.817	0.688	0.5487	0.308	0.7515	3.1132	55
Mexico	74	0.779	0.677	0.4967	0.343	0.8168	3.1125	56
Bulgaria	56	0.816	0.664	0.5503	0.4	0.6738	3.1041	57
Georgia	61	0.812	0.649	0.4795	0.318	0.8106	3.0691	58
Azerbaijan	88	0.756	0.649	0.4876	0.272	0.8931	3.0577	59
Costa Rica	62	0.81	0.709	0.5215	0.335	0.6745	3.05	60
Kuwait	64	0.806	0.663	0.5227	0.284	0.7507	3.0264	61
Iran	70	0.783	0.654	0.4391	0.309	0.8107	2.9958	62
Ukraine	74	0.779	0.64	0.4943	0.363	0.6593	2.9356	63
Montenegro	48	0.829	0.681	0.5095	0.354	0.5323	2.9058	64
Colombia	83	0.767	0.671	0.4681	0.308	0.6372	2.8513	65

Albania	69	0.795	0.681	0.4421	0.271	0.6432	2.8323	66
Argentina	46	0.845	0.684	0.5036	0.283	0.5012	2.8168	68
Armenia	81	0.776	0.663	0.5191	0.326	0.5047	2.7888	69
Belarus	53	0.823	0.655	0.4916	0.313	0.5057	2.7883	70
Peru	79	0.777	0.675	0.4367	0.288	0.5567	2.7334	71
Sri Lanka	72	0.782	0.668	0.4265	0.238	0.5865	2.701	72
Panama	57	0.815	0.694	0.4474	0.29	0.3411	2.5875	73
Bosnia and Herzegovina	73	0.78	0.672	0.4173	0.29	0.2944	2.4537	74
Ecuador	86	0.759	0.679	0.422	0.241	0.263	2.364	75

Source: Compiled by the author based on Human Development Reports (2020) (<http://hdr.undp.org/en/content/download-data>); World Health Statistics (2018), Monitoring health for the SDGs, World Health Organization, Geneva (https://who.int/gho/publications/world_health_statistics/2018/en/); Network Readiness Index (2020) (<https://networkreadinessindex.org>); Global Innovation Index (2020) (<https://www.globalinnovationindex.org/Home>); the Global Cyber security Index (2020) (<https://www.itu.int/epublications/publication/global-cybersecurity-index-2020/en/>)

In descending order, the ten leading countries in terms of the development of human capital in the digital economy are: Sweden, Singapore, the Netherlands, Switzerland, Great Britain, the United States, Finland, Denmark, Germany, and Norway. The United States, which has the highest global cyber security index, ranks sixth in terms of composite score while ranking 17th in terms of HDI (2020). In Iceland and Ireland, countries in the top ten for HDI, the global innovation index is low, which increases the risks of technological backwardness in the digital economy, thus limiting the conditions for the development of human capital in the future.

A digital barrier or digital divide—i.e., the unequal access of various segments of the population to information resources, information technologies, and equipment due to economic, physical, and competency-based restrictions—produces risks of discrimination and growing inequality between different social groups (Kim, 2018; Balog et al., 2020). A digital barrier will increase the segmentation of the labour market and the income gap between specialists of different skill levels. The highest risk of negative consequences in this regard are for the elderly, people with low levels of education and income, those employed in the segment of low-skilled labour, and those who rarely use the Internet (Vasilescu et al., 2020). The trend in job cuts will also seriously affect the interests of developing countries, in which developed countries have previously transferred production facilities. Rising unemployment will worsen the social and political environment in developing countries, increase migratory pressure on wealthy neighbours, and heighten international tensions (Rymarczyk, 2020).

Digitalisation can be the reason for the growth of discrimination in society. There is a case when a computer programmed to learn a language by processing a large amount of data began to operate with stereotypes drawn from the studied texts. Automatic facial recognition systems make more mistakes when working with people of colour, leading to increased false accusations and arrests. Additionally, influencers can manipulate the results of user queries in search engines and limit the amount of information important to certain social groups using targeted advertising tools (McKee, 2019). The collection and analysis of big data imply risks in creating individual social ratings and clustering the population, as this will exacerbate problems of social differentiation and unequal access to opportunities and social benefits (Koneva et al., 2019).

The risks of discrimination and the growth of social inequality will mean depriving part of the population of opportunities to develop their potential. This will have a negative impact on the development of human capital not only for disadvantaged social groups: The motivation for personal and professional development may decrease among the members of society outside disadvantaged social groups whose competitive level may fall. Besides, income and opportunity inequality is already widening due to the spread of COVID-19.

The implementation of risks in the field of inclusive education is primarily related to the discrepancy between the content of educational programs implemented by educational institutions and the

expectations of employers regarding graduates (Alhamami, 2020). It is necessary to change educational programs in accordance with emerging market demands. It should be taken into account that the owners of the highest qualification of human capital will be the main beneficiaries of the fourth industrial revolution (Rymarczyk, 2020).

The consideration of the risks in the development of competencies due to the demands of digital-economy employers is associated with a lack of the competencies necessary for training a competitive employee in the current labour market. Competencies can be grouped on the professional, socio-behavioural, and technical (digital) level. This combination will allow an individual to effectively perform professional tasks and implement interpersonal communications, leading to success in various areas of life and a comfortable existence in a digital society (Kelchevskaya and Shirinkina, 2019; Sima et al., 2020).

A number of studies discuss cognitive, financial, and entrepreneurial competencies. Employees in most positions will require skills such as the ability to concentrate and self-learn, emotional literacy and empathy, creativity, environmental awareness, and cross-culturalism (Peshkova and Samarina, 2018). It has also been noted that changes in the professional environment and career growth contribute changes in the required set of competencies for the individual⁸.

It is possible to generate the required magnitude of students' competencies by creating educational clusters (Alexankov et al., 2018). Representatives of employers should be involved in the educational process; telecommunications infrastructure should be developed within and between educational institutions; and international cooperation should be strengthened in the form of the advanced training of teaching staff abroad (Avetisyan and Gevorgyan, 2020). It is possible to increase the effectiveness of the educational component of human capital through resources related to the goals of universal digitalisation, the popularisation of digital tools, the modernisation of the system for training and motivating teachers, and the introduction of changes in the criteria and mechanisms for monitoring the educational process (Frolova et al., 2020).

The uncertainty and security threats emerging in cyberspace require governments to create institutional conditions to foster an atmosphere of trust between the subjects of the digital reality (Knox, 2018). The dilemma between the free exchange of information for the development and enrichment of knowledge and the restriction of access to information in the framework of the protection of intellectual property should be resolved based on the interests of developing human capital.

Human capital, which is an accumulation of knowledge and creativity, is becoming a key factor in economic development and a criterion for success at both the level of the individual company and the national economy. Today, the ongoing complication affecting the work of specialists requires them to constantly improve their competencies, while governments should invest heavily in education, healthcare, and retraining. At the state level, the tasks of ensuring network accessibility, the development of innovations, ensuring cyber security, and improving financial literacy are to be solved.

This study showed that the European countries are the world-leaders in terms of high human capital development. A lower level of innovation support and cyber security in non-leading countries (compared to the leaders) increases the risks associated with the development of human capital in the digital economy.

Overall, the scientific literature presented an extremely ambiguous assessment of the impact of digitalisation on overall employment in terms of whether digital transformation will cause an increase in demand for manual labour or, on the contrary, an increase in unemployment. The introduction of digital innovations in the economic and social spheres is often associated with growing risks of discrimination and growing inequality between different social groups. Second, the results of studying the impact of digital transformation on the level of income of the population were also ambiguous and require further

⁸Bobylev, S.N., Grigoriev, L.M. (Eds.), 2018. Report on human development in the Russian Federation for 2018. Analytical Center under the Government of the Russian Federation, p. 172.

study.

5. Conclusion

The fourth industrial revolution is determining the specifics of human capital development. Separate social groups previously considered to be the least protected in the labour market are receiving new opportunities through remote employment. Moreover, there is a growing demand for professionals who help develop the digital environment as well as for workers who have successfully mastered digital tools. On the other hand, the digitalisation of employment is a reduction in jobs and a drop in income due to the automation and robotisation of production. There is also a decrease in the rights of employees as a result of the refusal of employers regarding permanent employment when specialists switch to remote employment. Additionally, working in an uncertain and digitally fraught cyberspace increases the risk of making destructive decisions.

The same tools of the digital economy can have both positive and destructive effects on the process of human capital development. The positive impact is associated with the expansion of the individual's opportunities in the field of remote knowledge acquisition and medical care, with an increase in the individualisation level of the services provided and the emergence of new social lifts. The negative impact can be characterised by an increase in the level of stress of an individual due to information and emotional overload, a decrease in the motivation to master knowledge that is available online, a simplification of ideas about reality, and the potential for a monopoly in the global education market. The introduction of digital tools also increases the risks of discrimination and growing socio-economic inequalities.

The key areas for improving the efficiency of human capital at the present stage of digitalisation include altering educational programs in accordance with the trends in the digital development of the economy, the development of educational clusters, and the intensification of international academic mobility. Modern digital tools should be introduced into the educational environment, healthcare, and everyday life of all people. Digital transformation also requires professionals to acquire not only job skills but also cognitive, social, behavioural, digital, financial, and legal competencies. For this reason, new knowledge—especially in the domains of professional and personal development—are becoming a necessity for every individual striving to be competitive in modern world.

References

- Acemoglu, D., Restrepo, P., 2020. Robots and jobs: evidence from us labor market. *J Polit Econ* 128, 2188-2244. <https://doi.org/10.1086/705716>
- Alexankov, A.M., Trostinskaya, I.R., Pokrovskaya, N.N., 2017. Industry 4.0 requirements for quality of human capital and competences formed within educational institutions. In: *Institutions International Conference on Research Paradigms Transformation in Social Sciences. Proceedings of Social and Behavioural Sciences*, 18-21 May, Tomsk, Russia, 35, pp. 26-34. <http://doi.org/10.15405/epsbs.2018.02.4>
- Alhamami, A., Petri, I., Rezgui, Y., 2020. Promoting energy efficiency in the built environment through adapted BIM training and education. *Energies* 13 (9), 2308. <http://doi.org/10.3390/en13092308>
- Avetisyan, P.S., Gevorgyan, N.M., 2020. A free educational environment is the basis of human capital and the interrelation of the main social spheres. *Ekonomika Regiona* 16 (2) 494-506. <http://doi.org/10.17059/2020-2-12>
- Bailur, S., Masiero, S., 2017. Women's income generation through mobile Internet: a study of focus group data from Ghana, Kenya, and Uganda. *Gender Technology & Development* 21 (1-2), 77-98. <http://doi.org/10.1080/09718524.2017.1385312>
- Balog, M.M., Demidova, S.E., Troyan, V.V., 2020. The influence of digital transformation on the shadow economy. *ETAP: Economic Theory, Analysis, and Practice* 4, 58-72. <http://doi.org/10.24411/2071-6435-2020-10034>
- Balynin, I.V., 2020. Evaluation of the implementation of national projects in the Russian Federation in the direction of 'human capital': from problems to their solution [Ocenka realizaci i nacional'nyh proektov v Rossijskoj Federacii po napravleniyu 'Chelovecheskij kapital': ot problem k ihresheniyu]. *Self-Government* 3 (120), 128-132.
- Basch, J.M., Melchers, K.G., 2020. Technologie-medierte Einstellungsinterviews: EinÜberblicküberBefunde und offene-Fragen. *Gruppe. Interaktion. Organisation. Zeitschriftfür Angewandte Organisationspsychologie (GIO)* 51, 71-79. <https://doi.org/10.1007/s11612-020-00497-y>
- Bochaver, A.A., Dokuka, S.V., Sivak, E.V., Smirnov, I.B., 2019. Internet use and depressive symptoms in adolescents: review clinical psychology and special education. *Clinical Psychology and Special Education* 8 (3), 1-18. <http://doi.org/10.17759/cpse.2019080301>

- Cette, G., Nevoux, S., Py, L., 2021. The impact of ICTs and digitalization on productivity and labor share: evidence from French firms. *Economics of Innovation and New Technology*, 1-24 <https://doi.org/10.1080/10438599.2020.1849967>
- Chinoracký, R., Čorejová, T., 2019. Impact of digital technologies on labor market and the transport sector. In: *Proceedings of the 13th International Scientific Conference on Sustainable, Modern and Safe Transport (TRANSCOM)*, Novy Smokovec, Slovakia, pp. 94-1001. <https://doi.org/10.1016/j.trpro.2019.07.139>
- Corejova, T., Al Kassiri, M., 2016. Knowledge as the key to the global cooperation and its important role among nations. In: *3rd International Conference on Power and Energy Systems (PES 2016)*, Lee, G. (Ed.), Book Series: Lecture Notes in Earth Sciences-LNES, vol. 4. Bangkok, Thailand, pp. 181-183.
- Demidova, S., Chirkova, T., Balog, M., Petrova, O., 2019. Development of human capital in the aspect of financial security. In: *Proceedings of the International Scientific-Practical Conference 'Business Cooperation as a Resource of Sustainable Economic Development and Investment Attraction' (ISPCBC 2019)*. Atlantis Press, Paris, pp. 582-588.
- Dyba, M., Gernego, I., Dyba, O., Oliynyk, A., 2020. Financial support and development of digital rural hubs in Europe. *Management Theory and Studies for Rural Business and Infrastructure Development* 42 (1), 51-59. <http://doi.org/10.15544/mts.2020.06>
- Frolova, E.V., Rogach, O.V., Ryabova, T.M., 2020. Digitalization of education in modern scientific discourse: new trends and risks analysis. *European Journal of Contemporary Education* 9 (2), 313-336. <http://doi.org/10.13187/ejced.2020.2.313>
- Genz, S., Janser, M., Lehmer, F., 2019. The impact of investments in new digital technologies on wages—worker-level evidence from Germany. *Journal of Economics and Statistics* 239, 483-521. <https://doi.org/10.1515/jbnst-2017-0161>
- Gomez-Plana, A.G., Latorre, M.C., 2019. Digitalization, multinationals and employment: an empirical analysis of their causal relationships. *Journal of Economics and Statistics* 239, 399-439. <https://doi.org/10.1515/jbnst-2017-0153>
- Goos, M., Koningsb, J., Vandeweyer, M., 2015. Employment growth in Europe: the roles of innovation, local job multipliers and institutions. *SSRN Electronic Journal*, 1-38. <https://doi.org/10.2139/ssrn.2671765>
- Gregory, T., Salomons, A., Zierahn, U., 2019. Racing with or against the machine? Evidence from Europe. *SSRN Electronic Journal*, 12063. <https://doi.org/10.2139/ssrn.2815469>
- Islam, I. 2018. Automation and the future of employment: implications for India. *South Asian Journal of Human Resource Management* 5, 234-243. <https://doi.org/10.1177/2322093718802972>
- Kelchevskaya, N.R., Shirinkina, E.V., 2019. Regional determinants of effective use of human capital in the digital economy. *Economy of Region* 15, 465-482. <https://doi.org/10.17059/2019-2-12>
- Kim, J.-Y., 2018. The human capital gap: getting governments to invest in people. *Foreign Affairs* (July/August). Available from: <https://www.foreignaffairs.com/articles/2018-06-14/human-capital-gap>.
- Knox, B.J., 2018. The effect of cyberpower on institutional development in Norway. *Front. Psychol.* 9, 717. <http://doi.org/10.3389/fpsyg.2018.00717>
- Koneva, A.V., Lisenkova, A.A., 2019. Identity matrix in the digital age: social challenges to overcome the anonymity. *Tomsk State University Journal of Cultural Studies and Art History* 35, 14-28. <http://doi.org/10.17223/22220836/35/2>
- Laaser, W., 2018. Economic implications and stakeholder reactions in a digital university environment. *Red-Revista de Educacion a Distancia* 57, 4. <http://doi.org/10.6018/red/57/4>
- Lloyd, C., Payne, J., 2021. Fewer jobs, better jobs? An international comparative study of robots and 'routine' work in the public sector. *Industrial Relations* 52, 109-124. <https://doi.org/10.1111/irj.12323>
- Manakhova, I., Bystrov, A., Ignatyeva, G., Alekhina, O., 2019. Personnel security in the conditions of digitalization of the economy. In: *Proceedings of the Volgograd State University International Scientific Conference: Competitive, Sustainable and Safe Development of the Regional Economy*. AEBMR-Advances in Economics Business and Management Research, Volgograd, Russia, 83, 391-395. <https://doi.org/10.2991/cssdre-19.2019.76>
- Marinkovic, S., Nikolic, I., Rakicevic, J., 2018. Selecting location for a new business unit in ICT industry. In: *Proceedings of Rijeka Faculty of Economics*. *Journal of Economics and Business* 36 (2), 801-825. <http://doi.org/10.18045/zbe-fri.2018.2.801>
- McKee, M., van Schalkwyk, M.C.I., Stuckler, D., 2019. The second information revolution: digitalization brings opportunities and concerns for public health. *European Journal of Public Health* 29 (3-6). <http://doi.org/10.1093/eurpub/ckz160>
- Rodríguez Fernández, M.L., Pérez del Prado, D., 2018. El impacto de la economía 4.0 sobre las condiciones de trabajo y empleo. Estudio de caso en dos empresas de base tecnológica. *Cuadernos de Relaciones Laborales* 36, 355-372. <https://doi.org/10.5209/CRLA.60701>
- Rymarczyk, J., 2020. Technologies, opportunities and challenges of the industrial revolution 4.0: theoretical considerations. *Entrepreneurial Business and Economics Review* 8 (1), 185-198. <https://doi.org/10.15678/EBER.2020.080110>
- Sima, V., Gheorghie, I.G., Subic, J., 2020. Influences of the Industry 4.0 revolution on the human capital development and consumer behaviour: a systematic review. *Sustainability* 12 (10) 4035. <http://doi.org/10.3390/su1210403>
- World Bank, 2019. *World Development Report 2019: The Changing Nature of Work*. Washington, DC: World Bank. <https://doi.org/10.1596/978-1-4648-1328-3>
- Ugur, M., Mitra, A., 2017. Technology adoption and employment in less developed countries: a mixed-method systematic review. *World Development* 96, 1-18. <https://doi.org/10.1016/j.worlddev.2017.03.015>
- Vasilescu, M.D., Serban, A.C., Dimian, G.C., Aceleanu, M.I., Picatoste, X., 2020. Digital divide, skills and perceptions on digitalisation in the European Union—towards a smart labour market. *PLOS One* 15, e0232032. <https://doi.org/10.1371/journal.pone.0232032>

Zhou, Y., Mu, H.Y., Jiang, J.J., Zhang, L., 2012. Investigation of the impact of main control room digitalization on operators' cognitive reliability in nuclear power plants. *Work—A Journal of Prevention Assessment & Rehabilitation* 41, 714-721. <http://doi.org/10.3233/WOR-2012-0231-714>

