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PROBLEMS OF STRATEGY DEVELOPMENT, FINANCIAL AND ECONOMIC REGULATION IN INDUSTRY

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DEVELOPMENT OF SMART INDUSTRY AS AN EFFICIENT WAY TO IMPLEMENT THE POLICY OF NEOINDUSTRIALIZATION IN THE WORLD

The paper reveals modern trends of development of manufacturing systems, based on the principles of the Forth Industrial Revolution and linked with transition to the smart industry principles.

Smart enterprise is considered as the key primal segment of smart industry construction, which characterized with the possibility of control and tracking of industrial tools and industrial staff functioning through the Industrial Internet of Things. It also allows using data, collected for increasing productivity of labour, modification of technological processes and production quality.

Nowadays a number of countries all around the world formatted their own strategies of national mechanisms of smart industry's incipience. At the same time, there are some similarities and differences in the formatting of principles and implementation of approaches that can be observed in this context in leading industrial countries.

German's concept "Industry 4.0" was formed with the direct participation of governmental structures, scientific and business circles and considered the development of national industry, but not the global breakthrough. Implementation of this concept is directed on supporting of small and medium national manufacturers. In the USA the Industrial Internet Consortium was created as a non-commercial organization with open membership. Promoting the concepts of "sharing" and "open platforms", Consortium considers its main task to be an optimization of profitable assets with emphasize on total financial returns. Chinese "Made in China 2025" strategy was formed upon the initiative of the government and assumed its leading role in the management of economy and transformation processes. The strategy defines an ambitious task as the main goal – to turn China into the world leading manufacturer and high-tech state through the increasing of "intellectual" smart industry capacity by 2025.

Different appraisals of the abovementioned countries' prospects of the programs implementation show that today progressive businessmen no longer believe that transfer of production capacities to countries with cheap labour is a reliable way to succeed. This is due to the fact that goods have to fit the configuration of manufacturing, directed on satisfying the individual consumers' needs and requests. From now on, the industry can become more localized. On the other hand, development of a smart industry means qualitative leap in cooperation and coordination of enterprises, linked through the global computer networks with researchers, developers, suppliers, distributors, end-users, etc. all around the world.

Ukraine must form its own program of national manufacturing transition to "smart" grounds, because the analysis of foreign experience, conducted in the paper, reveals an inex-

pediency of “blindly copying” the foreign strategies. Given the current state of affairs, combined model of building the smart industry can be congruent one for Ukraine. This model represents a combination of profitable assets optimization (according to the US experience) and support of national small and medium businesses (according to the German experience). The latter can provide fast integration into world smart environment, development and export of the necessary advanced technologies and products for the network industry under existing circumstances.

Keywords: smart industry, Industry 4.0, Industrial Internet Consortium, Industrial Internet of Things, smart factory, cyber-physical production systems, information and communication technologies, big data.

JEL code: O140.

In April 2011, on the annual industrial Hannover Fair (Federal Republic of Germany), the basic provisions of the new industry development concept «Industry 4.0» were presented. The concept was initiated by the German Academy of Technical Sciences, German Research Center of Artificial Intelligence and the Federal Ministry of Education and Research of Germany.

In essence, this concept is the answer to the demands of time concerning the creation of new world economy architectonics after the global financial crisis of 2008-2009. This crisis emerged, inter alia, due to the reduction of the share of real economy (manufacturing area) and increase of the share of services.

The approach, proposed in the concept, assumes the increase of industrial production competitiveness through the integration of Cyber Physical Systems (CPS) principles in manufacturing processes of enterprises through the Internet-linking of manufacturing equipment, machines, constructions, and warehouses. The implementation of the Industrial Internet of Things (IIoT) and personalizing of manufacturing determined as the most important part of the Fourth Industrial Revolution, which is aimed to ensure the new quality of smart industry as the foundation of the world economy smart growth, based on knowledge, environmentally friendly technologies and product innovations.