СПИСОК ИСТОЧНИКОВ

- Acemoglu, D., Restrepo, P., 2020. Robots and jobs: evidence from us labor market. *J Polit Econ* 128, 2188-2244. <https://doi.org/10.1086/705716>
- Alexankov, A.M., Trostinskaya, I.R., Pokrovskaya, N.N., 2017. Industry 4.0 requirements for quality of human capital and competences formed within educational institutions. In: *Institutions International Conference on Research Paradigms Transformation in Social Sciences. Proceedings of Social and Behavioural Sciences*, 18-21 May, Tomsk, Russia, 35, pp. 26-34. <http://doi.org/10.15405/epsbs.2018.02.4>
- Alhamami, A., Petri, I., Rezgui, Y., 2020. Promoting energy efficiency in the built environment through adapted BIM training and education. *Energies* 13 (9), 2308. <http://doi.org/10.3390/en13092308>
- Avetisyan, P.S., Gevorgyan, N.M., 2020. A free educational environment is the basis of human capital and the interrelation of the main social spheres. *Ekonomika Regiona* 16 (2) 494-506. <http://doi.org/10.17059/2020-2-12>
- Bailur, S., Masiero, S., 2017. Women's income generation through mobile Internet: a study of focus group data from Ghana, Kenya, and Uganda. *Gender Technology & Development* 21 (1-2), 77-98. <http://doi.org/10.1080/09718524.2017.1385312>
- Balog, M.M., Demidova, S.E., Troyan, V.V., 2020. The influence of digital transformation on the shadow economy. *ETAP: Economic Theory, Analysis, and Practice* 4, 58-72. <http://doi.org/10.24411/2071-6435-2020-10034>
- Balynin, I.V., 2020. Evaluation of the implementation of national projects in the Russian Federation in the direction of 'human capital': from problems to their solution [Ocenka realizaci i nacional'nyh proektov v Rossijskoj Federacii po napravleniyu 'Chelovecheskij kapital': ot problem k ihresheniyu]. *Self-Government* 3 (120), 128-132.
- Basch, J.M., Melchers, K.G., 2020. Technologie-medierte Einstellungsinterviews: Ein Überblick über Befunde und offene Fragen. *Gruppe. Interaktion. Organisation. Zeitschrift für Angewandte Organisationspsychologie (GIO)* 51, 71-79. <https://doi.org/10.1007/s11612-020-00497-y>
- Bochaver, A.A., Dokuka, S.V., Sivak, E.V., Smirnov, I.B., 2019. Internet use and depressive symptoms in adolescents: review clinical psychology and special education. *Clinical Psychology and Special Education* 8 (3), 1-18. <http://doi.org/10.17759/cpse.2019080301>
- Cette, G., Nevoux, S., Py, L., 2021. The impact of ICTs and digitalization on productivity and labor share: evidence from French firms. *Economics of Innovation and New Technology*, 1-24 <https://doi.org/10.1080/10438599.2020.1849967>
- Chinoracký, R., Čorejová, T., 2019. Impact of digital technologies on labor market and the transport sector. In: *Proceedings of the 13th International Scientific Conference on Sustainable, Modern and Safe Transport (TRANSCOM)*, Novy Smokovec, Slovakia, pp. 94-1001. <https://doi.org/10.1016/j.trpro.2019.07.139>
- Corejova, T., Al Kassiri, M., 2016. Knowledge as the key to the global cooperation and its important role among nations. In: *3rd International Conference on Power and Energy Systems (PES 2016)*, Lee, G. (Ed.), Book Series: Lecture Notes in Earth Sciences-LNES, vol. 4. Bangkok, Thailand, pp. 181-183.
- Demidova, S., Chirkova, T., Balog, M., Petrova, O., 2019. Development of human capital in the aspect of financial security. In: *Proceedings of the International Scientific-Practical Conference 'Business Cooperation as a Resource of Sustainable Economic Development and Investment Attraction' (ISPCBC 2019)*. Atlantis Press, Paris, pp. 582-588.
- Dyba, M., Gernego, I., Dyba, O., Oliynyk, A., 2020. Financial support and development of digital rural hubs in Europe. *Management Theory and Studies for Rural Business and Infrastructure Development* 42 (1), 51-59. <http://doi.org/10.15544/mts.2020.06>
- Frolova, E.V., Rogach, O.V., Ryabova, T.M., 2020. Digitalization of education in modern scientific discourse: new trends and risks analysis. *European Journal of Contemporary Education* 9 (2), 313-336. <http://doi.org/10.13187/ejced.2020.2.313>
- Genz, S., Janser, M., Lehmer, F., 2019. The impact of investments in new digital technologies on wages—worker-level evidence from Germany. *Journal of Economics and Statistics* 239, 483-521. <https://doi.org/10.1515/jbnst-2017-0161>
- Gomez-Plana, A.G., Latorre, M.C., 2019. Digitalization, multinationals and employment: an empirical analysis of their causal relationships. *Journal of Economics and Statistics* 239, 399-439. <https://doi.org/10.1515/jbnst-2017-0153>
- Goos, M., Koningsb, J., Vandeweyer, M., 2015. Employment growth in Europe: the roles of innovation, local job multipliers and institutions. *SSRN Electronic Journal*, 1-38. <https://doi.org/10.2139/ssrn.2671765>
- Gregory, T., Salomons, A., Zierahn, U., 2019. Racing with or against the machine? Evidence from Europe. *SSRN Electronic Journal*, 12063. <https://doi.org/10.2139/ssrn.2815469>
- Islam, I. 2018. Automation and the future of employment: implications for India. *South Asian Journal of Human Resource Management* 5, 234-243. <https://doi.org/10.1177/2322093718802972>
- Kelchevskaya, N.R., Shirinkina, E.V., 2019. Regional determinants of effective use of human capital in the digital economy. *Economy of Region* 15, 465-482. <https://doi.org/10.17059/2019-2-12>
- Kim, J.-Y., 2018. The human capital gap: getting governments to invest in people. *Foreign Affairs* (July/August). Available from: <https://www.foreignaffairs.com/articles/2018-06-14/human-capital-gap>.
- Knox, B.J., 2018. The effect of cybberpower on institutional development in Norway. *Front. Psychol.* 9, 717. <http://doi.org/10.3389/fpsyg.2018.00717>
- Koneva, A.V., Lisenkova, A.A., 2019. Identity matrix in the digital age: social challenges to overcome the anonymity. Tomsk

- State University Journal of Cultural Studies and Art History 35, 14-28. <http://doi.org/10.17223/22220836/35/2>
- Laaser, W., 2018. Economic implications and stakeholder reactions in a digital university environment. *Red-Revista de Educacion a Distancia* 57, 4. <http://doi.org/10.6018/red/57/4>
- Lloyd, C., Payne, J., 2021. Fewer jobs, better jobs? An international comparative study of robots and 'routine' work in the public sector. *Industrial Relations* 52, 109-124. <https://doi.org/10.1111/irj.12323>
- Manakhova, I., Bystrov, A., Ignatyeva, G., Alekhina, O., 2019. Personnel security in the conditions of digitalization of the economy. In: *Proceedings of the Volgograd State University International Scientific Conference: Competitive, Sustainable and Safe Development of the Regional Economy. AEBMR-Advances in Economics Business and Management Research*, Volgograd, Russia, 83, 391-395. <https://doi.org/10.2991/cssdre-19.2019.76>
- Marinkovic, S., Nikolic, I., Rakicevic, J., 2018. Selecting location for a new business unit in ICT industry. In: *Proceedings of Rijeka Faculty of Economics. Journal of Economics and Business* 36 (2), 801-825. <http://doi.org/10.18045/zbe-fri.2018.2.801>
- McKee, M., van Schalkwyk, M.C.I., Stuckler, D., 2019. The second information revolution: digitalization brings opportunities and concerns for public health. *European Journal of Public Health* 29 (3-6). <http://doi.org/10.1093/eurpub/ckz160>
- Rodríguez Fernández, M.L., Pérez del Prado, D., 2018. El impacto de la economía 4.0 sobrelascondiciones de trabajo y empleo. Estudio de caso en dos empresas de base tecnológica. *Cuadernos de Relaciones Laborales* 36, 355-372. <https://doi.org/10.5209/CRLA.60701>
- Rymarczyk, J., 2020. Technologies, opportunities and challenges of the industrial revolution 4.0: theoretical considerations. *Entrepreneurial Business and Economics Review* 8 (1), 185-198. <https://doi.org/10.15678/EBER.2020.080110>
- Sima, V., Gheorghe, I.G., Subic, J., 2020. Influences of the Industry 4.0 revolution on the human capital development and consumer behaviour: a systematic review. *Sustainability* 12 (10) 4035. <http://doi.org/10.3390/su1210403>
- World Bank, 2019. *World Development Report 2019: The Changing Nature of Work*. Washington, DC: World Bank. <https://doi.org/10.1596/978-1-4648-1328-3>
- Ugur, M., Mitra, A., 2017. Technology adoption and employment in less developed countries: a mixed-method systematic review. *World Development* 96, 1-18. <https://doi.org/10.1016/j.worlddev.2017.03.015>
- Vasilescu, M.D., Serban, A.C., Dimian, G.C., Aceleanu, M.I., Picatoste, X., 2020. Digital divide, skills and perceptions on digitalisation in the European Union—towards a smart labour market. *PLOS One* 15, e0232032. <https://doi.org/10.1371/journal.pone.0232032>
- Zhou, Y., Mu, H.Y., Jiang, J.J., Zhang, L., 2012. Investigation of the impact of main control room digitalization on operators' cognitive reliability in nuclear power plants. *Work—A Journal of Prevention Assessment & Rehabilitation* 41, 714-721. <http://doi.org/10.3233/WOR-2012-0231-714>

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SECTION 4

**MANAGEMENT OF KNOWLEDGE AND INNOVATION
FOR SUSTAINABLE DEVELOPMENT**

РАЗДЕЛ 4

**УПРАВЛЕНИЕ ЗНАНИЯМИ И ИННОВАЦИЯМИ
В ИНТЕРЕСАХ УСТОЙЧИВОГО РАЗВИТИЯ**

Research article

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**ACHIEVING SUSTAINABLE DEVELOPMENT THROUGH THE
EFFECTIVENESS AND EFFICIENCY OF EU STRUCTURAL AND
INVESTMENT FUNDS IN SELECTED MEMBER STATES WITH A SPECIAL
FOCUS ON BULGARIA**

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Abstract

The present research is focused on achieving sustainable development through the evaluation of the effectiveness of implementing European funds in member states, with a special focus on Bulgaria. The aim of this article is to analyse the added value of European funds and their effectiveness and efficiency on the national economy to understand their proper contribution to the sustainable development of concrete member states. Based on official data, both on national and European levels and their comprehensive analysis, the author concluded that the effectiveness of European Union (EU) funds and therefore their role in the sustainable development of the country varies depending on the member state. The national management system and its ability to act flexibly and adaptively is crucial in terms of optimizing the added value of the initial planned and allocated resources from programmes funded by European Structural and Investment Funds (ESIF). Although there are very clear rules and specific legislation concerning the level of financial support, as can be seen from the data, member states with relatively the same level of development, population and territorial area begin the programming period with different planned budgets for ESIF programmes. Therefore, apart from everything else, the strong negotiation skills of the governmental representatives in the process of programming the next programming period are necessary to obtain good starting results.

Keywords: Sustainable development, European Union, European Funds, European Programmes, ESIF, member states, efficiency

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ДОСТИЖЕНИЕ УСТОЙЧИВОГО РАЗВИТИЯ ЗА СЧЕТ ЭФФЕКТИВНОСТИ СТРУКТУРНЫХ И ИНВЕСТИЦИОННЫХ ФОНДОВ ЕС В ОТДЕЛЬНЫХ ГОСУДАРСТВАХ-ЧЛЕНАХ НА ПРИМЕРЕ БОЛГАРИИ

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Аннотация

Настоящее исследование сосредоточено на достижении устойчивого развития посредством оценки эффективности использования европейских фондов в государствах-членах, с особым акцентом на Болгарию. Целью этой статьи является анализ добавленной стоимости европейских фондов и их эффективности для национальной экономики, чтобы понять их надлежащий вклад в устойчивое развитие конкретных государств-членов. Основываясь на официальных данных, как на национальном, так и на европейском уровнях, и их всестороннем анализе, автор пришел к выводу, что эффективность фондов Европейского союза (ЕС) и, следовательно, их роль в устойчивом развитии страны варьируется в зависимости от государства-члена ЕС. Национальная система управления и ее способность действовать гибко и адаптивно имеет решающее значение с точки зрения оптимизации добавленной стоимости первоначально запланированных и выделенных ресурсов из программ, финансируемых Европейскими структурными и инвестиционными фондами (ЕСИФ). Хотя существуют очень четкие правила и конкретное законодательство, касающиеся уровня финансовой поддержки, как видно из данных, государства-члены с относительно одинаковым уровнем развития, населением и территорией начинают период программы развития с разными запланированными бюджетами для программ ЕСИФ. Поэтому, помимо всего прочего, для получения хороших стартовых результатов необходимы сильные навыки ведения переговоров представителями правительства в процессе разработки программ развития на следующий период.

Ключевые слова: Устойчивое развитие, Европейский союз, Европейские фонды, Европейские программы, ЕСИФ, государства-члены, эффективность

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1. Introduction

The effectiveness and efficiency of the European Union (EU) has always been the subject of serious public debate, especially in the last few years. The reasons for this could be found in various aspects, with the measures and decisions taken in the fight against the COVID-19 (lockdown, vaccination process, different measures for precautions, etc.) on one hand and Brexit and its consequences over both the EU member states and the United Kingdom on the other. Also, the effectiveness and efficiency of EU funds and programmes are usually an object of vivacious discussion in terms of identifying which member states are net payers and which countries are the biggest beneficiaries. This debate could also be interpreted in terms of achieving sustainable development for the national economy through the following two steps: first, to make a comprehensive assessment of the effectiveness and efficiency of EU Structural and Investment Funds and second, if necessary, to identify specific measures to improve their contribution to national sustainable development. At the end of each programming period, the European Commission (EC) initiated a broad discussion among member states covering different types of stakeholders in an attempt to identify the most important priorities for policy development for the next programming period. It is obvious that these priorities will refer to and will impact diversely on the member states due to the differences between their economic development and specific national problems and characteristics. The idea of the current study is to understand the level of efficiency of EU structural and investment funds (ESIF) in different member states as a direct result of fundamental EU policies. In this specific context, the major aim of the current article is to analyse the official data both on EU and national levels of concrete member states to understand the concrete rate of efficiency of EU funds in a country. The scientific novelty of the current article could also be considered in this line, namely to give a clear methodology for assessing the effectiveness of European funds. The results of the current analysis could be a base for governmental decisions in concrete member states to improve their national systems for programming and implementing EU funds. Despite the fact that EU funds are the subject of various scientific research, the attention of the scholars still covers precise aspects (for instance, impact on small-medium enterprises (SME) development in a concrete region, the effect of training provided by the European Social Fund, etc.) and does not reveal the entire picture and methodology for assessing the impact of ESIF at a national level.

2. Literature Review

The effectiveness and efficiency of the EU are the focus of various scientific researches covering different spheres of policies, legislation, regulations, financial results, bank systems, etc. This attention is easily explicable, keeping in mind that the EU is one of the leading economic players on a global scale. In a more recent context, the variety of exploring the efficiency and effectiveness of the EU again is a leading feature for scholars.

For instance, the different kinds of European regulations and their effectiveness are developed in the context of water resources and agriculture activities (Wuijts, 2021), food policy regulation (Landwehr and Hartmann, 2020), EU data breach notification obligation (Nieuwesteeg and Faure, 2018) and EU bank regulatory framework (Benczur et al., 2017).

On the other hand, European efficiency has also been examined in various aspects, in recent years predominantly in terms of the environment and, more specifically, in the field of energy efficiency. Some of the researches present comparative analysis among member states based on different criteria (Malinauskaite et al., 2020; Bertoldi and Mosconi, 2020; Malinauskaite et al., 2019), while others explore comprehensively specific subjects, such as energy efficiency policy for buildings (Economidou et al., 2020; Economidou et al., 2020a; Camaras et al., 2020), or the relation between population habit of the population and its electricity consumption (Pais-Magalhaes et al., 2020). Bioenergy efficiency in EU member states is also an object of scholarly attention (Abdulwakil et al., 2020; Strapasson et al., 2020).

When we consider efficiency in the EU context, we could point out some different aspects of this term, such as efficiency in aquaculture production (Gutiérrez et al., 2020), policy planning and man-

agement of agriculture efficiency in EU countries (Toma et al., 2017) and the economic performance of companies (Löschel et al., 2019).

However, the importance of European funds and their impact on the development of EU member states is usually a subject of dynamic scientific exploration, which is logically because EU funds are the financial instruments for providing and implementing EU policy. Numerous studies have been dedicated to EU funds, covering their special features. For instance, some authors explore the complex relationship and intensity of interaction along the axis of EU funds, local opportunities and Euroscepticism (Crescenzi et al., 2020). Interesting research is focused on bribery, abuse of subsidies and corruption in EU programmes for the environment. The authors claim that corruption is one of the biggest difficulties and challenges facing the EU, including environmental programmes and special subsidies. They claim that political leaders and oligarchs across the bloc continue to misappropriate agricultural subsidies, particularly for their personal benefit (Teichmann, 2020). One possible solution in the fight against corruption is transparency, which must be obligatory for all stakeholders in all member states.

When we review the scientific literature in the specific field of EU funds, we must outline that there are also numerous studies exploring different characteristics in a concrete EU fund or programme. For instance, some authors have implemented a special methodology to reveal the optimal allocation coming from the European Cohesion Fund (ECF) (Dicharry et al., 2019). They have analysed data from different member states for a ten-year period in implementation programmes funded by the European ECF, based on Dicharry et al.'s analysis that indicates that the ECF should be concentrated on poor countries having a large population size, and where the ECF has a strong ability to promote economic growth (2019). Special attention to the European cohesion policy and specific interventions in terms of citizens' awareness are the subject of another research (Cunico et al., 2021). Other articles have explored the oldest EU funds: the European Social Fund (Pelucha et al., 2019) and the European Regional Fund (Agovino, 2019).

Probably, one of the major scientific focuses is on the different EU programmes. Here we could mark several interesting aspects, such as analysis of the planning and implementation of rural programmes (Andersson et al., 2017), the role of intermediary organisations in the context of sub-programmes (Pisani et al., 2020), developing relationships between Europe and Asia through the Erasmus Mundus (Guerrero-Pérez et al., 2020) and the role of the local authorities in the process of solid-waste recycling market using European 2020 Horizon Strategy (Expósito and Velasco, 2018) or specific initiative such as European SME Instrument on the EC Horizon 2020 (Mina et al., 2021).

Although there is a variety of research dedicated to EU funds and programmes, the scientific literature remains relatively modest when we consider the overall efficiency or different aspects of EU funds' efficiency. In recent years, we could point to the research elaborated by Gouveia, Henriques and Costa (Gouveia et al., 2021). They explored the efficiency of European funds in a specific context of SME competitiveness in different EU regions. After a comprehensive data analysis, they conclude that national inefficient programmes mainly need to reduce their dependence on EU co-funding to become efficient, whereas almost all inefficient regional programmes need to improve their capacity for execution (Gouveia et al., 2021). SME competitiveness developed with the financial support of EU programmes and funds is a subject of a study exploring the specific situation of this relation for SME in Danube delta, revealing through the help of "the three-dimensional impact of the absorption effects of European funds" (Bostan et al., 2019).

Particular national dimensions of assessment effectiveness in specific programmes in a concrete sector of the economy are developed by Pajewski et al. (2020). The authors present special aspects of agriculture and the environment in Poland. Almost in the same field of agriculture, but this time considering the situation in Romanian's rural areas, tourism and EU funds are explored by Galluzzo (2021).

In this specific context, the major goal of the present article is to reveal and analyse the added value of European funds and their effectiveness and efficiency on different national economies in the context

of sustainable development.

3. Materials and Methods

To reveal the real effectiveness and efficiency of EU funds and their impact on different national economies among member states, we used official data for the initial analysis. The specific methodology is presented in Figure 1. The first step is to collect official financial data from different units of the EC, covering two basic lines: budget data for ESIF programmes for selected member states of the EU in terms of their planning and budget data for ESIF programmes for selected member states in terms of their real implementation so far. The second step was to collect the same data from the national authorities to compare the level of real implementation and state of play. This comparison will allow us to understand whether there is a serious delay between national reporting of ESIF programme implementation and the Commission's results. In case of delay, further analysis will be made to understand whether this result is based on the systematic problem or whether it is due to the specific national characteristics for a concrete member state. The third and fourth steps are to collect and compare the data on the specific contributions that each member state has to provide to the EU budget. Since this information could be considered sensitive for the EU, we will try to find alternative but also official sources to collect basic information. This information is needed to assess the effectiveness and efficiency of ESIF at the concrete member-state level.

The fifth step of the methodology is to identify the costs and benefits of selected member states in terms of ESIF. For this purpose, we need detailed information on all programmes supported by ESIF in concrete member states with their financial allocation to the specific priority axes. In Bulgaria, such specific and at the same time official information could be found through the public module of the National Information System for the management and monitoring of EU funds in Bulgaria, which is a platform managed by the Central Coordination Unit within the Council of Ministers' Administration. In the process of calculating the benefits and costs here, we must make the following definitions and explanations, which will be applied in the research:

- For "costs" in this specific area, we will understand only the net contribution that each member state has to pay for its membership in the EU.

- For "benefits" in this specific area, we will understand the financial resources coming through the line of national or regional programmes, implemented at the national level and supported by European Structural and Cohesion Funds (ESIF).

From this initial "incomes," we will exclude from further calculation specific financial resources allocated for Technical Assistance Priority Axes of all programmes and co-financed support from the national funding of the programmes (which is 15% for ERDF and ESF and 20% for the Cohesion Fund). The reason for excluding finance under technical assistance is the following: usually technical assistance of one programme supports specific activities related to overall management of the programme typical for Managing Authority of the programme (programming, implementation, monitoring and control, internal audit activities, communication, publicity and transparency measures, training of employees in Managing Authority and Intermediate Body, etc.). In this research, we try to analyse and identify the pure effectiveness and efficiency of ESIF funds through the programmes implemented at the national level. The financial sources allocated to all technical assistance axes of the programmes are dedicated to supportive activities and therefore do not lead to a direct impact. In case of assuming that the rest of the measures and procedures planned within the other priority axes of the programmes are important and crucial for national development, the national government would have the possibility and administration for this in traditional institutions without forming, training and building the capacity of a specific new unit for this.

Based on the initial collected data and further calculations explained in the present methodology, we will be able to analyse the results.

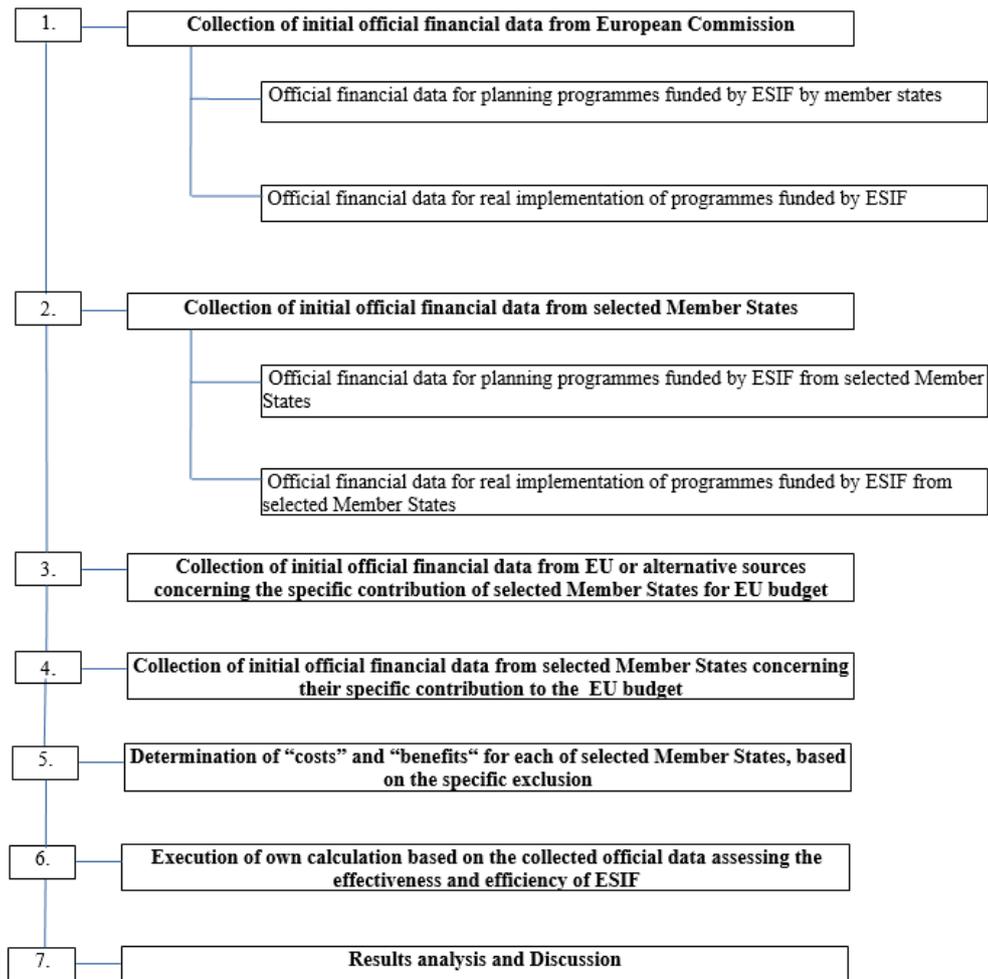


Figure 1. Specific methodology of the research for assessing the effectiveness and efficiency of ESIF in selected EU member states.

Analysis of the collected data was made using the following scientific methods: deduction, comparative analysis and synthesis, and systematization.

4. Results

The discussion concerning net contributors and beneficiaries among member states of the EU is a complex and difficult question for several reasons, including that different policies are executed through the help of numerous funds, specific financial instruments, initiatives, programmes, etc. and implemented on different levels (EU, national, transnational, cross border, regional, interregional, etc.). All the above-mentioned factors make it almost impossible to understand which country benefits from its membership and which ones are ‘net contributors’. Usually, this calculation is based on, on one side, the contribution for the EU budget of the member states and on the other, the total planned budget of the programmes, under which a member state is contracted under the Partnership Agreement for the concrete programming period.

Nevertheless, there are various sources that expose which member states are beneficiaries and which are net contributors. For instance, according to the statistical information, based on the EC data for 2018¹, there are 10 EU member states that could be considered as ‘net contributors’ for the EU budget, namely: Germany (+17,213 mln euro), the UK (+9,770 mln euro), France (+7,442 mln euro), Italy (+6,695 mln euro), The Netherlands (+4,877 mln euro), Sweden (+1,983 mln euro), Austria (+1,534

¹European Commission, 2021. URL: <https://www.statista.com>

mln euro), Denmark (+ 1,468 mln euro), Finland (+679 mln euro) and Ireland (+542 mln euro). On the bottom of this rank, the places for the best five beneficiaries among member states of the EU are Poland (-11,632 mln euro), Hungary (-5,029 mln euro), Greece (-3,202 mln euro), Portugal (-3,316 mln euro) and Romania (-3,035). Bulgaria takes 11th place among beneficiary countries (-1,585 mln euro), four positions after Belgium (-2,590 mln euro) and two positions after Luxembourg (-1,631 mln euro).

Having this as an informational starting point, we will explore in detail the implementation of ESIF programmes in selected member states, with a special focus on Bulgaria. For the present analysis, our focus will cover the following member states among the beneficiary countries: Hungary, Portugal, Belgium, Lithuania, Estonia and Romania. The reasons for choosing these countries are the following: Belgium was one of the countries at the very beginning of EU and is a good example of tradition in implementation of EU funds; Portugal is an example of well implementation of EU funds, including the Cohesion Fund; Hungary, Lithuania and Estonia are examples of countries part of the first big enlargement of EU, and Romania is a member state with the same expertise in EU funds as Bulgaria.

The next figure presents the progress achieved by these selected member states in the implementation of ESIF programmes.

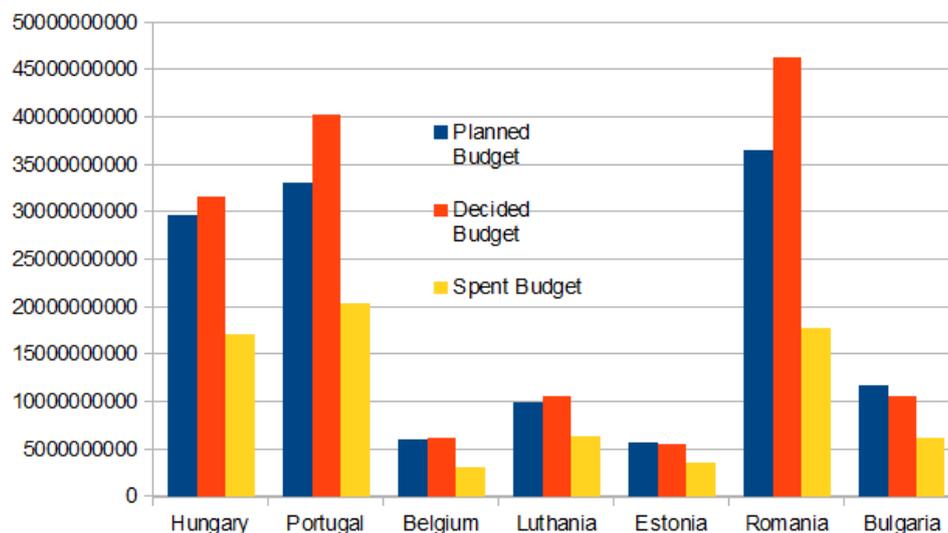


Figure 2. ESIF 2014–2020: Implementation progress (total cost) for selected member states

Source: EC, cumulative data per member state, as of 31.12.2020.2

As can be seen in Figure 2, there are obvious differences between member states in programming and the real implementation process of ESIF programmes. On the other hand, at the end of 2020, most had contracted more financial resources than the initial planning (Hungary, Portugal, Lithuania and Romania). This fact could be easily explained by the concrete efforts made by the managing authorities and the Central Coordination Unit of those member states to absorb all planned resources for the rest of the programming period. The other indicator that must be put on further exploration is the ratio between the planned and real spent budgets (Fig. 3).

According to this indicator, Lithuania takes the first position, with 64% implementation and real payments to the beneficiaries, followed by Estonia and Portugal, with 62% real financial implementation. Hungary holds the third position (58%), followed by Bulgaria (53%), Belgium (50%) and Romania (49%), which are at the bottom in this rank. This real financial implementation for a seven-year period could be considered relatively normal; there are no dramatic deviations or delays achieved by any of the selected member states. This opinion could be further supported by the additional data coming from EU member states such as France (66% implementation), Germany (62%) and Denmark (51%). The abso-

²European Commission, 2021, EU expenditure and revenue 2014-2020, https://ec.europa.eu/budget/graphs/revenue_expenditure.html

lute leader in this specific ESIF programme implementation from all member states through the end of 2020 is Finland, with 82% of real payments to beneficiaries.

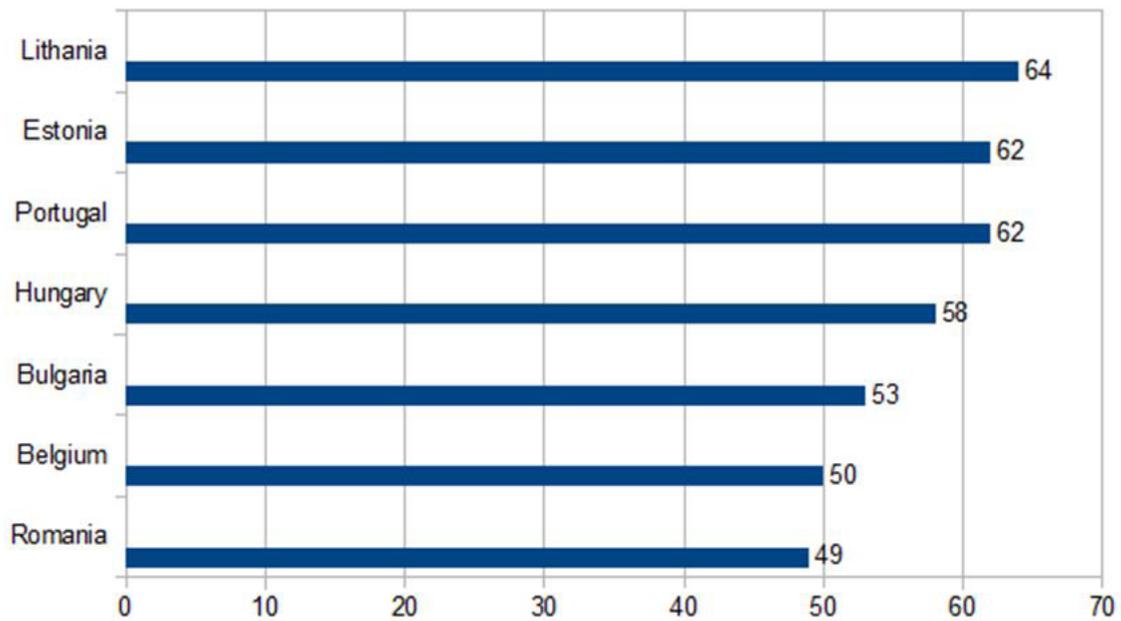


Figure 3. Achieved financial implementation progress of ESIF programme by member states.

Based on the ratio between planned and real spent budget

Source: EC, cumulative data as of 31.12.2020

To explore financial effectiveness on a national level, we must compare specific data for expenditures and revenue by country and year. Due to the limitations of the current study, we will explore only three of the initial selected countries: Hungary, Belgium and Romania.

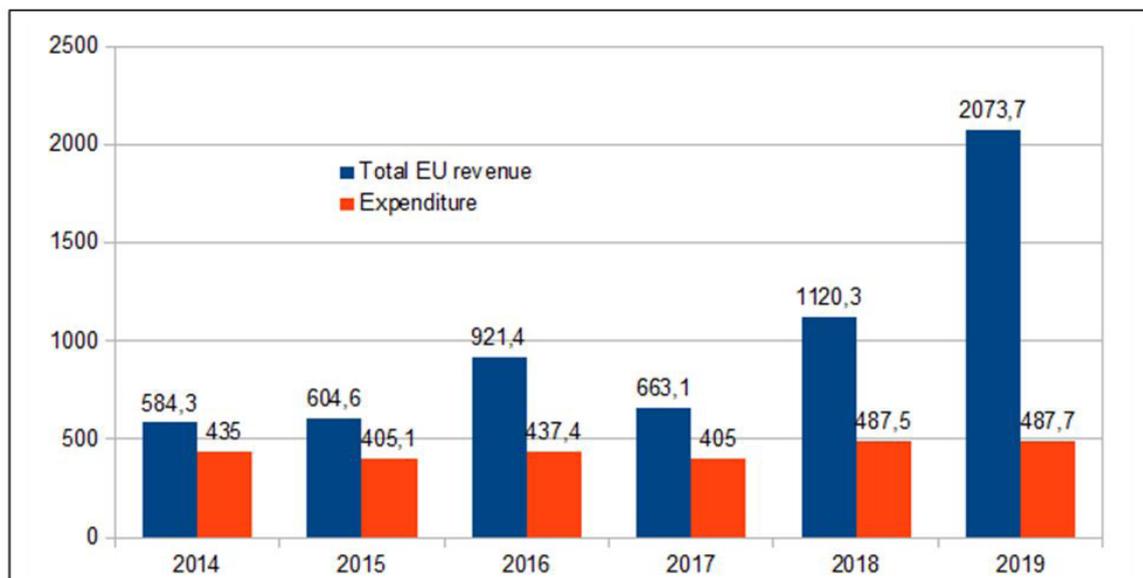


Figure 4. Financial implementation of EU programmes and funds in Hungary (EUR million)

Source: Based on EC data, 2020.

Specific data for the financial implementation of all EU funds and programmes in concrete EU member states are based on the EC data but converted to the point of view of the concrete member state. As can be seen from Figures 4, 5 and 6, our initially selected member states have different revenue and

expenditures, which depends on the complexity of criteria, including the level of development of the country. Therefore, it is not surprising that Belgium has the smallest level of financial intensity in terms of revenue among the considered member states, and Romania possesses the biggest level of financial support coming from different EU programmes and funds.

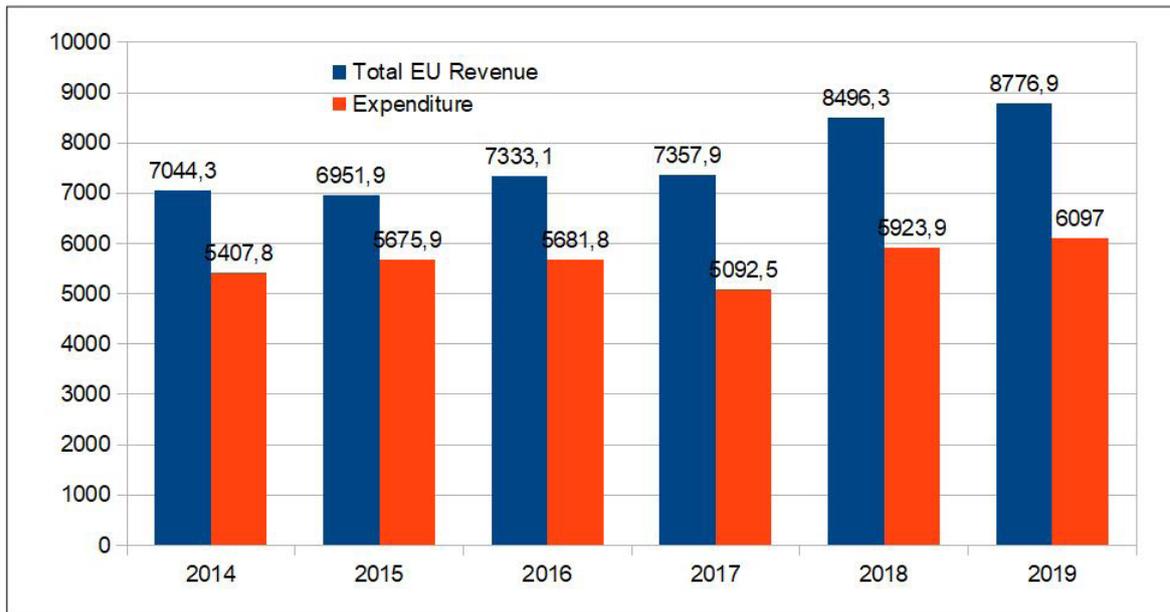


Figure 5. Financial implementation of EU programmes and funds in Belgium (EUR million)

Source: Based on EC data, 2020.³

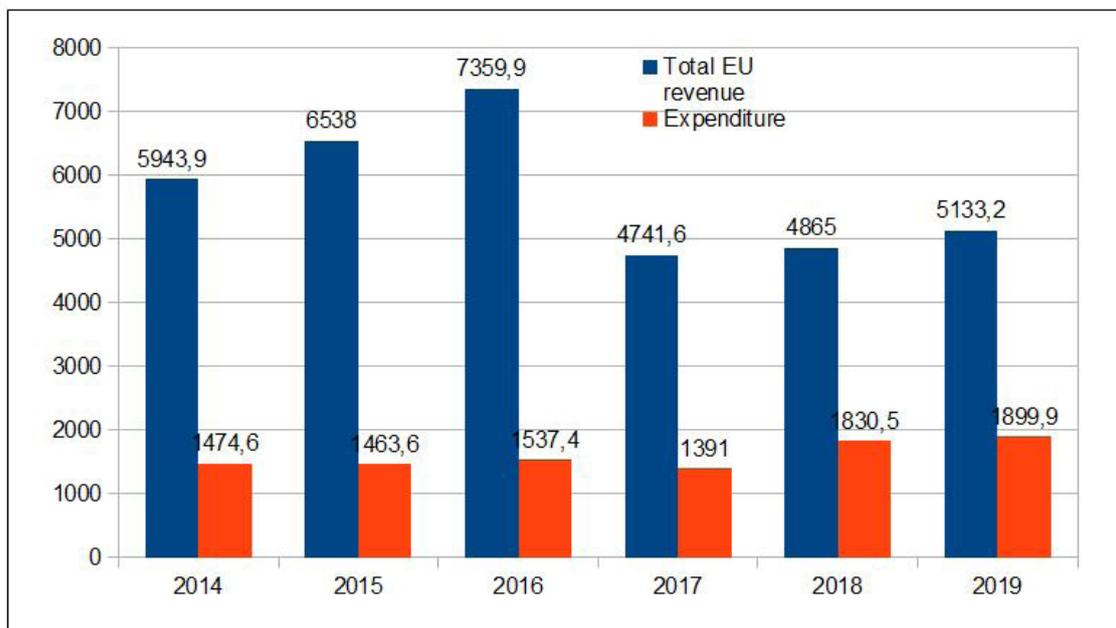


Figure 6. Financial implementation of EU programmes and funds in Romania (EUR million)

Source: Based on EC data, 2020.