According to McKinsey & Co, by 2025 the IIoT technologies will cover from 80% to 100% of the world processing industry [1]. Thus, no wonder that the problems of smart industry become the theme of numerous academic papers, analytical materials, different reviews and international institutes' and organizations' reports all around the world (e.g. [2,16]). At the same time, the number of Ukrainian publications on this topic is not that significant. Some issues of smart specialization and Industry 4.0 are examined in the papers by I. Egorov [3], Y. Ryzhova [4], I. Matuchenko [5], V. Skitsko [6], etc. A number of papers by the specialists of the Institute of Industrial Economics of NAS of Ukraine are devoted to problems of further development of the national industry on the “smart” principles. Among other problems, the actuality of the Ukrainian economy transition to neoindustrial development model with the aim of increasing the level of social and economical quality are substantiated in them. Also, some works analyze the current state of Ukrainian industry and determine the key directions that should be taken into account when creating the new strategy of its development [7], identify features of industrial smart enterprises and smart industry and obstacles that should be overcome for national industry renovation using IIoT [8]. In some papers, the authors describe the problems of complication and robotization of Ukrainian

manufacturing, in conditions where the industry is characterized by considerable physical and moral depreciation of productive assets and uncongenial investment climate [9].

However, in contrast to many advanced economies of the world, the integral concept of smart industry formation and development is not developed in Ukraine yet. That is why various aspects of this important issue demand further special research to consider not only the best world practices, but also to take into account technical, technological, structural, institutional features of the Ukrainian industry.

Respectively, the *purpose* of this paper is to analyze the processes of smart industry development in the leading countries of the world and to define the prospects, caused by this development, in the whole world and in Ukraine in particular.

The primary link of the smart industry is a smart enterprise, characterized with the possibility to control and track tools and staff by mean of IIoT and to use data collection for the improvement of productivity, technological processes and upgrading the quality of production.

Smart enterprise can also be considered in terms of hardware interaction, primary data, software, artificial and human intelligence. Information, received by sensors, log-files and searching robots from physical systems to computer networks is collected, transmitted, pre-processed, stored, visualized, analyzed and used by highly qualified staff for industrial products and manufacturing process modeling.

Practical implementation of such cooperation with real-time processing of big data is concerned in [10]. As was noticed in [11, p. 654], big data technologies describe new generation of technologies and architectures, intended to enrich economical profit from the very large volume of different data with the help of high-speed capture, finding and/or analysis. This definition describes four specific features of big data – volume, variety, velocity and value. As a result, "4Vs" definition is widely used for characterizing big data [12].

For understanding these data the following instruments of advanced analysis are used – intellectual analysis, predictive analytics, object-oriented analysis, real-time scoring, prognostic modeling, optimization, etc. [12, p. 675-677; 13]. Factory managers can use developed («upgraded») analytics for deep immersion in historical data about manufacturing processes. This allows defining and optimizing the factors that have the biggest impact on the final results. The majority of global commodity producers in the wide specter of industries and geographic locations already accumulated a lot of real-time data, collected during the stage of primary manufacture and on market. Using the integration and analysis of previously isolated arrays (including non-structured and barely-structured [11, p. 654]), they have the possibility to offer new important ideas [13]. All gained information is used for data-driven decision making (DDD) [14] both in the area of current management influences and in strategic management of various industrial systems [15, p. 9]. However, today creation of a safe network is still a rather urgent problem. Such a network would guaranty invulnerability of integrated with the Internet physical systems and related manufacturing processes from cyber attacks.

Manufacturing enterprises (companies) in future will probably need to withdraw from their own production of spare parts and to increase the number of suppliers. They also need to base their work on Just-in-Time and Just-in-Sequence principles. Accordingly, these would demand the high level of coordination and cooperation, when carrying out processes, based on management decentralization and stop constant

attempts to standardize and to plan developing production processes and chains.

As it was mentioned above, a number of countries with advanced economies formulated their own strategies about the main directions and mechanisms of implementing smart industry at national level. At the same time, it is worth paying special attention to similarities and differences of the strategies of these countries – industrial leaders, located on different continents – Germany, the USA and China (that in the nearest future will play the main role in the building of a new model of economic development – the smart growth of the world economy).