However, we still need further information to understand the effectiveness of ESIF on concrete member states. Going directly to this specific problem, we must have reliable official data for the specific

³European Commission, 2021, EU expenditure and revenue 2014-2020, https://ec.europa.eu/budget/graphs/revenue_expenditure.html

implementation of ESIF on a member-state level. For this purpose, our study will focus on Bulgaria, for which we have sufficient official information (from the public module of the National Information System for Management and Monitoring of EU Funds in Bulgaria–UMIS 2020, managed by the Central Coordination Unit within the Council of Ministers’ Administration).

Bulgaria implemented 10 programmes for the 2014–2020 programming period, supported by ESIF. Two of them, OP Transport and Transport Infrastructure and OP Environment, were financed by the Cohesion Fund (CF) and the European Regional Development Fund (ERDF). Programmes financed by the ERDF were OP Regions in Growth, OP Innovation and Competitiveness and OP SME Initiative. OP Science and Education for Smart Growth was financed by two European Funds: ERDF and the European Social Fund (ESF). ESF supported the following programmes in Bulgaria: OP Human Resource Development and OP Good Government. OP Maritime and Fishery was financed by the European Maritime and Fishery Fund, while the Rural Development Programme was financed by the European Agriculture Fund for Rural Development.

To identify the real impact of all of these programmes at the national level, we will execute some calculations. First, from the lists of programmes, we will not include the OP Good Governance (with total budget of 280 469 249 euro, and ECF funding of 238 398 862 euro), since this programme has a precise scope, covering authorities from the national system of management EU funds and programmes. Here, in our study, we will try to reveal the direct effect of measures not supported activities. Following this line of basic considerations, we will focus only on the EU share of the programmes’ budget, and we will exclude from further calculation the specific budget of each programme coming for technical assistance (the reason for this remains the same—to reveal the real impact of EU ESIF programmes in Bulgaria). The results of these calculations are presented in Table 1.

Table 1. Programmes in Bulgaria supported by European Structural and Cohesion Funds (for the period 2014–2020) in euro

Source: Bulgarian Government⁴, UMIS Public 2021, author’s calculation

N	Name of the Programme	Total Budget	EU Funding	National Funding	Budget of Technical Assistance Priority Axis – EU funding	Final EU Incomes Planned Resources
1.	OP Transport and Transport Infrastructure	1 789 123 639	1 520 755 090	268 368 549	40 517 316	1 480 237 774
2.	OP Environment	1 734 666 074	1 474 466 161	260 199 913	40 406 026	1 434 060 134
3.	OP Regions in Growth	1 648 278 759	1 416 801 442	231 477 317	44 535 000	1 372 266 442
4.	OP Innovation and competitiveness	1 655 159 319	1 438 064 222	217 095 097	35 423 468	1 402 640 754
5.	OP Science and Education for Smart Growth	690 244 017	595 110 178	95 133 839	21 169 651	573 940 527
6.	OP Human Resource Development	1 402 709 811	1 237 800 270	164 909 541	22 529 428	1 215 270 842
7.	OP SME Initiative	102 000 000	102 000 000	0	0	102 000 000
8.	OP Maritime and Fisheries	104 287 847	80 774 373	23 513 474	4 124 937	76 649 436
9.	Rural Development Programme	3 068 046 674	2 487 658 748	580 387 926	39 716 320	2 447 942 428

As a result, in the last column of Table 1 we have Final EU incomes planned resources under each ESIF programme in Bulgaria, which was obtained following the algorithm:

⁴Bulgarian Government, 2021. Information system for Management and Monitoring of EU Funds in Bulgaria 2020, <http://2020.eufunds.bg/en>

Final EU incomes planned resources = total budget of programme – national funding – budget of the Priority Axis Technical Assistance (EU contribution)

Table 2. Implementation and state of play of programmes in Bulgaria supported by European Structural and Cohesion Funds (for the period 2014–2020) in euro, actual data from March 2021

Source: Bulgarian Government, UMIS public, 2021, author’s calculation.

N	Name of the Programme	Total EU Funding	Final EU Incomes Planned Resources	State Of Play EU Contribution	
				Contracted Amounts	Actual Amounts Paid
1.	OP Transport and Transport Infrastructure	1 520 755 090	1 480 237 774	1 329 678 545	812 939 654
2.	OP Environment	1 734 666 074	1 434 060 134	1 638 478 188	1 081 889 866
3.	OP Regions in Growth	1 648 278 759	1 372 266 442	1 300 087 610	816 587 569
4.	OP Innovation and competitiveness	1 655 159 319	1 402 640 754	1 233 896 415	749 602 710
5.	OP Science and Education for Smart Growth	690 244 017	573 940 527	568 229 562	300 866 454
6.	OP Human Resource Development	1 402 709 811	1 215 270 842	1 153 707 060	756 206 436
7.	OP SME Initiative	102 000 000	102 000 000	102 000 000	102 000 000
8.	OP Maritime and Fisheries	104 287 847	76 649 436	68 328 422	27 514 395
9.	Rural Development Programme	3 068 046 674	2 447 942 428	439 649 557	41 239 479
Total		12 012 534 906	10 105 008 337	7 834 055 359	4 688 846 563

The next step was to calculate the progress achieved by each managing authority (MA) of the programme under all priority axes without technical assistance. For this purpose, we collected two types of data: the contracted budget between the MA and beneficiary and the actual amount paid, the resources that have reached the beneficiary. This is the final effect that we will try to compare as a direct real result to the national economy from ESIF programmes implemented at the Bulgarian national level.

For this purpose, we need to introduce only one additional indicator—the Bulgarian contribution to the EU budget—presented in Figure 7.

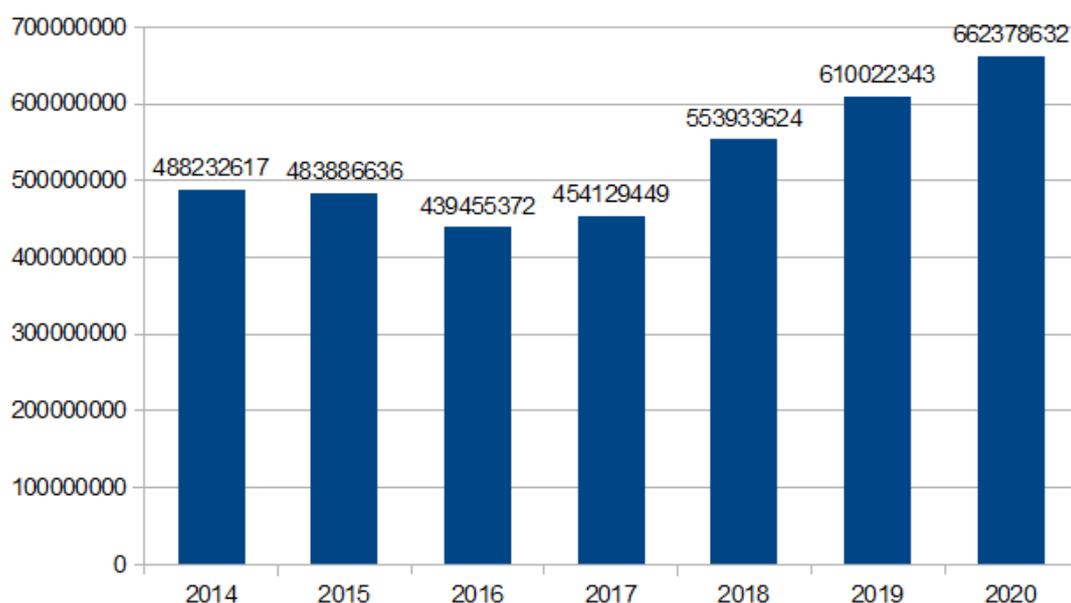


Figure 7. Bulgarian contribution to the EU budget by years, in euros.

Source: Bulgarian Ministry of Finance, 2020.⁵

⁵Bulgarian Ministry of Finance, 2021. URL: <https://www.minfin.bg/en/883>

Based on official data from the Bulgarian Ministry of Finance and additional calculations of the author, Bulgarian contribution to the EU budget for the period 2014–2020 is in total 3,692,038,673 euros. For the same period under partnership agreement, Bulgaria contracted 10 ESIF programmes with a total budget (EU share) of 12 012 534 906 euros. By March 2021, implementing ESIF programmes, Bulgaria has succeeded in contracting with beneficiaries a total budget of 7 834 055 359 euros (EU share), of which 4 688 846 563 euros (EU share) has already been paid to the beneficiaries. This comparison, graphically presented in Figure 8, will give us the level of the final effectiveness and efficiency of ESIF in Bulgaria, achieved by national authorities for the programming period 2014–2020 until March 2021.

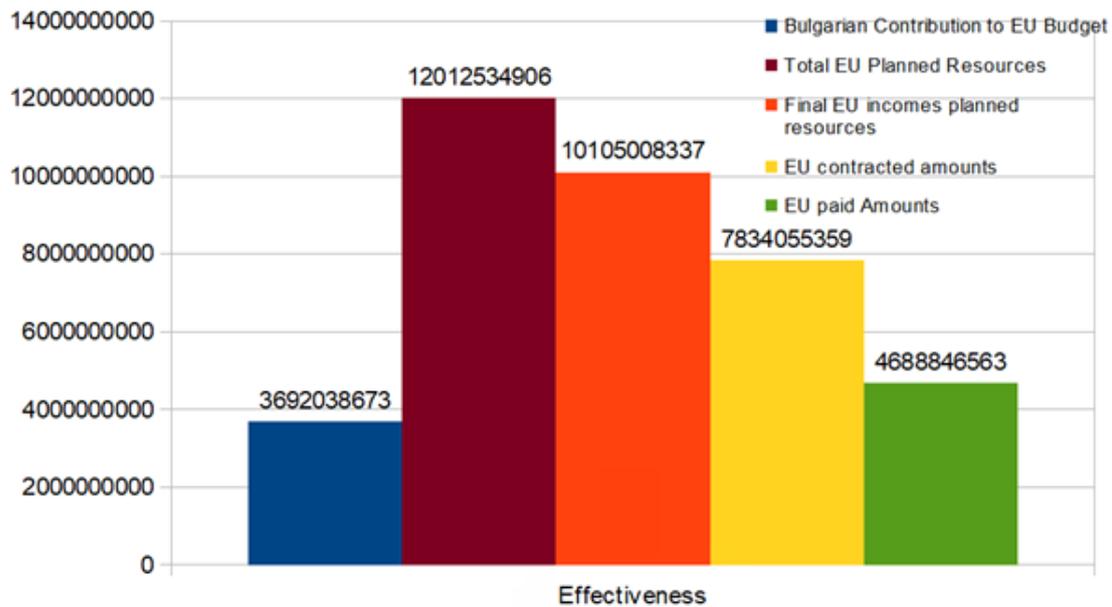


Figure 8. Financial interactions between Bulgaria and EU for the period 2014-2020

As can be seen in the figure, the difference between Bulgarian contribution to the EU budget, presented in the first column of the figure and the real benefits (the last column) under ESIF programmes is not so impressive and serious even for Bulgaria as a typical member state, usually considered as a real beneficiary of the EU policies, programmes and funds.

4. Discussion

Achieving sustainable development through the improvement of the effectiveness and efficiency of implementation of European Structural and Investments Funds at the national level is critical for some of the member states, including Bulgaria. The results from the current survey clearly indicate several critical points that have to be considered in terms of exploring the effectiveness and efficiency of programmes funded by ESIF at the national level. The first critical point is connected to the contracted budget under partnership agreement between the EU and member state. Although there are very clear rules and specific legislation concerning the level of financial support, as can be seen from data, member states with relatively same level of development, population and territorial area begin the programming period with different planned budgets for ESIF programmes (for instance, comparison between Hungary and Bulgaria). Therefore, apart from everything else, the strong negotiation skills of the governmental representatives in the process of programming the next programming period are necessary to obtain good starting results.

On the second place comes as a critical point the ability of MA and the entire national system for planning, implementation and management of EU funds to act flexibly and adaptively, with a strong focus on the beneficiaries’ needs and design different procedures with attention to the real needs of

potential beneficiaries. All these efforts must be directed towards fully absorbing and investing in the planned budget under ESIF programmes. Here, we must mention that good timing in implementing ESIF programmes is crucial, including in terms of optimizing the added value and real impact of the invested resources.

For a seven-year period, Bulgaria has succeeded in achieving a real impact of the economy's total investments of 996 807 890 euros, which is far from the initially planned resources (approximately 142 million euros per year). However, there is still time to complete the programming period of 2014–2020, but the timing and delay are obvious.

5. Conclusion

Bulgaria, as a member state of the European Union, came with the second wave of EU enlargement and could usually be considered a typical beneficiary country—less developed than the rest of the member states. On the other hand, in these complex times, when the pandemic brings about an economic crisis, achieving sustainable development, especially with the help of European funds, could be considered one of the major priorities for a national economy. ESIF programmes are dedicated to overcoming the differences between EU regions and therefore these programmes are the main instrument to implement this basic policy of the EU. Yet, despite the initial planned resources in the partnership agreement (signed between the EC and each member state), the Bulgarian authorities failed to sufficiently manage ESIF programmes in terms of achieving the best level of impact of invested resources. We analysed results achieved so far from Bulgaria and our analysis clearly shows that the Bulgarian management system of EU funds is not effective and has to be seriously improved to achieve a better ratio between contracted and spent/ invested resources. Therefore, the effectiveness and efficiency of ESIF programmes at the national level achieved by Bulgarian authorities could be considered insufficient and insignificant, especially in comparison to other member states. According to official data, the efforts made by all stakeholders thus far remain unnecessarily heavy and cumbersome compared to the added value they bring.

References

- Abdulwakil, M.M., Abdul-Rahim, A.S., Alsaleh, M., 2020. Bioenergy efficiency change and its determinants in EU-28 region: Evidence using least square dummy variable corrected estimation. *Biomass. Bioenerg.* 137, 105569. <https://doi.org/10.1016/j.biombioe.2020.105569>
- Agovino, M., Casaccia, M., Crociata, A., Sacco, P.L., 2019. European Regional Development Fund and pro-environmental behaviour. The case of Italian separate waste collection. *Socio Econ Plan Sci* 65, 36–50. <https://doi.org/10.1016/j.seps.2018.02.001>
- Andersson, A., Höjgård, S., Rabinowicz, E., 2017. Evaluation of results and adaptation of EU Rural Development Programmes, *Land Use Policy*, Volume 67, Pages 298–314. <https://doi.org/10.1016/j.landusepol.2017.05.002>
- Benczur, P. et al., 2017. Evaluating the effectiveness of the new EU bank regulatory framework: A farewell to bail-out? *Journal of Financial Stability* 33, 207–223. <https://doi.org/10.1016/j.jfs.2016.03.001>
- Bertoldi, P., Mosconi, R., 2020. Do energy efficiency policies save energy? A new approach based on energy policy indicators (in the EU Member States). *Energ Policy* 139, 111320. <https://doi.org/10.1016/j.enpol.2020.111320>
- Bostan, I. et al., 2019. The three-dimensional impact of the absorption effects of European funds on the competitiveness of the SMEs from the Danube Delta, *Ind Crop Prod* 132, 460–467. <https://doi.org/10.1016/j.indcrop.2019.02.053>
- Camaras, C., Kalahasthi, L.K., Rosado, L., 2020. Drivers and barriers to energy-efficient technologies (EETs) in EU residential buildings. *Energ Built Env* 3, 290–301. <https://doi.org/10.1016/j.enbenv.2020.08.002>
- Crescenzi, R., Di Cataldo, M., Giua, M., 2020. It's not about the money. EU funds, local opportunities, and Euroscepticism. *Reg Sci Urban Econ* 84, 103556. <https://doi.org/10.1016/j.regsciurbeco.2020.103556>
- Cunico, G., Aivazidou, E., Mollona, E., 2021. Building a dynamic theory of citizens' awareness of European Cohesion Policy interventions. *Eur J Oper Res* 289, 758–773. <https://doi.org/10.1016/j.ejor.2020.07.017>
- Dicharry, B., Nguyen-Van, P., Pham, T. K. C., 2019, 'The winner takes it all' or a story of the optimal allocation of the European Cohesion Fund, *Eur J Polit Econ* 59, 385–399. <https://doi.org/10.1016/j.ejpoleco.2019.05.003>
- Economidou, M. et al., 2020. Review of 50 years of EU energy efficiency policies for buildings. *Energ Buildings*. 225, 110322. <https://doi.org/10.1016/j.enbuild.2020.110322>
- Expósito, A., Velasco, F., 2018. Municipal solid-waste recycling market and the European 2020 Horizon Strategy: A regional efficiency analysis in Spain. *J Clean Prod* 172, Pages 938–948. <https://doi.org/10.1016/j.jclepro.2017.10.221>
- Galluzzo, N., 2021, A quantitative analysis on Romanian rural areas, agritourism and the impacts of European Union's financial subsidies. *J Rural Stud* 82, 458–467. <https://doi.org/10.1016/j.jrurstud.2021.01.025>
- Gouveia, M.C., Henriques, C.O., Costa, P., 2021. Evaluating the efficiency of structural funds: An application in the com-

- petitiveness of SMEs across different EU beneficiary regions. *Omega* 101, 102265. <https://doi.org/10.1016/j.omega.2020.102265>
- Guerrero-Pérez, M. O., Yeung, K. L., 2020. Erasmus Mundus EurasiaCat: A successful EU-Asian network for research in Materials Science and Catalysis. *Catal Today* 356, 37. <https://doi.org/10.1016/j.cattod.2020.07.006>
- Gutiérrez, E., Lozano, S., Guillén, J., 2020. Efficiency data analysis in EU aquaculture production. *Aquaculture* 520, 734962. <https://doi.org/10.1016/j.aquaculture.2020.734962>
- Landwehr, S.C., Hartmann, M., 2020. Industry self-regulation of food advertisement to children: Compliance versus effectiveness of the EU Pledge. *Food Policy* 91, 101833. <https://doi.org/10.1016/j.foodpol.2020.101833>
- Löschel, A., Lutz, B.J., Managi, S., 2019. The impacts of the EU ETS on efficiency and economic performance – An empirical analyses for German manufacturing firms. *Resour Energy Econ* 56, 71–95. <https://doi.org/10.1016/j.reseneeco.2018.03.001>
- Malinauskaite, J. et al., 2020. Energy efficiency in the industrial sector in the EU, Slovenia and Spain. *Energy*, 208, 118398. <https://doi.org/10.1016/j.energy.2020.118398>
- Malinauskaite, J. et al., 2019. Energy efficiency in industry: EU and national policies in Italy and the UK. *Energy* 172, 255–269. <https://doi.org/10.1016/j.energy.2019.01.130>
- Mina, A. et al., 2021, Public funding of innovation: Exploring applications and allocations of the European SME Instrument. *Res Policy* 50, 104131. <https://doi.org/10.1016/j.respol.2020.104131>
- Nieuwesteeg, B., Faure, M., 2018. An analysis of the effectiveness of the EU data breach notification obligation. *Comput Law Sec Rev* 34, 1232–1246. <https://doi.org/10.1016/j.clsr.2018.05.026>
- Pais-Magalhaes, V., Moutinho, V., Robaina, M., 2020. Determinants of the household electricity consumption efficiency of an ageing population: Evidence for the EU-28. *Energy Reports*, 6, 415–422, in: *Proceedings of the 7th International Conference on Energy and Environment Research*. <https://doi.org/10.1016/j.egy.2020.11.193>
- Pajewski, T., Malak-Rawlikowska, A., Gołębiewska, B., 2020. Measuring regional diversification of environmental externalities in agriculture and the effectiveness of their reduction by EU agri-environmental programs in Poland. *J Clean Prod* 276, 123013. <https://doi.org/10.1016/j.jclepro.2020.123013>
- Pelucha, M., Kveton, V., Potluka, O., 2019, Using mixed method approach in measuring effects of training in firms: Case study of the European Social Fund support. *Eval Program Plann* 73, 146–155. <https://doi.org/10.1016/j.evalprogplan.2018.12.008>
- Pisani, E., Andriollo, E., Masiero, M., Secco, L., 2020. Intermediary organisations in collaborative environmental governance: Evidence of the EU-funded LIFE sub-programme for the environment (LIFE-ENV). *Heliyon* 6, e04251. <https://doi.org/10.1016/j.heliyon.2020.e04251>
- Strapasson, A. et al., 2020. EU land use futures: Modelling food, bioenergy and carbon dynamics. *Energy Strategy Reviews* 31, 100545. <https://doi.org/10.1016/j.esr.2020.100545>
- Teichmann, F., Falker, M.C., Sergi, B.S., 2020. Gaming environmental governance? Bribery, abuse of subsidies, and corruption in European Union Programs. *Energy Research & Social Science* 66, 101481. <https://doi.org/10.1016/j.erss.2020.101481>
- Toma, P. et al., 2017. A non-parametric bootstrap-data envelopment analysis approach for environmental policy planning and management of agricultural efficiency in EU countries. *Ecol Indic* 83, 132–143. <https://doi.org/10.1016/j.ecolind.2017.07.049>
- Wuijts, S. et al., 2021. Protection of drinking water resources from agricultural pressures: Effectiveness of EU regulations in the context of local realities. *J Environ Manage* 287, 112270. <https://doi.org/10.1016/j.jenvman.2021.112270>

СПИСОК ИСТОЧНИКОВ

- Abdulwakil, M.M., Abdul-Rahim, A.S., Alsaleh, M., 2020. Bioenergy efficiency change and its determinants in EU-28 region: Evidence using least square dummy variable corrected estimation. *Biomass. Bioenerg.* 137, 105569. <https://doi.org/10.1016/j.biombioe.2020.105569>
- Agovino, M., Casaccia, M., Crociata, A., Sacco, P.L., 2019. European Regional Development Fund and pro-environmental behaviour. The case of Italian separate waste collection. *Socio Econ Plan Sci* 65, 36–50. <https://doi.org/10.1016/j.seps.2018.02.001>
- Andersson, A., Höjgård, S., Rabinowicz, E., 2017. Evaluation of results and adaptation of EU Rural Development Programmes, *Land Use Policy*, Volume 67, Pages 298–314. <https://doi.org/10.1016/j.landusepol.2017.05.002>
- Benczur, P. et al., 2017. Evaluating the effectiveness of the new EU bank regulatory framework: A farewell to bail-out? *Journal of Financial Stability* 33, 207–223. <https://doi.org/10.1016/j.jfs.2016.03.001>
- Bertoldi, P., Mosconi, R., 2020. Do energy efficiency policies save energy? A new approach based on energy policy indicators (in the EU Member States). *Energy Policy* 139, 111320. <https://doi.org/10.1016/j.enpol.2020.111320>
- Bostan, I. et al., 2019. The three-dimensional impact of the absorption effects of European funds on the competitiveness of the SMEs from the Danube Delta, *Ind Crop Prod* 132, 460–467. <https://doi.org/10.1016/j.indcrop.2019.02.053>
- Camaras, C., Kalahasthi, L.K., Rosado, L., 2020. Drivers and barriers to energy-efficient technologies (EETs) in EU residential buildings. *Energy Built Env* 3, 290–301. <https://doi.org/10.1016/j.enbenv.2020.08.002>
- Crescenzi, R., Di Cataldo, M., Giua, M., 2020. It's not about the money. EU funds, local opportunities, and Euroscepticism. *Reg Sci Urban Econ* 84, 103556. <https://doi.org/10.1016/j.regsciurbeco.2020.103556>
- Cunico, G., Aivazidou, E., Mollona, E., 2021. Building a dynamic theory of citizens' awareness of European Cohesion Policy interventions. *Eur J Oper Res* 289, 758–773. <https://doi.org/10.1016/j.ejor.2020.07.017>

- Dicharry, B., Nguyen-Van, P., Pham, T. K. C., 2019, 'The winner takes it all' or a story of the optimal allocation of the European Cohesion Fund, *Eur J Polit Econ* 59, 385–399. <https://doi.org/10.1016/j.ejpoleco.2019.05.003>
- Economidou, M. et al., 2020. Review of 50 years of EU energy efficiency policies for buildings. *Energ Buildings*. 225, 110322. <https://doi.org/10.1016/j.enbuild.2020.110322>
- Expósito, A., Velasco, F., 2018. Municipal solid-waste recycling market and the European 2020 Horizon Strategy: A regional efficiency analysis in Spain. *J Clean Prod* 172, Pages 938–948. <https://doi.org/10.1016/j.jclepro.2017.10.221>
- Galluzzo, N., 2021, A quantitative analysis on Romanian rural areas, agritourism and the impacts of European Union's financial subsidies. *J Rural Stud* 82, 458–467. <https://doi.org/10.1016/j.jrurstud.2021.01.025>
- Gouveia, M.C., Henriques, C.O., Costa, P., 2021. Evaluating the efficiency of structural funds: An application in the competitiveness of SMEs across different EU beneficiary regions. *Omega* 101, 102265. <https://doi.org/10.1016/j.omega.2020.102265>
- Guerrero-Pérez, M. O., Yeung, K. L., 2020. Erasmus Mundus EurasiaCat: A successful EU-Asian network for research in Materials Science and Catalysis. *Catal Today* 356, 37. <https://doi.org/10.1016/j.cattod.2020.07.006>
- Gutiérrez, E., Lozano, S., Guillén, J., 2020. Efficiency data analysis in EU aquaculture production. *Aquaculture* 520, 734962. <https://doi.org/10.1016/j.aquaculture.2020.734962>
- Landwehr, S.C., Hartmann, M., 2020. Industry self-regulation of food advertisement to children: Compliance versus effectiveness of the EU Pledge. *Food Policy* 91, 101833. <https://doi.org/10.1016/j.foodpol.2020.101833>
- Löschel, A., Lutz, B.J., Managi, S., 2019. The impacts of the EU ETS on efficiency and economic performance – An empirical analyses for German manufacturing firms. *Resour Energy Econ* 56, 71–95. <https://doi.org/10.1016/j.reseneeco.2018.03.001>
- Malinauskaite, J. et al., 2020. Energy efficiency in the industrial sector in the EU, Slovenia and Spain. *Energy*, 208, 118398. <https://doi.org/10.1016/j.energy.2020.118398>
- Malinauskaite, J. et al., 2019. Energy efficiency in industry: EU and national policies in Italy and the UK. *Energy* 172, 255–269. <https://doi.org/10.1016/j.energy.2019.01.130>
- Mina, A. et al., 2021, Public funding of innovation: Exploring applications and allocations of the European SME Instrument. *Res Policy* 50, 104131. <https://doi.org/10.1016/j.respol.2020.104131>
- Nieuwesteeg, B., Faure, M., 2018. An analysis of the effectiveness of the EU data breach notification obligation. *Comput Law Sec Rev* 34, 1232–1246. <https://doi.org/10.1016/j.clsr.2018.05.026>
- Pais-Magalhaes, V., Moutinho, V., Robaina, M., 2020. Determinants of the household electricity consumption efficiency of an ageing population: Evidence for the EU-28. *Energy Reports*, 6, 415–422, in: *Proceedings of the 7th International Conference on Energy and Environment Research*. <https://doi.org/10.1016/j.egy.2020.11.193>
- Pajewski, T., Malak-Rawlikowska, A., Gołębiewska, B., 2020. Measuring regional diversification of environmental externalities in agriculture and the effectiveness of their reduction by EU agri-environmental programs in Poland. *J Clean Prod* 276, 123013. <https://doi.org/10.1016/j.jclepro.2020.123013>
- Pelucha, M., Kveton, V., Potluka, O., 2019, Using mixed method approach in measuring effects of training in firms: Case study of the European Social Fund support. *Eval Program Plann* 73, 146–155. <https://doi.org/10.1016/j.evalprogplan.2018.12.008>
- Pisani, E., Andriollo, E., Masiero, M., Secco, L., 2020. Intermediary organisations in collaborative environmental governance: Evidence of the EU-funded LIFE sub-programme for the environment (LIFE-ENV). *Heliyon* 6, e04251. <https://doi.org/10.1016/j.heliyon.2020.e04251>
- Strapasson, A. et al., 2020. EU land use futures: Modelling food, bioenergy and carbon dynamics. *Energy Strategy Reviews* 31, 100545. <https://doi.org/10.1016/j.esr.2020.100545>
- Teichmann, F., Falker, M.C., Sergi, B.S., 2020. Gaming environmental governance? Bribery, abuse of subsidies, and corruption in European Union Programs. *Energy Research & Social Science* 66, 101481. <https://doi.org/10.1016/j.erss.2020.101481>
- Toma, P. et al., 2017. A non-parametric bootstrap-data envelopment analysis approach for environmental policy planning and management of agricultural efficiency in EU countries. *Ecol Indic* 83, 132–143. <https://doi.org/10.1016/j.ecolind.2017.07.049>
- Wuijts, S. et al., 2021. Protection of drinking water resources from agricultural pressures: Effectiveness of EU regulations in the context of local realities. *J Environ Manage* 287, 112270. <https://doi.org/10.1016/j.jenvman.2021.112270>

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Research article**DOI:** <https://doi.org/10.48554/SDEE.2022.1.5>**DIGITAL INEQUALITY OF RUSSIAN REGIONS**Olga Yanovskaya¹, Natalya Kulagina^{2*}, Natalya Logacheva²¹International Academy of Sciences ‘Eurasia’, Nursultan, Republic of Kazakhstan, yanovskaya_o@mail.ru²Bryansk State University of Engineering and Technology, Russia, kulaginana2013@yandex.ru, logacheva_natali@inbox.ru

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Abstract

Digitalisation processes are sources of the active growth of national economies. They provide competitive advantages and protect national priorities in the long and short term. Their pace is rapidly accelerating, as new ways of collecting, processing and transmitting big data are emerging based on the ‘digital traces’ left by information during its use. This leads to the need to develop tools for the qualitative assessment of digital transformation processes to justify management decisions and improve project management. Therefore, the purpose of this article is to develop theoretical and methodological provisions and practical recommendations for assessing trends in the processes of digitalisation to subsequently conduct an inter-regional analysis, identify the causes of digital inequality and find ways for their elimination based on general and particular scientific methods: comparative and statistical analysis, methods of comprehensive assessment and ranking of statistical information reflecting the efficiency of digitalisation processes. The authors developed their own approach to assessing the efficiency of digital transformation processes at the regional level. A distinctive feature of the methodology proposed is the inclusion of indicators that reflect the development of the digital infrastructure, use of digital technology, personnel availability and innovation activity, which are integrated into three indices and eventually form an additive model for the comprehensive assessment of the digitalisation processes taking place in the region. This methodological approach was tested to assess the digital transformation processes taking place in the regions in the Central Federal District of Russia. The regions were grouped according to the level of their digital development. The results of the study allowed us to identify six groups of regions and draw the conclusion that there is a problem of digital inequality despite similar economic conditions and potential. To improve the methodological tools, we suggest using methods of expert evaluation and introducing significance ranks for the selected indices. This is the basis for improving regional strategies, adjusting the targets of regional projects carried out within the Digital Economy Programme and searching for options for effective interaction between all parties operating in the digital ecosystem so that the economy and its competitiveness could grow.

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ЦИФРОВОЕ НЕРАВЕНСТВО РОССИЙСКИХ РЕГИОНОВ

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Аннотация

Процессы цифровизации представляют собой источники активного роста экономик стран, обеспечивают их конкурентные преимущества и защиту национальных приоритетов в позиции, как долгосрочной, так и краткосрочной перспективы. Темпы ее стремительно ускоряются, так как появляются новые способы сбора, обработки и передачи больших данных на основе «цифровых следов», которые оставляет информация при ее использовании. Это приводит к необходимости разработки инструментария качественной оценки процессов цифровой трансформации для обоснования управленческих решений и совершенствования проектного менеджмента. Поэтому целью данной статьи является разработка теоретико-методологических положений и практических рекомендаций по оценке тенденций процессов цифровизации с целью последующего проведения межрегионального анализа для выявления причин цифрового неравенства и поиска резервов их устранения. На основе общенаучных методов, частных научных методов: сравнительного, статистического анализа, методов комплексной и рейтинговой оценки и статистической информации, отражающей результативность процессов цифровизации, разработан авторский подход к оценке эффективности процессов цифровой трансформации на региональном уровне. Отличительной особенностью предлагаемой методики является учет показателей, отражающих развитие цифровой инфраструктуры и использование цифровых технологий, кадровое обеспечение, инновационную активность, которые интегрируются в три индекса и в итоге формируют аддитивную модель комплексной оценки процессов цифровизации региона. В результате апробации разработанного методического подхода была проведена оценка процессам цифровой трансформации регионов, входящих в состав Центрального федерального округа России, а в последствии выделены группы регионов по уровню цифрового развития. Результаты исследования позволили выделить шесть групп регионов, что позволило сделать вывод о существующей проблеме цифрового неравенства при схожих условиях хозяйствования и имеющемся потенциале.

Ключевые слова: регион, цифровое неравенство, цифровая трансформация, цифровые технологии, цифровое развитие, цифровизация

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1. Introduction

On the one hand, the active processes of digital transformation occurring over the last 20 years around the world stimulate the growth of economies in various countries, but on the other hand, bring the problem of digital inequality to a new level, making it common for individual countries, regions and sectors. This means that some countries are increasingly lagging behind due to the immaturity of their digital infrastructure and a myriad of problems caused by many demographic, political, social, economic, technological and environmental factors.

In the context of global development, every country faces the challenge of digital inequality, which can be removed either in a natural way or by drawing on substantial external resources. However, for an adequate assessment of the possibilities for reducing digital inequality, one must have a suitable set of methodical and methodological tools, since the result of digitalisation processes should be considered as various effects rather than as total investments. For this reason, if elements such as the current level of digital inequality, the amounts of financial resources allocated for digitalisation processes and the effects obtained are compared with each other, can provide opportunities for improving federal and regional programmes, changing the strategic development priorities, and, consequently, systematising the resources for increasing competitiveness and reducing the differentiation of digital development.

The matters of reducing the digital divide correlate with the matters of adequate assessment of its acceptable level, the problems of preserving human capital and using it efficiently, the development of an information society and digital infrastructure, insurance of digital maturity and improvement of the general state policy, all of which can help to reduce the influence of various barriers on the way to digital transformation.

Since the late 1990s, many works have touched upon the problem of growing digital inequality. In particular, Attewell¹, Norris², DiMaggio, Hargittai³, Van Deursen and Van Dijk⁴ discuss unequal access to knowledge, the possibilities of knowledge using via the Internet, the technologies and specifics of their application due to the social stratification of society, etc.

The digital divide is a complex and dynamic phenomenon, while social stratification, which is observed in unequal access to the Internet, is blamed by Safiullin and Moiseeva is its underlying cause (Safiullin, 2019).

Scientific interest in the problems of the digital development of society has led to the emergence of a theory of three levels of the digital divide, including the following major components:

- 1) The level of access to the Internet and Information Computer Technology (ICT);
- 2) The level of digital competence of the users and their digital literacy;
- 3) The level of social advantages the users obtain if digital technology is used properly and to a sufficient extent in their professional and private lives (Gladkova, 2019).

The concept of the digital divide makes us look for an interdisciplinary approach to reducing this issue. In their studies, an increasing number of researchers and experts stop to associate the problems of the digital divide with geographic factors, but instead focus on social aspects. In particular, Hargittai points out that one of the causes of the digital divide is that users have quite different competences in

¹Attewell, P., 2001. The first and second digital divides. *Sociology of Education*. 74, 252–259.

²Norris, P., 2001. *The Digital Divide: Civic Engagement, Information Poverty, and the Internet Worldwide*. Cambridge, UK: Cambridge University Press.

³DiMaggio, P., Hargittai, E., 2001. From the ‘digital divide’ to ‘digital in-equality’: Studying Internet use as penetration increases. Princeton University. Working papers series. Available at: <https://www.princeton.edu/~artspol/work-pap/WP15%20-%20DiMaggio%2BHargittai.pdf> (

⁴Van Deursen, A., Van Dijk, J., 2014. The digital divide shifts to differences in usage. *New Media and Society*. 16, 507–526. DOI: <https://doi.org/10.1177/1461444813487959>

working in a digital environment.⁵

Scientific research more and more frequently discusses the fact that in the case of equal access to digital technologies, well-developed digital infrastructure and connections in a digital ecosystem, a different effect, performance and social advantages can be reached. All of this is considered in the works by Ragnedda (2018), Einav, Levin,⁶ Varian⁷, Haber, Stornetta⁸, Golovina, Polyenin, Adamenko, Khegay and Schepinin (2020).

The causes of digital inequality cannot be investigated without researching how the tools of Industry 4.0 (Big Data, Internet of Things, machine learning, artificial intelligence, etc.) affect the level of socio-economic development of individual countries and regions in terms of access to modern end-to-end technologies and their use for improving the standard and quality of living. These important aspects are discussed in the studies by researchers such as Babkin, Burkaltseva, Kosten (2017) Vorobyev, Pshenichnicov, Tyulin (2017), Barefoot, Curtis, Jolliff, Nicholson, Omonhundo (2018), Bukht and Heeks (2017).

One controversial issue is the choice of a system of indicators for making quantitative comparisons within the world community, individual countries, regions, sectors and entities based on widely available statistics. When selected, the indicators must ensure the possibility of evaluating various groups of factors that influence the mechanism of economic management, as well as forms and methods for regulating digitalisation processes (Norman⁹, Mulgan¹⁰, Brynjolfsson, McAfee, Spence¹¹).

Russia saw the beginning of active digitalisation processes in 2017, when the most important laws and regulations were introduced, laying the foundation for the digital transformation of the economy (Digital Economy of the Russian Federation Program, 2017–2030 Strategy for Developing Information Society in the Russian Federation). This was the time when some federal measures were taken and President Putin emphasized the need for developing the potential of breakthrough technologies, tools for storing and protecting big amounts of information and practical introduction of smart solutions for better efficiency and competitiveness of economic entities at various levels.

According to research conducted by McKinsey, an international consulting company, Russia's projections about the contribution of digitalisation to the Gross Domestic Product (GDP) of the country by 2025 do not look that optimistic. The growth in the Russian GDP will amount to 4.1–8.9 trillion rubles, which is equal to 19–34% of the planned figures. The analytical report prepared by the experts says that to triple the share of the digital economy in Russia from 3.2 trillion rubles in 2015 to 9.6 trillion in 2025, the average yearly growth rate must be maintained at the level of 12%, which was observed in 2010–2015. This is equal to an increase in the share of the digital economy up to 8–10% of the GDP, which is inherent in the countries leading the world market.¹²

One of Russia's strategic short-term goals is to ensure that it is one of the world's leading economic systems, which is hardly possible without reducing the range of digital inequality and finding additional tools for achieving competitiveness.