Germany took the course at modern technologies unification and IIoT and became the leader among the EU member-countries in the area of "Industry 4.0". Interest in implementation of new technologies and the corresponding receipt of potential dividends was first demonstrated by such leading industrial corporations as Siemens, ThyssenKrup, Robert Bosch, and BASF. According to some estimations, the German business can invest in IIoT infrastructure up to 40 billion euro per year till 2020 [16].

Taking into account that smart industry is much more than stand-alone enterprises and their products, the big German corporations traditionally allocate significant amounts of funds to provide fundamental and applicable R&D, aimed at ensuring the development of smart industry. This development should be based on collaboration with researchers, developers, suppliers, distributors, consumers, etc. through the information and communication technologies – the ICT (mobile Internet, IIoT, cloud technologies and others), which will result in creation of a global digital platform for coordination and increasing of active participation of all partners in separate chains and in the whole global network.

Today Germany relies on the formation of bases of the smart industry in its traditional activities (firstly – in manufacturing industry, mechanical engineering and automotive industry), which provide it a leading place amongst the EU and world economies; at the second stage – in traffic and logistic complex and directly related to them manufacturing of specific equipment, complex automated, integrated and cyber-physical manufacturing systems, sensors of pneumatic control systems, actuators, etc., and, at the third place, in the sphere of information and communication technologies.

Nowadays, a lot of German manufacturing enterprises are the world leaders in the abovementioned fields of economic activity. Their further development in the context of creation of smart manufacturing should retain leading positions of Germany in international markets of products' manufacturing that will remain volatile and uncertain for a long time. Increasing the speed and flexibility of reaction to customers' demand can reduce the negative impact of high labour costs, which is comparatively high in German manufacturing industry and can amount up to 20 % of general costs [17, p. 14].

New technologies are actively implemented in German industry (Embedder Systems, Smart Factory, Robuste Netze, Cloud Computing, IT-Security), that stimulates the inflow of significant investments to transition to smart industry principles in engineering, automotive, electrical engineering, chemistry, ICT, agriculture areas. All this greatly increases the attractiveness of Germany as a location for smart businesses.

On its part, the state is taking measures to stimulate the use of digital technologies in the national economy. In particular, the country has developed and approved at the state level the "Information and Communication Technology Strategy" [17, p. 16], which suggests the expansion of

the necessary infrastructure, accelerated development of digital technologies and their implementation into production, solving the issues of cyber-security.

In March 2015, the Federal Ministry of Economics and Energy and the Federal Ministry of Education and Research of Germany created the biggest network platform in the country – Plattform Industrie 4.0, – which took into account the positive experience of functioning of such communicative platforms of business unions as BITCOM, VDMA and ZVEI. Architecture, norms, standards of research and development work (SRDV) is among the traditional blocks. The special attention is paid to such questions as network system safety, law, education and qualification upgrade, interconnection of governmental, business, scientific and social representatives. One of the main platform tasks is the coverage of existing pilot projects and their consistent implementation in business model. As at the end of 2015, the platform already united more than 7 thousand enterprises [17, p. 17].

German experience is already studied and implemented by some other industrialized EU member-countries, which adopted similar state programs [2, 17]: Netherlands – Smart Factory, France – Alliance Industrie du Futur, the United Kingdom – High Value Manufacturing Catapult, Italy – Fabbrica del Futuro, Belgium – Made Different.

In the *USA*, the establishment of the Industrial Internet Consortium TM, IIC (hereinafter, the Consortium) in 2014 by the companies AT&T, Cisco, General Electric and Intel become a significant event [18]. It was founded as a non-profit organization with open membership. The goal of the organization is to help eliminate barriers between different technologies in order to provide maximum access to big data and to improve the integration of physical and digital environment. Consortium will facilitate connection and optimization of resources, operations and data to disclose business values in all industries.

For the USA, just as for Germany, modernization of industrial sector and the unification of digital network of manufacturing equipment with virtual world is one of the key priorities. As the US government assumes, one of the main tasks of its strategy is the reindustrialization and returning the country to the circle of industrial leaders[1]. However, it should be noted, that the approaches and objectives set by Germany and the United States on their way to reindustrialization and the new smart industry building differ significantly.

The concept “Industry 4.0” means the development of German industry and provides, first of all, the national rather than global breakthrough. Its main objective is optimization of manufacturing, work with standards and the orientation on hi-tech landscape. The main focus is on small and medium enterprises. This concept does not deny access to international companies with the aim of obtaining manufacturing components on the condition of their purchase by other companies.

Instead, the Consortium's ideology is "shared use", since it is believed that only by taking on the experience of others, and

[1] In his inaugural speech the new President of the USA D. Trump described this problem as follows: «One by one, the factories shuttered and left our shores, with not even a thought about the millions upon millions of American workers left behind. The wealth of our middle class has been ripped from their homes and then redistributed across the entire world. But that is the past. And now we are looking only to the future. … Every decision on trade, on taxes, on immigration, on foreign affairs, will be made to benefit American workers and American families. We must protect our borders from the ravages of other countries making our products, stealing our companies, and destroying our jobs. Protection will lead to great prosperity and strength.» (CNN. Inaugural address: Trump's full speech. 2017. – Available at: http://edition.cnn.com/2017/01/20/politics/trump-inaugural-address/ [Accessed 24 January 2017]).

not duplicating one another, one can achieve general progress without unnecessary expenses. The instrument of increasing the US companies' efficiency is the global network of Internet, to which almost all the equipment in the world is connected, providing data and feedback.

The Consortium focuses on the development of many areas of economy: industry, energy, medicine, traffic, agriculture, utility services. It sees its goal in optimizing profitable assets, focusing on overall financial returns. Creation of open platforms that can form the future standards and replace formal standardization is also promoted. A distinctive feature of the Consortium's views, which distinguishes it from other similar programs, is the unification of existed objects in one safe production network.

To some extent, it may seem that the US policy (conception of "common use" and "open platforms") contradicts the official statements of the government regarding the revival of the industrial capacity of the country. But in this respect it is worth mentioning that the smart industry tends to a solvent consumer. Game rules, guaranteed by law in the USA (warranty of copyrights, investor's protection, independence of the judiciary, low level of corruption, high level of human development and availability of financial capital, etc.), combined with developed area of SRDV, give vast possibilities of using the advanced international experience in different areas and the good chance to achieve the world leading positions in the development of smart industry to the country.

China occupies a special place among the abovementioned countries that understand the importance of smart manufacturing for its industrial future and have already developed its own policies and programs for development and application of IIoT. In 2015, the government of the country approved a strategic document 'Made in China 2025' (further – Strategy), which points the priorities of Chinese industry on the grounds of modern smart technologies [19, p. 39]. Besides, China anticipates accelerating of the integration of information technology and manufacturing sector with the development of industrial Internet on the foundation of Internet Plus initiative realization. This initiative is essential for the economy, digital economy transformation and for cloud platform building, which promote the expansion of interconnections both within the industrial companies and in manufacturing chains in general [19].

Taking into consideration the features of political system of the country, it is not surprising that the start of smart modernization was given by the Chinese government and the country policy, concerning its implementation, is build on "top to bottom" principle. The strategy has an ambitious goal – China's transformation into the world leading manufacturer and the country with high technologies by 2025. It has to be achieved through the increasing of "intellectual" capacity of smart industry. Special feature of Strategy is the leading role of the government in managing the economy and transformation processes.

Just as with the US Consortium ideology, the tasks of Strategy in China are not limited to the development of industry only, but also include nine priorities: improvement of industrial innovation; the integration of information technology and production; support of Chinese brands; implementation of "green" production; promoting breakthrough achievements in ten key sectors of economy (IT; numerical control tools and robotics; space and aerial production; marine equipment and hi-tech ships; advanced railway transport equipment; energy-saving vehicles and vehicles, that function on new types of energy (renewable); power equipment; agricultural machinery; new materials; biological medicine and hi-tech med-

ical devices); progressive restructuring of manufacturing sector; promotion of service-oriented manufacturing and sector of industrial services; internationalization of production.