There is a need for a comprehensive assessment of the digitalisation processes taking place in regional economic systems. The results obtained can be the basis for improving the programmes of digital development in the country, aimed at reducing the differences in digital development between various

⁵Hargittai, E., 2002. Second Level Digital Divide: Differences in People's Online Skills. *First Monday*. 7, 4. Available at: <https://firstmonday.org/article/view/942/864> (accessed: 17.06.2019)

⁶Einav, L., Levin, J., 2014. Economics in the age of big data, *Science*346, pp. 715–721.

⁷Varian, H.R., 2014. Big data: new tricks for econometrics. *Journal of Economic Perspectives*. 28, 8.

⁸Haber, S., Stornetta, S., 1991. How to time stamp digital document. *Lecture Notes in Computer Science*. 537, 437–455.

⁹Norman, A.C., 1993. *Information Society: An Economic Theory of Discovery, Invention and Innovation*. Boston, Kluwer Academic Publishers, 120.

¹⁰Mulgan, G.J., 1991. *Communications and Control: Networks and New Economies of Communication*. Oxford, Polity, 19.

¹¹Brynjolfsson, E., McAfee, E., Spence, M., 2014. *New world order. Labor, capital, and ideas in the power law economy*. *Foreign Affairs*. 93.

¹²McKinsey report. URL: <https://www.mckinsey.com/russia/our-insights/ru-ru>. (accessed: 18.03.2021).

regions. They can also be used to analyse the contribution of every individual region to the achievement of the target indicators, according to the federal digital economy project. Thus, the problem of digital inequality in the Russian regions calls for extensive theoretical research, scientific evidence and more sophisticated tools for developing practical solutions.

2. Literature review

Digitalisation processes penetrating the global socio-economic environment make the development trajectories of economic systems evolve. These processes contribute to the transformation of public administration and the adaptation of business models towards the challenges the digital economy faces today. This leads to a modification of the traditional forms of relationships and their principles, a transformation of behavioural strategies and, despite obvious advantages, the problem of digital inequality.

To study the problems of inequality in various social groups, territories and countries in terms of digital technology tools, as early as 1997, the UNO coined a new term—information poverty. It includes a few characteristics: financial, technical, educational, preparatory, cultural, demographic and linguistic.¹³

In the early 2000s, the Organization for Economic Cooperation and Development coined the term ‘digital divide’, which refers to ‘the gap between individuals, households, businesses and geographic areas at different socio-economic levels with regard both to their opportunities to access information and communication technologies (ICT) and to their use of the Internet for a wide variety of activities’¹⁴.

Starting from the 2000s, matters concerning the evaluation of global digital inequality were considered primarily in terms of the geographic aspect and in relation to the unequal access to the Internet and digital technologies. This was the basis for referring countries to either being informationally rich or informationally poor.

Further research into the problem of digital inequality was based on a simulation of numerous factors that correlate strategy and policy at all levels of management. For example, 2001 witnessed the appearance of the ‘income – infrastructure – human capital – policy’ model. The calculations made with this model show that the key factors of the digital divide are the level of income, the quality of regulation and the competitiveness of the telecommunication market.

The differences in the level of economic, social and political development of individual countries, as well as the state policy, are some of the most important premises for them being essentially differentiated in terms of the availability of up-to-date ICT and digital tools used by the people, as noted by Ragnedda and Muschert in their study.¹⁵

The digital divide as a form of digital inequality can be assessed in a comprehensive way based on an analysis of technological, social and economic aspects. The existing approaches to studying these problems vary in terms of the determinants they rely on for evaluating, to a certain degree, the digitalisation processes occurring in the society and the end-to-end digital technologies being used.

For example, the Intelligence Unit of *the Economist* considers the Internet coverage in 100 countries, as it is an essential condition of digitalisation. The Inclusive Internet Index suggested for calculation includes the production of four sub-indices: availability, affordability, relevance and readiness¹⁶.

The International Telecommunication Union suggests that the development characteristics of the ICT infrastructure and demand for ICT be used as the resulting indicators of digital transformation. The

¹³Digital inequality. Science and life [Electronic resource]. URL: <http://www.nkj.ru/archive/articles/6053/> (accessed: 30.03.2021)

¹⁴Understanding the digital divide. OECD. 2001. URL: <http://www.oecd.org/internet/ieconomy/1888451.pdf> (Date of retrieval: 30.03.2021).

¹⁵Ragnedda, M., Muschert, G.W., (eds.) 2013. *The Digital Divide: The Internet and Social Inequality in International Perspective*. New York, NY: Routledge.

¹⁶The Inclusive Internet Index 2020, <https://theinclusiveinternet.eiu.com/explore/countries/performance>.

ICT Development Index includes the calculation of 11 indicators grouped into subsystems: ICT access, ICT use and ICT skills¹⁷.

In terms of the evaluation of the obligations imposed on the International Telecommunication Union (ITU) member states, the Global Cybersecurity Index considers the processes of digitalisation. When calculating its integrated indicator, the ITU considers five sub-indices: legal aspects of cybersecurity (legal), technical aspects of cybersecurity (technical), organisational aspects of cybersecurity (organisational), the skills of a country to build a cybersecurity system (capacity building) and international cooperation in the field of cybersecurity (cooperation)¹⁸.

The opportunities of various countries for carrying on e-commerce in the business-to-customer segment underlie an approach suggested by United Nations Conference on Trade and Development, (UNCTAD) via the B2C E-Commerce Index. The comprehensive assessment uses an integrated indicator obtained from the average mean of four indicators: the share of individuals using the Internet, the share of individuals aged 15 or older having a bank account, the number of secure internet servers per 1 million people and the integrated index 'UPU Postal Reliability Score'¹⁹.

The methodological approach of the European Commission implies calculating 31 indicators that are grouped into five areas: communications (landline broadband access, mobile broadband access, speed of the Internet and cost), human capital (basic skills and communications, long-term opportunities), use of the Internet (content, communications and transactions), integration of digital technology (e-business and e-commerce) and public digital services (e-government). The result of the comprehensive assessment is the Digital Economy and Society Index²⁰.

Bhaskara Chakravorty and Ravi Shankara Chaturvedi, researchers from the Fletcher School at Tufts University, suggested using the Digital Evolution Index to assess the maturity of the digital economy, given a country's involvement in international digital trade. The specifics of their approach is that the final indicator is calculated based on the analysis of trends in 170 indicators, which are systematised into four sub-indices: supply conditions, demand conditions, institutional environment, innovation and change. The results of their studies in 60 countries worldwide allowed them to make up a map called the 'Digital Planet' and define four trajectory zones: Watch Out countries, Break Out countries, Stand Out countries, and Stall Out countries²¹.

The Network Readiness Index (NRI), developed by the Portulans Institute and the World Information Technology and Services Alliance (WITSA), can be used to evaluate the development of digital technology and its impact on the economic growth of a country. It includes 62 indicators. Each indicator refers to a certain group of sub-indices: technology, people, governance and impact, whose comprehensive assessment is made based on the arithmetic mean²².

The International Institute for Management Development (IMD) compiles the World Digital Competitiveness Ranking, which is based on evaluating the countries in terms of the intensity of development and practical use of digital technology, leading to the transformation of public administration, business models and society. The final index, which is used for ranking the countries, consists of three sub-indices: knowledge, technology and future readiness. Fifty-one analytical indicators were used to calculate them²³. The Institute for Information Society Development and the Ministry of Communications and

¹⁷Measuring the Information Society Report 2017 http://www.itu.int/en/ITU-D/Statistics/Documents/publications/misr2017/MISR2017_Volume1.pdf.

¹⁸Global Cybersecurity Index (CGI) 2018': https://www.itu.int/dms_pub/itu-d/opb/str/D-STR-GCI.01-2018-PDF-E.pdf

¹⁹https://unctad.org/en/PublicationsLibrary/tn_unctad_ict4d14_en.pdf.

²⁰The Digital Economy and Society Index (DESI). Final Report. European Commission. <https://ec.europa.eu/digital-single-market/en/desi>

²¹Global Cybersecurity Index (CGI) 2018'. https://www.itu.int/dms_pub/itu-d/opb/str/D-STR-GCI.01-2018-PDF-E.pdf

²²<https://networkreadinessindex.org/wpcontent/uploads/2020/03/The-Network-Readiness-Index-2019-Newversion-March-2020-2.pdf>

²³<https://www.imd.org/wcc/world-competitivenesscenter-rankings/world-digital-competitiveness-rankings-2019/>

Mass Media²⁴ elaborated a methodology for forming the rankings of the constituent entities of the Russian Federation. It is based on an integral index measuring the development of the information society (including 15 sub-indices) and can be used for a comprehensive assessment of the factors affecting the evolution of the information society and the use of ICT for development.

The Center for Digital Technology Competence (Rosatom State Corporation), together with experts from research organisations, universities and businesses, suggested its own way to assess the digital divide in economic sectors that are analysed from the perspective of digital technologies used by enterprises according to OECD standards and are distinguished by the classifier of the types of economic activity. The methodological tools are based on the principle of a Russian doll; the total number of indicators used depends on the level of assessment. The method of distances from the reference values is used as a basis, and the procedure for normalising the initial data is applied in the calculations.²⁵

Stepanova, Ukhanova, Grigorishchin and Yakhyaev proposed an approach to differentiating the constituent entities of the Russian Federation based on two integral indices that consider the digital activity of the population, organisations and the digitalisation of the state: the Digitalization Index of the region (Id), which defines the digital activity of the subjects of an ecosystem, and the Digitalization Conditions Index of the region (Idc), based on which the digital ecosystems of Russian regions are evaluated. A matrix analysis based on the k-maximum method represents a procedure for reducing a given number of observations to several groups with similar characteristics. Since the indicators selected for evaluating digital ecosystems are stimulating indicators (the higher their value, the better), then the maximum value of the x variable (indicator) acts as k (Maksimova, 2019).

Based on the adapted ICT Development Index (IDI), Karyshev built his own statistical method for evaluating digital inequality²⁶. The calculations rely on three blocks of indicators, while the resulting index and sub-indices are measured using an arithmetical mean formula, whose weights are determined based on the implicit logic of the experts in each case:

- 1 block: Core indicators of the use of ICT by businesses (12 indicators)
- 2 block: Core indicators for the ICT sector (2 indicators)
- 3 block: Core indicators on trade in ICT goods.

Gladkova, Garifullin and Ragnedda Massimo built their methodological approach on the three-levelled theory of digital inequality. According to the authors, the theory allows for more detailed studies of the digital divide, as it investigates the social prerequisites for digital inequality. A system of indicators is suggested in the context of each level.

For example, the first level of digital inequality characterises the following indicators: data on the total number of internet users (broadband, mobile Internet), the number of internet subscribers, the number of households having access to the Internet, the degree of internet coverage, mobile radiotelephone (cellular) communication coverage, the average internet access cost, the average internet connection speed, and the type and quantity of devices with internet connection.

The indicators determining the qualitative characteristic of the second level of digital inequality are as follows: the data on digital literacy/the level of digital competencies/users' skills, the level of internet openness of the region (applicable to Russia), the data on the motivation to use the Internet and ICT, given the users' socio-demographic characteristics, the practice of using the Internet, etc.

The indicators measuring the third level of digital inequality include data on the benefits of the

²⁴Methodology for assessing the advancement of the information society in the constituent entities of the Russian Federation/ The Institute for Development of Information Society; Ministry of Communications and Mass Media. https://d-russia.ru/wp-content/uploads/2016/04/methodika_otsenka_io.pdf

²⁵The National Index of Digital Economy Development: Pilot implementation. Public Corporation 'Rosatom', 2018.

²⁶Karyshev, M.Yu., 2011. The statistical method for measuring the digital economy: searching for an integral indicator. *Accounting and statistics*, 4, 74–82.

Internet and ICT, expressed, among other things, in the dynamics and specifics of the online services that are used, their adaptation to user requests, the work of e-government, various opportunities for users' professional self-realisation, etc. (Gladkova, 2019).

A special feature of the approach proposed by Safiullina, Abdukaeva and Elshina is the possibility of identifying indicators according to the profiles of federal (regional) projects. To perform calculations, the entire array of the source information must be divided into five groups of sub-indices: personnel and education (three calculated indicators), research competencies and technical capacities (three calculated indicators), information infrastructure (seven calculated indicators), information security (two calculated indicators) and legal regulation (analysis of information from websites). The index method of analytical information aggregation and ordering is used, with the initial data normalised (Kuzovkova, 2019).

A complex system of integral, generalising and partial indicators that take into account the maturity of the economy and society was proposed by Kuzovkova, Salyutina and Kukhareenko (Dobrinskaya, 2019). In particular, the researchers highlighted an integral indicator of digital development at the stage of digitalization of operational and business processes, as well as management, production and consumption systems and structures; an integral indicator of digital development at the stage of digital transformation of the economy and society, and an integral indicator of digital development at the stage of formation of a single national digital space. The state of digital development is evaluated by objects and their rankings are compiled based on normalised values of private indicators, given the significance of individual and consolidated indicators.

The authors substantiated seven sub-indices and their weights, which can be used together with an additive model to obtain the resulting value of the Digitalisation Index for each constituent entity of the Russian Federation (RF):

1. Regulatory control and administrative indicators of digitalisation
2. Skilled personnel and training programmes
3. Availability and formation of research competencies and technological capacities, including the level of research and development
4. Information infrastructure
5. Information security
6. Economic indicators of digitalisation
7. Social effect from digitalisation.

According to the results of the calculations, two main causes of the digital divide were identified. They are the inequality in technological opportunities and insufficient digital skills and competencies²⁷.

As seen, each of the approaches to assessing the level of digital development of economic systems differs from the others in terms of the assessment indicators, description of individual effects from digital technologies, and characteristics of institutional aspects.

After analysing the foreign and national methodological approaches to assessing the level of digital transformation and finding ways to reduce the digital divide, it can be concluded that they can be used to a very limited extent, given the conditions in the Russian Federation. This is caused by the following circumstances:

- Today, the single bank of statistical information supported by Rosstat contains no information for carrying out research that details or draws objective conclusions about the current situation.

²⁷Digital Life of Russian Regions. What Does Digital Breakthrough Depend on? https://iems.skolkovo.ru/downloads/documents/SKOLKOVO_IEMS/Research_Reports/SKOLKOVO_IEMS_Research_Digital_life_of_russian_regions_2020-06-09_ru.pdf

- There are still discussions about which indicators should be prioritised.
- There is no clear separation of the indicators that characterise the trends of the digital economy and its efficiency in certain industries, sectors and levels of the economy.
- The dynamic processes of digitalisation and changes in the global market transform the requirements for legal regulation, digital infrastructure, cybersecurity, digital government and digital technologies. All of this calls for prompt adjustments in the methodological approaches for making adequate qualitative and quantitative assessments.
- Most of the methodologies proposed exclude the possibility of analysing and monitoring the indicators that are used, since the periods for providing economic systems by these constituent entities vary greatly.
- Additional studies into the characteristics of the regions must be conducted to consider the entire data provided. This implies that a separate system of indicators should be used for individual regions and should consider their development and potential.
- Due to the high labour intensity of the calculations, some indicators are ‘morally’ outdated and cannot fully reflect real digital transformation processes.
- The foreign methodological approaches do not consider the special features of individual countries, in particular, innovative, financial, investment potential and other components, as well as the most important social characteristics that lead to significant differentiation in the use of ICT.
- The existing national approaches to assessing the efficiency of the digital economy do not consider the indicators that reflect the possibilities of having highly qualified personnel and the innovative activity of the region, which, we believe, cannot be excluded from the integral assessment.
- Modern sources of information lack any common understanding of the terminology that characterises the digitalisation processes, which leads to different interpretations of the concepts and inconsistency in the systems of indicators that characterise them. This is typical of different levels of administration in various aspects.

3. Materials and methods

This study relies on a system approach, methods of ranking scores, expert evaluation, comprehensive assessment, comparison, standardization of indicators, induction and deduction and statistical analysis of data. The source information included statistics from official publications and the Rosstat website, data on trends in the digitalisation processes in the country and its individual regions from the ‘Digital Russia’ website²⁸, and the reports of the Analytical Center for the Government of the Russian Federation.

The digital differentiation of Russian regions is the result of inconsistent socio-economic policy and the uncertain contours of strategic development. Each region independently determines the priority areas of end-to-end digital technologies and the opportunities for them being used, given the state of the digital infrastructure and its developmental prospects.

For example, according to the 2019 data of the Analytical Center for the Government of the Russian Federation, 80% of all regions (altogether there were 79 respondent regions) called Big Data and wireless communication technologies their top priority (Figure 1)²⁹.

Considering the digital initiatives implemented in sectors, three leading segments should be distinguished: healthcare, comfortable urban environment and personnel for the digital economy (Figure 2).

²⁸<https://d-russia.ru/>

²⁹The Current Development of Projects in the Digital Economy in the Russian Regions. Analytical report. <https://ac.gov.ru/archive/files/publication/a/23243.pdf> (accessed: 16.03.2021).

The current situation in the regions is caused by numerous circumstances that influence the practical implementation of the projects aimed at the digitalisation of the economy, the use of end-to-end digital technologies and the state of the digital ecosystem, which creates the digital divide (Figure 3).

Obviously, the lack of qualified personnel capable of tackling the problems in digitalisation, plus the imperfect current legislation, are among the key factors hindering the digital transformation processes in the regions.

Moreover, these aspects are identical for almost all regions. Only three out of 70 constituent entities gave a positive answer about the absence of problems in the digitalisation projects they are implementing.

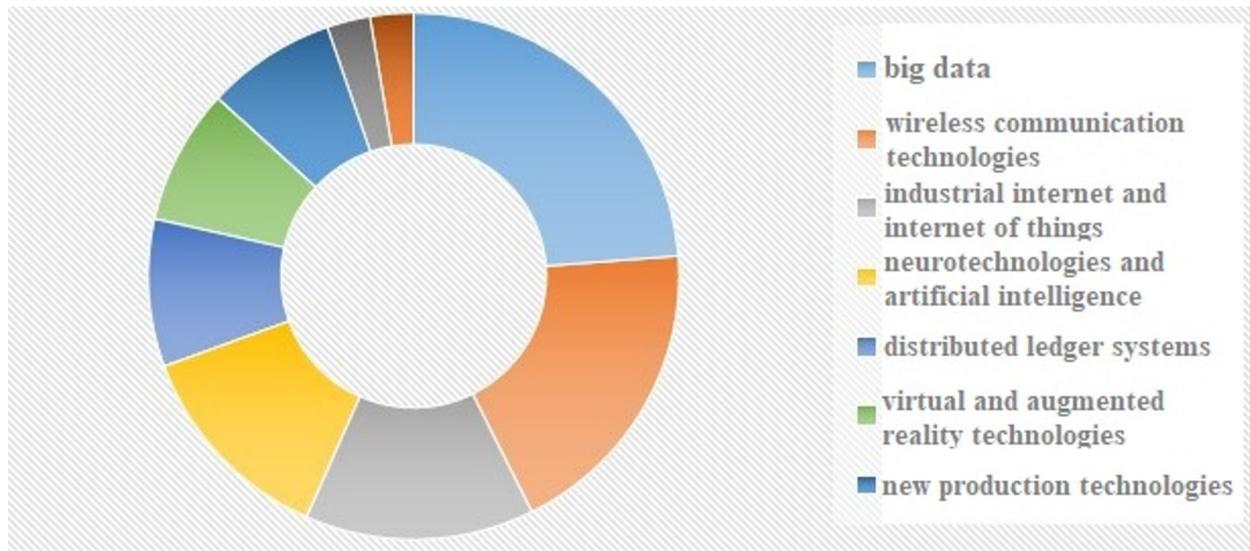


Figure 1. Priority end-to-end digital technologies in the regions of Russia according to 2019 data (Source: Analytical center for the results of a survey of regional executive authorities [ROIV]).

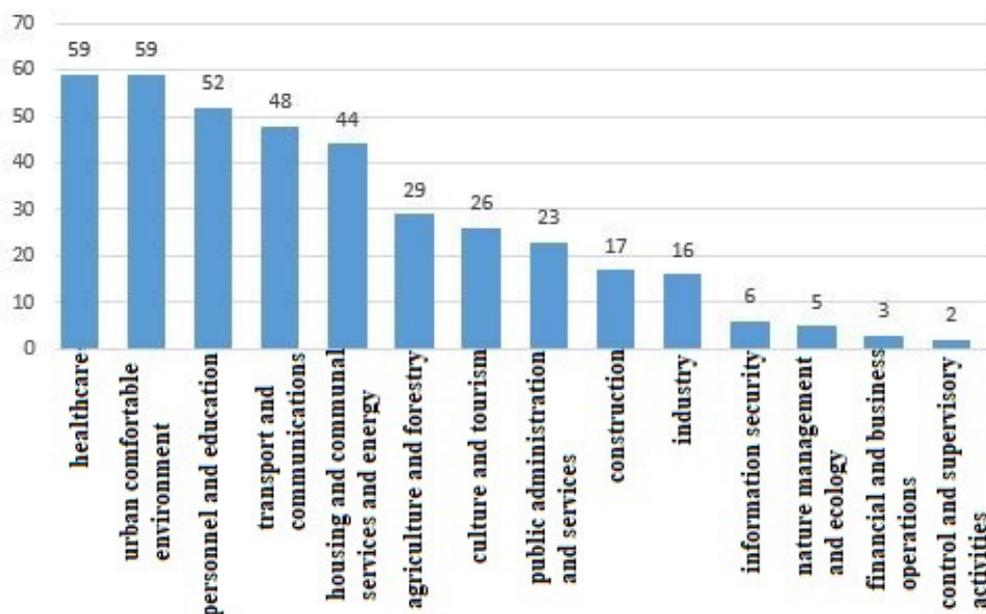


Figure 2. Priority sectors of digital transformation in the regions of Russia (according to 2019 data (Source: Analytical center for the results of a survey of regional executive authorities [ROIV]).

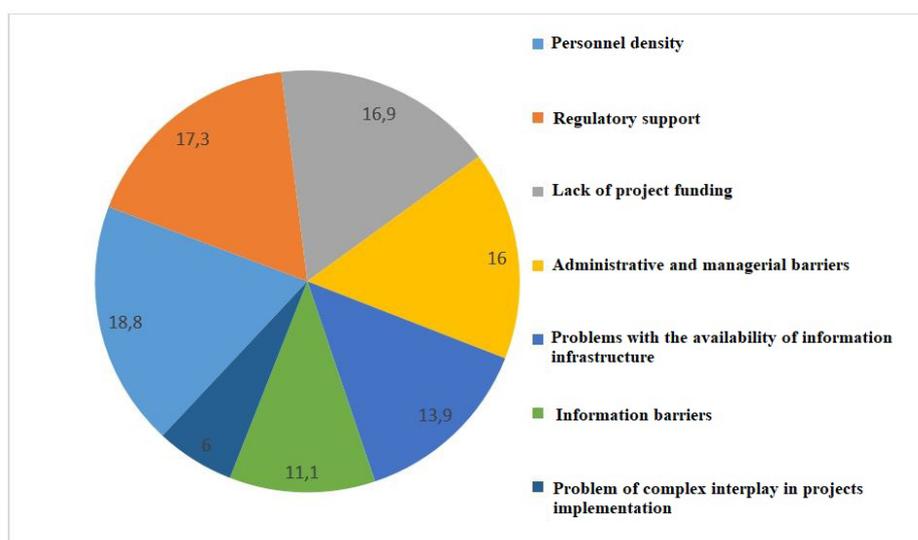


Figure 3. The structure of barriers to the digital transformation processes in the Russian regions, %, according to a survey of 70 regions for 2019. (Source: Analytical center for the results of a survey of regional executive authorities [ROIV])

Due to the above circumstances, a separate group of indicators had to be formed to analyse the current state of this problem and the possibility of its resolution within a region. Also, the experts' opinion was that the low level of digital culture is a significant barrier to the introduction of end-to-end digital technologies in different economic sectors and industries.

The digital transformation of Russian regions depends primarily on the ICT sector. Therefore, when a set of indicators is chosen for assessing the efficiency of digital transformation processes and identifying the digital divide, this group is the most important. This is because the digital divide can be reduced in the regions in case there are comprehensive programmes for developing information networks, improving the quality and access to digital services, introducing modern digital platforms and services, enhancing the functionality of the e-government, etc.

Active digital transformation processes mean that innovative activity increases due to fundamental and applied research and the growing number of personnel involved in research and development. As a result, there is a rise in the quantities of products, work and digital services, which is a qualitative characteristic and requires, in our opinion, special consideration (Ragnedda, 2018).

Thus, we propose an original approach to assessing digital transformation processes through an integrated criterion, which considers the current state of the digital infrastructure, personnel potential and innovative development. Figure 4 illustrates the decomposition of the algorithm presented.

We believe that the assessment mechanism can be used to control the digital transformation process in a region because of various changes aimed at reducing the digital divide and developing ways to increase digital activity.

The comprehensive assessment of the digitalisation processes in a regional economy (Kdt) can be represented as an additive dependence:

$$Kdt = IDI + Idp + Iia; \quad (1)$$

where IDI is the Digital Infrastructure and Technology Index;

Idp is the Personnel for Digital Economy Index;

Iia is the Innovative Activity Index.

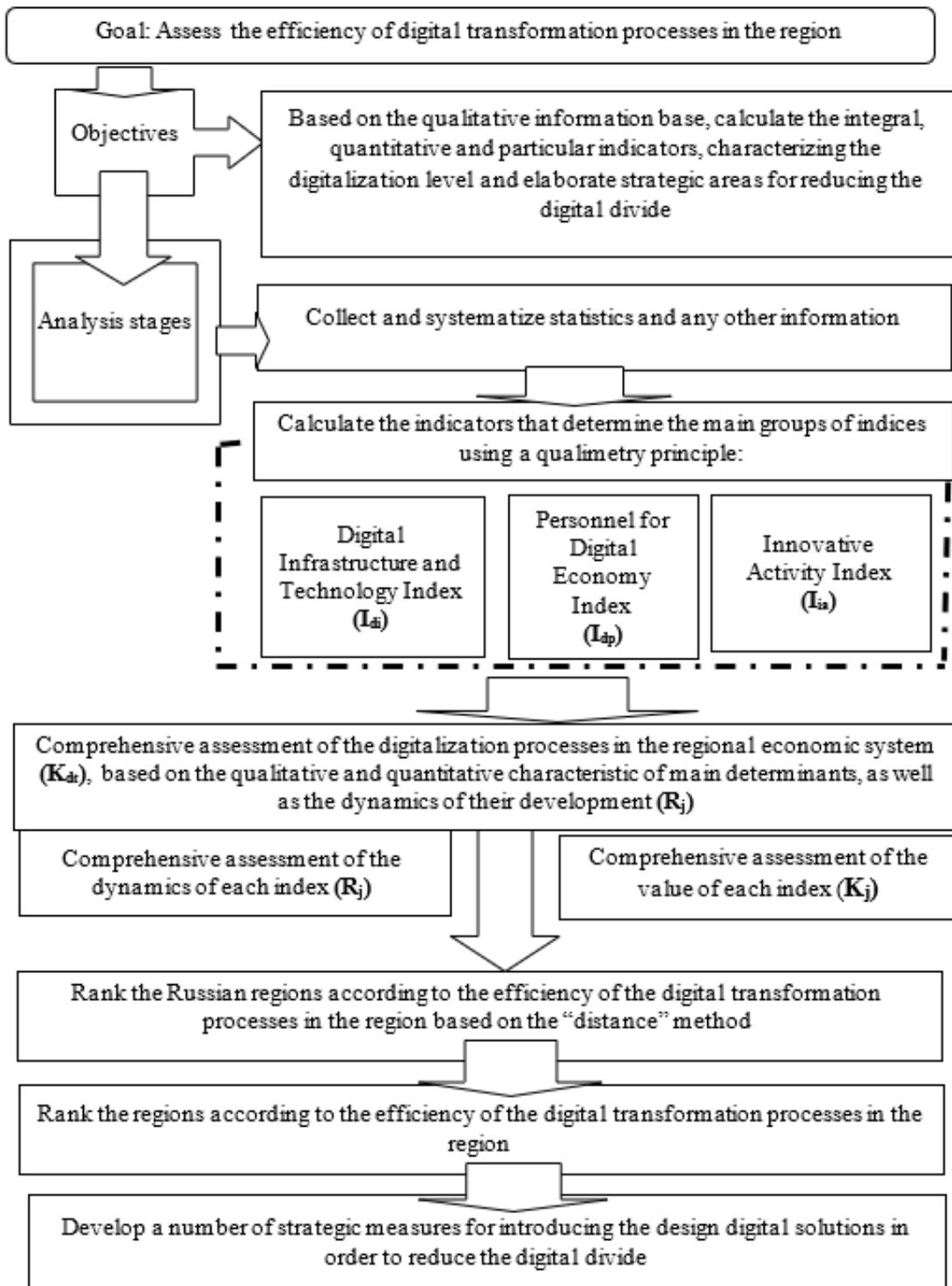


Figure 4. The authors’ approach to comprehensively assessing the efficiency of the digital transformation of a regional economic entity

Table 1 shows the system of qualitative and quantitative indicators to be calculated. It can be used to assess the level of digital inequality in the regions and to find reserves for reducing the imbalance in digital development.

Table 1. System of indicators for assessing the determinants that characterise the digital transformation of the regional economic system

Index	System of indicators for assessing the digital development determinants (F)
Digital Infrastructure and Technology Index (I _{DI})	Labour productivity in the economic sectors, %
	Share of digital products in the GRP, %
	Maturity of the regulatory framework for digital transformation solutions, %
	Level of digital competencies in the regional centres, %
	Implemented digitalization cases, units
	Share of the purchased (leased) national software in the total purchases, %
	Subscribers to the broadband landline Internet per 100 people, units
	Subscribers to the broadband mobile Internet per 100 people, units
	Share of households with access to the broadband Internet in the total number of households, %
	Share of organisations using the Internet in the total number, %
	Share of organisations using the broadband Internet in the total number, %
	Share of organisations that have a website, %
	Number of personal computers per 100 employees, units
	Number of personal computers with access to the Internet per 100 employees, units
	Share of organisations using special software total, %
	Share of organisations using special software for scientific research, %
	Share of organisations using special software for designing, %
	Share of organisations using special software for automated production control and / or managing some technical means and technological processes, %
	Share of organisations using special software for tackling organisational, managerial and economic problems, %
	Share of organisations using special software for financial settlements in electronic form, %
	Share of organisations using special software for providing access to databases through global information networks, including the Internet, %
	Share of organisations using special software for training programs, %
	Share of organisations using CRM, ERP, SCM systems, %
	Share of organisations using special software for electronic legal reference systems, %
	Share of organizations using software, %
	Share of organizations using local computer networks, %
	Share of organisations using electronic document management systems, %
	Share of organisations using electronic data exchange between their own and external information systems, according to exchange formats, %
	Share of households with a personal computer, %
	Share of the population using the Internet

Personnel for Digital Economy Index (I_{dp})	Number of students enrolled in training programs for skilled workers, employees, thousand people, including those in IT programmes
	Skilled workers and employees, thousand people, including in graduates from IT programmes, people
	Number of students enrolled in Bachelor's, Specialist's, and Master's programs, thousand people, - Including those in IT programmes
	Enrollment in bachelor's, specialists, master's programs—total, thousand people, including those in IT programmes
	Graduation of bachelor's, specialists, master's, thousand people, including those in IT programs
	Number of graduate students, people, including in IT areas of training
	Number of PhD students, people, including in IT programs
	Population who received a personal digital certificate
	Number of teaching staff who received digital skills in AVE programs
	Number of employees in various economic sectors who received digital skills under AVE programs
	Highly qualified personnel in the digital sector of the economy, %
	Cybersecurity specialists, %
	Educational institutions teaching digital competencies, %
	Innovative Activity Index (I_{ia})
Research and development organisations, units	
Number of personnel involved in research and development, people	
Internal research and development costs, million rubles	
Internal fundamental research costs, million rubles	
Internal applied research costs, million rubles	
Issued patents for inventions, units	
Created advanced production technologies, units	
Issued patents for utility models, units	
Innovative activity of organisations, %	
Costs of innovative activities in organisations as a percentage of the total goods, work, services	
Innovative goods as a percentage of the total goods, work, services, million rubles	

As you can see, the list of indicators in the table illustrates the qualitative processes of digitalization and is grouped into three system-forming blocks, which are logically interconnected and, in our opinion, fully reflect the current development trends.

In contrast to the above approaches to assessing the processes of the digital divide, the system of indicators we propose has the following strengths:

- It considers the innovation block, which is not considered by researchers and practitioners and is not included in any of the approaches to evaluating digitalization. As you know, digitalization processes cannot be actively implemented without an increase in the level of innovative activity.

- It has three most important indicators in the 'Digital Infrastructure and Technology' block of the three most important indicators that reflect the digital initiatives of regional development: level of digital competencies in the regional centres, %; implemented digitalization cases, units; share of purchased

(leased) national software in total purchases, %.

- The structure of the 'Personnel for the Digital Economy' block includes indicators that show to what extent digital competencies are developed. It is an important condition for activating digitalization processes and achieving the planned effect: the number of teaching staff who have received digital skills in the programmes of further vocational education and the number of workers in various sectors of the economy who have received digital skills in the programmes of further vocational education.

- The differentiation of indicators by three indices makes it possible to use the methods of factor analysis to determine the effect of various determinants on the level of digital inequality.

- The system of the proposed indicators is based on official information presented in statistical compilations and analytical studies.

- The list of indicators can be reduced to meet the objectives of analytical research.

Since the calculations include heterogeneous indicators, the qualitative assessment is obtained using a traditional normalising procedure, which implies that all the determinants are divided into two groups—simulating indicators and de-simulating indicators. The further calculation algorithm suggests that various methods of comprehensive assessment are used (Figure 6).

4. Results

To test the methodological approach suggested by the authors, many of the quantitative and qualitative indicators were calculated using statistics on the regions that are constituents of the Central Federal District of the Russian Federation³⁰. The period of study is 2018–2019. Table 2 shows the estimated data by indices and a comprehensive assessment of the digital transformation levels of the analysed population of the regions.

Table 2. Results of calculations of the integral indicator and the components of the determinants of digital transformation of the regions of the Central Federal District of the Russian Federation

Constituent Entities of the Central Federal District	2018			2019			2018	2019
	I_{DI}	I_{dp}	I_{ia}	I_{DI}	I_{dp}	I_{ia}	K_{dt}	K_{dt}
Belgorod region	0.3822	0.1730	0.3141	0.3915	0.1970	0.2946	0.869	0.883
Bryansk region	0.3214	0.0922	0.1422	0.3445	0.1070	0.1318	0.556	0.583
Vladimir region	0.3251	0.0615	0.1203	0.3450	0.0712	0.1182	0.507	0.534
Voronezh region	0.3861	0.1496	0.3274	0.3972	0.1512	0.3215	0.863	0.870
Ivanovo region	0.3945	0.0349	0.1237	0.4060	0.0496	0.1105	0.553	0.566
Kaluga region	0.4368	0.0583	0.3144	0.4429	0.0850	0.3128	0.810	0.841
Kostroma region	0.2295	0.0644	0.1378	0.2396	0.0733	0.1262	0.432	0.439
Kursk region	0.2815	0.1134	0.3214	0.3048	0.1297	0.3195	0.7163	0.754
Lipetsk region	0.2463	0.1007	0.2855	0.2844	0.1189	0.2792	0.734	0.761
Moscow region	0.3918	0.1540	0.3246	0.4244	0.1619	0.3177	0.870	0.904
Oryol region	0.2522	0.0722	0.1722	0.2603	0.0899	0.1640	0.4966	0.514
Ryazan Oblast	0.2916	0.0461	0.1834	0.3071	0.0531	0.1752	0.521	0.575
Smolensk region	0.3041	0.0582	0.2861	0.3261	0.0674	0.2722	0.648	0.666
Tambov region	0.3678	0.1022	0.3298	0.3937	0.1188	0.3210	0.799	0.834
Tver region	0.2145	0.0763	0.1477	0.2263	0.0901	0.1350	0.439	0.451

³⁰Russian Regions. 2020 Socio-Economic Indicators. https://gks.ru/bgd/regl/b20_14p/Main.htm (accessed 16.03.2021)

Tula region	0.2586	0.0807	0.2331	0.2657	0.08110	0.2243	0.5724	0.571
Yaroslavl region	0.2897	0.0530	0.2538	0.3014	0.0690	0.2402	0.60	0.611
Moscow	0.4376	0.1583	0.3314	0.4413	0.16663	0.3245	0.927	0.932

Source: Calculated by the authors based on statistics of Rosstat

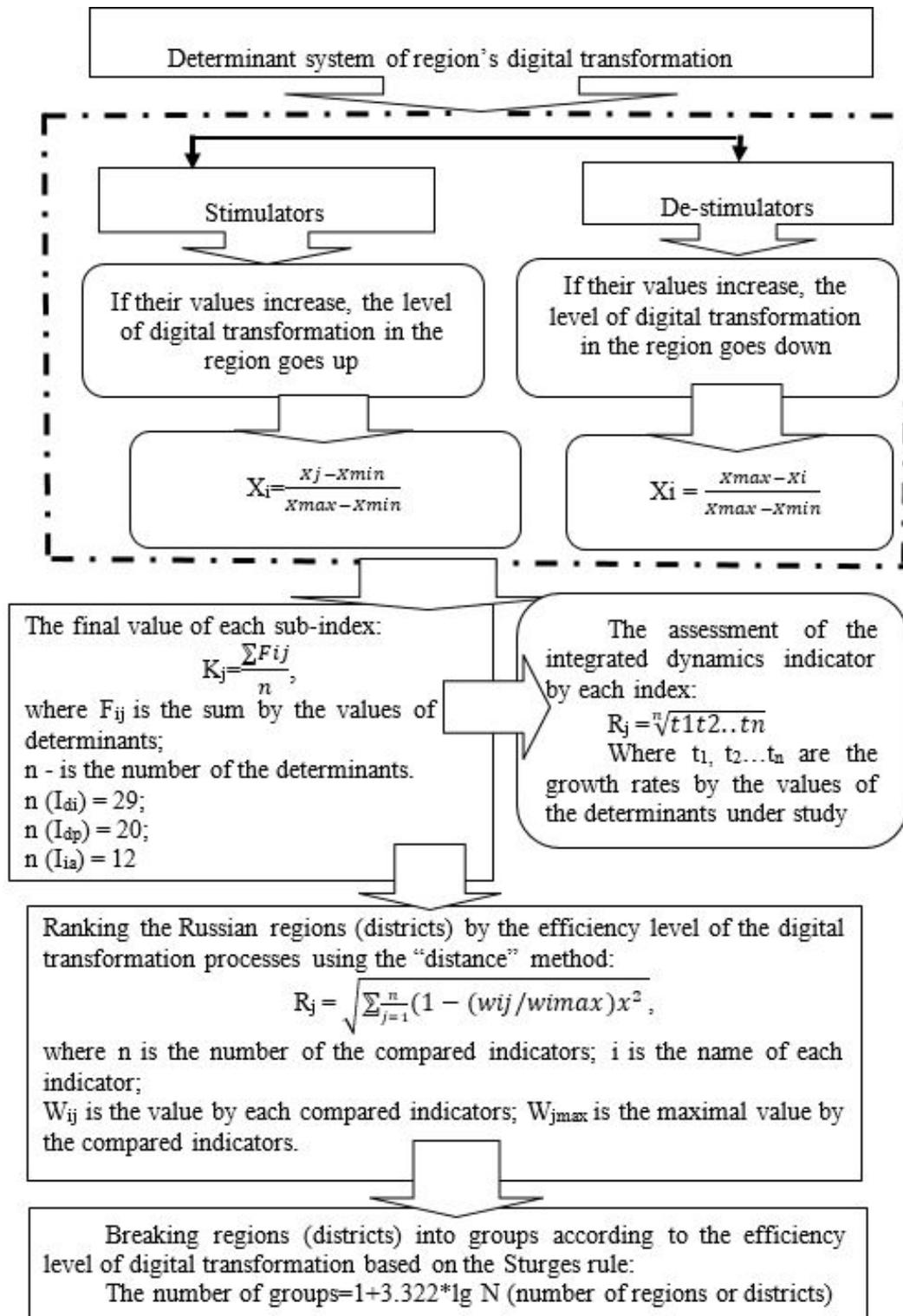


Figure 5. Methodological approach to a comprehensive assessment of the determinants characterising the digital transformation of regional economic systems for evaluating the level of the digital divide

As we can see from the table, the integrated indicator of the digital transformation within each of the regions we are considering tends to grow compared to the level of 2018. However, it occurs only

due to the increasing values of ‘Digital Infrastructure and Technology’ and ‘Personnel for Digital Economy’. This situation is due to the financing of the measures taken within the national projects and aimed at reaching the target indicators. It should also be noted that the value of the Innovative Activity Index tends to decline, which is a factor impeding active processes of digital transformation in regional economic systems and calls for special attention and support measures, as it is one of the major causes of the digital divide. At the same time, we should not forget that the quality state of the regional innovation system is an intensive factor affecting the development of the national economy (Ragnedda, 2018).

The research should break up regions by group according to their level of digital transformation. Then it will be possible to identify the causes of the digital divide and adjust the strategies for digital development of the regions. We grouped the regions using the Sturges rule³¹.

Based on the results of the calculations and assessments, six groups of regions were identified given the level of digital development based on the design value ranges (Table 3).

Table 3. Groups of regions of the Central Federal District of the Russian Federation by the efficiency level of digital transformation processes

Groups of Regions	Design value ranges		Regions	Level
I	0.436	0.537	Kostroma region Oryol region Tver region	Outsider regions
II	0.537	0.635	Bryansk region Vladimir region Ivanovo region Ryazan region Tula region Yaroslavl region	The initial level of development of digitalisation processes
III	0.635	0.733	Smolensk region	The average level of development of digitalisation processes
IV	0.733	0.831	Kursk region Lipetsk region	Active regions
V	0.831	0.929	Belgorod region Voronezh region Kaluga region Tambov region	Advanced regions
VI	0.929	1.0	Moscow region Moscow	Leading regions

As you can see, Moscow and the Moscow region are the leading regions. Their distinctive feature is active digitalisation processes in all spheres of life. Numerous pilot projects that were launched clearly demonstrate the possibilities of improving the quality and standard of living of the people.

The group of advanced regions includes Belgorod, Voronezh, Tambov and Kaluga regions. This is because regional government bodies pay a lot of attention to the development of the IT sector and building effective chains of interaction between the participants in the digital ecosystem, which opens up new opportunities and prospects.

The calculations show that the Kursk and Lipetsk regions are active regions. The digital transformation processes have affected all sectors of the economy, strategic documents have been adopted for implementing digital development, and educational institutions in the regions are actively involved in

³¹Sedler, M.I., Sedler, M.X., 2013. Statistical Methods in Quality Management: Course book. /St. Petersburg State Polytechnic University.

training workers for the digital economy, which is done, in particular, through additional educational programmes funded by the federal budget.

Among the regions with an average level of development of digitalisation processes is the Smolensk region. The digital infrastructure in the region is relatively developed; most people prefer using an electronic mechanism for obtaining services, and there are up-to-date educational programmes for working in the digital environment.

The fourth group was the most numerous among the ones presented. It includes six regions—Bryansk, Vladimir, Ivanovo, Ryazan, Tula and Yaroslavl. The basic level of digitalisation processes in these regions can be explained by the fact that these digitalisation processes are slow in the entire economic system. That is, digitalisation processes occur only in certain sectors, for example in healthcare or in the transport sector. No clear mechanism has yet been provided for interaction between educational institutions and regional government bodies in terms of training highly qualified workers, developing digital infrastructure and expanding cluster forms of interaction. Regional projects must be improved and accommodated with the target figures of the strategy for the socio-economic development of the regions.

Based on the calculation results, the Kostroma, Oryol and Tver regions are categorized as outsider regions. The slow pace of digitalisation is caused by the lack of a sufficient number of regional digital transformation cases, the low level of initiatives for industrial digitalisation, and the absence of experience in creating cluster structures in the IT sector, even though the regions have the appropriate resource potential to do so.

All of the above implies that there is a problem of differentiation of the digital development of regional economic systems and the plans and programmes for the strategic development of territories have to be adjusted so that the consequences of the current situation can be mitigated and new points of economic growth can be found.

4. Discussion

The tools proposed by the authors for assessing the level of digital transformation can be used to measure the performance of regional government bodies in terms of achieving the target indicators of regional projects under the National Digital Economy Program. For instance, the results achieved in the interregional analysis of similar operating conditions can be used to systematise the strengths and weaknesses of the digital solutions being implemented. They can also help in developing a set of measures to eliminate threats and enhance initiatives, which ultimately implies that the vector of the strategic development of the territory is adjusted accordingly.

The following conclusions were made after carrying out a comparative analysis of the results obtained from the study of the approach proposed by the authors, given the methodology for assessing the digital development of regions and identifying the causes of the digital divide.

According to the results of the Digital Russia Index³², calculated based on public information, events and their citations, the final ranking represents the sum of the score and the ranking of the regions by the level of their digital development, as well as a comparison of the districts of the Russian Federation. In contrast to the tools proposed by the authors, one of the ‘bottlenecks’ of this approach is the predominant use of expert evaluations rather than official statistics, which leads to several distortions. The approach does not consider opportunities for a comparative assessment in the context of constituent entities that are parts of districts, which seems inappropriate. Moreover, the ranking does not take into account the innovative activity of the regions, even though innovations are the most important tool of digital transformation and these elements cannot be considered in isolation from each other.

For example, the ranking “Digital Life of Russian Regions” prepared by a team of researchers from the SKOLKOVO Moscow School of Management³³, is based on the use of a model built by

³²<https://d-russia.ru/vyshla-polnaya-versiya-rejtinga-regionov-po-urovnyu-razvitiya-tsifrovizatsii-tsifrovaya-rossiya.html>

³³https://iems.skolkovo.ru/downloads/documents/SKOLKOVO_IEMS/Research_Reports/SKOLKOVO_IEMS_Research

Dasgupta and his colleagues and regions are ranked depending on the state of factors that affect the level of secondary digitalisation and cause digital divide. The factors are broken down into three groups: (1) income level, (2) human capital and (3) the region's digitalisation policy. They are considered in relation to the region's transportation system, financial sector, healthcare, media, education and administration. In our opinion, the approach we propose is much broader, as it can be used for evaluating innovative activity as well as for considering a large list of indicators that characterise the potential for developing personnel for the digital economy. For example, this ranking considers the entire educational system with just two system indicators—total higher educational institutions and educational institutions that use distance-learning technologies. Thus, it is impossible to fully analyse people's readiness to acquire digital skills. Moreover, the 'Administration' block is analysed only by learning about whether people are registered on Gosuslugi (public services portal) and does not consider the most important areas for the development of e-government, which are covered in our methodology.

The results of the analysis of the Digital Economy Development Index calculated by Rosatom Corporation³⁴ are based on a set of indicators systematised into groups of factors: state policy and regulation, human capital, research and development and innovations, business environment, information security, digital economy, digital infrastructure, digital government, digital healthcare, digital business, digital citizens, competitiveness and economic growth, new business models and organisation of activities. Thus, all the characteristics of digital transformation processes can be considered on a large scale. On the other hand, it should be noted that it may be difficult to calculate many of these indicators due to their inaccessibility to interested users. Therefore, the system of indicators we propose makes it unnecessary to specify digital development indicators in such detail, allowing us to obtain an objective assessment and determine groups of regions according to similar characteristics of their digital transformation.

The undoubted advantage of the methodological approach we propose is that it relies on a system of indicators calculated using open-source data, which makes the calculations and decision-making more efficient. Also, a distinctive feature of our approach is that the data can be visualized using the simplest means of information processing, and integrated indices can be projected. Also, the proposed system of indicators is resistant to dynamic digitalisation processes, and the assessment tools themselves can be enhanced with expert evaluation methods to rank indices by significance. To do so, an expert community must be involved, since the conditions, factors and goals of a particular region can affect the significance of each index.

5. Conclusion

The results of the digital development goals depend on the active processes of digital transformation in certain regions, industries and economic sectors. They lean on the potential available, the digital transformation strategy and initiative decisions, which take the form of the readiness of regional government to put concrete digital solutions into life. This requires a clear prioritisation of regional development based on a detailed analysis of the key socio-economic indicators and forecasted trends (Alexandrova, 2019).

The active digitalisation processes taking place in regional economic systems contribute to their qualitative transformation and help the development trajectory change towards ensuring competitive advantages. The digital potential of the region and the initiatives of businesses and government can create new opportunities, not just inside the region. They can facilitate the opening of international markets, which is one of Russia's strategic priorities.

The level of digital transformation in regions should be assessed primarily to obtain reliable and objective information about various aspects of the region's digital transformation. Therefore, the methodological approach we propose includes three major components—the Digital Infrastructure and Development Index, the Personnel for Digital Economy Index, and the Innovation Activity Index—which are aggregated with 61 analytical indicators.

Digital_life_of_russian_re

³⁴National Digital Economy Development Index: Pilot Implementation. Moscow, Rosatom State Corporation, 2018.

Approbating the algorithm based on statistics about the regions of the Central Federal District of the Russian Federation, we managed to obtain a comprehensive assessment of the digital transformation processes. We used the Sturges rule to distinguish regions by their level of digital transformation, based on specific characteristics and certain indicators achieved by regional economic systems.

Following the results of an analytical study of the Russian regions included in the Central Federal District, six groups of regions were found according to their levels of digital development:

Outsider regions (Kostroma, Oryol and Tver regions);

Regions with a basic level of digitalisation processes (most of the regions in the Central Federal District—the Bryansk, Vladimir, Ivanovo, Ryazan, Tula and Yaroslavl regions);

The Smolensk region has an average level of digitalisation;

The Kursk and Lipetsk Regions are regions with active digitalisation processes;

The advanced regions are Belgorod, Voronezh, Kaluga and Tambov regions;

The Moscow region and Moscow are the leading regions.

The data obtained are the basis for adopting a set of measures aimed at taking strategic actions in the field of project management and digitalisation of the regions and improving the tools currently used for assessing the achievement of the target indicators included in the federal projects. In particular, action plans must be developed to reduce the level of digital differentiation in these regions. Among other things, much attention should be paid to the quality of the digital environment, the availability of up-to-date digital services and platforms for citizens, educating people on digital skills, making people more mobile, providing them with access to the elements of the digital infrastructure, and creating conditions for more intense innovative activities to increase the level of implemented digital solutions.

Thus, the level of development of the digital ecosystems in the regions can be assessed in a reliable and accurate way only if the algorithm used for the assessment takes into account not just the individual characteristics of these systems but also their full content, including the subjects of digitalisation of the economy and society, environmental conditions, territorial features, information technology, scientific and innovative advances, and the availability of infrastructure.

References

- Alexandrova, T.V., 2019. Digital divide in Russian regions: Causes, assessment, ways for closing. *Journal of Economy and Business* 8, 9–12.
- Babkin, A.V., Burkaltseva, D.D., Kosten, D.G., Vorobyev, Y.N., 2017. Formation of digital economy in Russia: Essence, peculiarities, technical normalization, and problems of development. *Journal of Engineering Science and Technology*, 10, 9.
- Babkin, A.V., Burkaltseva, D.D., Pshenichnicov, V.V., Tyulin, A.C., 2017. Cryptocurrency and technology in digital economy: Development genesis. *St. Petersburg State Polytechnical University. J Econ.* 10, 9.
- Barefoot, K., Curtis, D., Jolliff, W., Nicholson, J., Omonhundro, R., 2018. *Defining and Measuring the Digital Economy*. Washington: Bureau of Economic Analysis (accessed: 15.03.2021).
- Borkova, E.A., Barsukova, M.A., Plotnikov, V.A., Vatlina, L.V., 2019. Comparative analysis of tools for estimation of investment climate of territories. *Humanities and Social Sciences Reviews* 7, 1336–1346.
- Bukht, R., Heeks, R., 2017. *Defining, Conceptualising, and Measuring the Digital Economy*. Development Informatics. Manchester: Centre for Development Informatics Global Development Institute, University of Manchester.
- Dobrinskaya, D.E., Martynenko, T.S., 2019. Digital divide in Russia: Features and trends. *Public Opinion Monitoring: Economic and Social Changes* 5, 100–119. <https://doi.org/10.14515/monitoring.2019.5.06>
- Elokhova, A.M., Aleksandrova, T.V., 2019. Approaches to evaluating the results of the digital transformation of the Russian economy. *Accounting. Analysis. Audit.* 6, 24–35. <https://doi.org/10.26794/2408-9303-2019-6-5-24-35>.
- Gladkova, A.A., Garifullin, V.Z., Ragnedda, M., 2019. A three-level model of digital inequality: Today's opportunities and constraints (case study of the Republic of Tatarstan). *The Bulletin of Moscow University. Journalism.* 4, 41–72.
- Golovina, T., Polyinin, A., Adamenko, A., Khegay, E., Schepinin, V., 2020. Digital twins as a new paradigm of an industrial enterprise. *Int J Technol* 11, 1115–1124.
- Kuzovkova, T.A., Salyutina, T.Y., Kukharensko, E.G., 2019. The methodological grounds and results of the integral assess-

- ment of the digital development of the economy and society. *Quality Century*. 3, 106–122.
- Maksimova, T.G., Popova, I.N., 2019. Statistical evaluation of the results of the digital transformation of the Russian regions' economy. *SRU ITMO. Series 'Economics and Environmental Management* 1, 52–60. <https://doi.org/10.17586/2310-1172-2019-12-1-52-60>.
- Ragnedda, M., 2018. Conceptualizing digital capital. *Telematics and Informatics* 35, 2366–2375. <https://doi.org/10.1016/j.tele.2018.10.006>
- Ragnedda, M., Kreitem, H., 2018. The three levels of digital divide in east EU countries. *World of Media. Journal of Russian Media and Journalism Studies* 4, 5–27. <https://doi.org/10.30547/worldofmedia.4.2018>.
- Safiullin, A.R., Moiseeva, O.A., 2019. Digital divide: Russia and the world in the time of the fourth Industrial Revolution. *The Scientific and Technical Bulletin of St. Petersburg State Polytechnic University. Economic Sciences*. 12, 26–37. <https://doi.org/10.18721/JE.12602>
- Safiullin, M.R., Abdukaeva, A.A., Elshin, L.A., 2019. Assessing and analyzing the digital transformation of regional economic systems in the Russian Federation: Methodological approaches and their approbation. *Vestnik Universiteta* 1(12), 133–143.
- Stepanova, V.V., Ukhanova, A.V., Grigorishchin, A.V., Yakhyaev, D.B., 2019. Evaluating the digital ecosystems of Russian regions economic and social changes. *Facts, Trends, and Forecast* 12, 73–90. <https://doi.org/10.15838/esc.2019.2.62.4>
- Van Deursen, A., Van Dijk, J., 2018. The first-level digital divide shifts from inequalities in physical access to inequalities in material access. *New Media and Society*. 1–22. <https://doi.org/10.1177/1461444818797082>

СПИСОК ИСТОЧНИКОВ

- Alexandrova, T.V., 2019. Digital divide in Russian regions: Causes, assessment, ways for closing. *Journal of Economy and Business* 8, 9–12.
- Babkin, A.V., Burkaltseva, D.D., Kosten, D.G., Vorobyev, Y.N., 2017. Formation of digital economy in Russia: Essence, peculiarities, technical normalization, and problems of development. *Journal of Engineering Science and Technology*. 10, 9.
- Babkin, A.V., Burkaltseva, D.D., Pshenichnicov, V.V., Tyulin, A.C., 2017. Cryptocurrency and technology in digital economy: Development genesis. *St. Petersburg State Polytechnical University. J Econ*. 10, 9.
- Barefoot, K., Curtis, D., Jolliff, W., Nicholson, J., Omonhundro, R., 2018. *Defining and Measuring the Digital Economy*. Washington: Bureau of Economic Analysis (accessed: 15.03.2021).
- Borkova, E.A., Barsukova, M.A., Plotnikov, V.A., Vatlina, L.V., 2019. Comparative analysis of tools for estimation of investment climate of territories. *Humanities and Social Sciences Reviews* 7, 1336–1346.
- Bukht, R., Heeks, R., 2017. *Defining, Conceptualising, and Measuring the Digital Economy*. Development Informatics. Manchester: Centre for Development Informatics Global Development Institute, University of Manchester.
- Dobrinskaya, D.E., Martynenko, T.S., 2019. Digital divide in Russia: Features and trends. *Public Opinion Monitoring: Economic and Social Changes* 5, 100–119. <https://doi.org/10.14515/monitoring.2019.5.06>
- Elokhova, A.M., Aleksandrova, T.V., 2019. Approaches to evaluating the results of the digital transformation of the Russian economy. *Accounting. Analysis. Audit*. 6, 24–35. <https://doi.org/10.26794/2408-9303-2019-6-5-24-35>.
- Gladkova, A.A., Garifullin, V.Z., Ragnedda, M., 2019. A three-level model of digital inequality: Today's opportunities and constraints (case study of the Republic of Tatarstan). *The Bulletin of Moscow University. Journalism*. 4, 41–72.
- Golovina, T., Polyanin, A., Adamenko, A., Khegay, E., Schepinin, V., 2020. Digital twins as a new paradigm of an industrial enterprise. *Int J Technol* 11, 1115–1124.
- Kuzovkova, T.A., Salyutina, T.Y., Kukhareenko, E.G., 2019. The methodological grounds and results of the integral assessment of the digital development of the economy and society. *Quality Century*. 3, 106–122.
- Maksimova, T.G., Popova, I.N., 2019. Statistical evaluation of the results of the digital transformation of the Russian regions' economy. *SRU ITMO. Series 'Economics and Environmental Management* 1, 52–60. <https://doi.org/10.17586/2310-1172-2019-12-1-52-60>.
- Ragnedda, M., 2018. Conceptualizing digital capital. *Telematics and Informatics* 35, 2366–2375. <https://doi.org/10.1016/j.tele.2018.10.006>
- Ragnedda, M., Kreitem, H., 2018. The three levels of digital divide in east EU countries. *World of Media. Journal of Russian Media and Journalism Studies* 4, 5–27. <https://doi.org/10.30547/worldofmedia.4.2018>.
- Safiullin, A.R., Moiseeva, O.A., 2019. Digital divide: Russia and the world in the time of the fourth Industrial Revolution. *The Scientific and Technical Bulletin of St. Petersburg State Polytechnic University. Economic Sciences*. 12, 26–37. <https://doi.org/10.18721/JE.12602>
- Safiullin, M.R., Abdukaeva, A.A., Elshin, L.A., 2019. Assessing and analyzing the digital transformation of regional economic systems in the Russian Federation: Methodological approaches and their approbation. *Vestnik Universiteta* 1(12), 133–143.
- Stepanova, V.V., Ukhanova, A.V., Grigorishchin, A.V., Yakhyaev, D.B., 2019. Evaluating the digital ecosystems of Russian regions economic and social changes. *Facts, Trends, and Forecast* 12, 73–90. <https://doi.org/10.15838/esc.2019.2.62.4>
- Van Deursen, A., Van Dijk, J., 2018. The first-level digital divide shifts from inequalities in physical access to inequalities in material access. *New Media and Society*. 1–22. <https://doi.org/10.1177/1461444818797082>

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