With enormous financial, industrial and human capital in the last decade, China is increasing heavily its scientific and technical potential. Realization of significant investments and intensification of the development of its own sphere of SRDV allows China not only to copy EU and US technologies, but also to promote its own (including digital ones). A vivid example of this is the researches of Alibaba Group, Lenovo etc. However, the results of SRDV cannot provide the targeted rate of Chinese economy growth yet. Therefore, Chinese companies use various methods for attracting foreign technologies in their own industrial production, from official[1], to semiofficial and non-official[2] (taking into consideration that the issue of intellectual property rights' protection on the territory of China is still not completely resolved).

To implement the Strategy in practice in 2016 profile ministries and agencies created a fund that amounted 3.05 billion US dollars. The main goals of this fund is investing in advanced sectors of industry, supporting the modernization of traditional sectors of industry and boosting the high technical level of industry as a whole.

It is worth mentioning that the Strategy provides the division of enterprises into three categories: frontrunners, hopefuls and latecomers. The category of leaders include a small group of companies that already apply the principles of smart industry and which are already integrated into and compete on the world markets. The second category is represented by the majority of state-owned and private enterprises and includes the enterprises on the stage of transmission from the Industry 2.0 to the Industry 3.0. These categories of enterprises are the most numerous and form the base for all Chinese industry. They provide the working places to the majority of workers, employed in industry. Investing in re-equipment and implementation of the principles of smart industry in this category of enterprises will be done by the abovementioned fund. The third category is formed by the enterprises with the large share of manual labor, which in the future will lose their positions both in the national and foreign markets.

The hidden impact of automation on the labour market and the shortage of highly skilled personnel greatly reduces the ability and desire of many Chinese enterprises to invest in costly upgrades of equipment. Therefore, the Strategy may fail to reach the goal of the large-scale modernization of production and its transition to the principles of "smart industry". Instead, it has good chances to improve the key components of the country's industry and to create the influent groups of global leaders of smart economic growth of economy in the nearest future. In the long run, given the improvement of living standard of the population (the population of China is larger than the population of any other country), the development of human capital, accelerated increase of scientific and technical potential of the country, etc. contribute to China's transformation into the smart industry leader in Asia

[1] This implies, for example, to the placement on the territory of China their entire production cycle of such automotive giants as Volkswagen, Toyota, Peugeot, Citroen, Honda, Renault, Nissan, BMW; an acquisition of the Swedish concern VOLVO by a Chinese company Geely in 2010; an acquisition of US companies Continental Motors (in 2010) and Cirrus Aircraft (in 2011) by Chineese air company AVIC.

[2] E. g.: Huawei (SecurityLab.ru by Positive Technologies [URL]. – Availaible at: http://www.securitylab.ru/news/tags/Huawei/ [Accessed at: 04 November 2017])

and one of the leading countries in the world.

In *Ukraine, the* situation with formulating and implementation of strategic approaches, concerning development of smart industry is not in its best yet. The reason for that is a well- known issues with innovations, connected with a generally unfavorable investment environment, short rules of behaviour for business entities and low level of investments in SRDV [20]. One of the consequences of such situation, among others, is a weak position of Ukraine in the world ratings, namely – ICT development index (76^{th} place in the world) [21].

Nevertheless, it should be noted that there is already some progress in promoting the development of the smart industry at the initiative of "bottom". In 2016, the Association of Industrial Automation Enterprises of Ukraine together with the Association of Innovative Development of Ukraine founded the movement “Industry 4.0 in Ukraine” [22]. This movement includes nearly 60 companies (the majority of which is well-known brands of ACU and IT), leading system integrators and about 10 customers, including "ArcelorMittal Kryviy Rih". Several strategic initiatives were developed during the work of the Association concerning Smart Factory and Industry 4.0, including creation of new technology parks and road maps for digital transformation of enterprises.

There are other examples of industrial enterprises’ placement by leading world producers on the territory of Ukraine, including Leoni company, whose innovative technologies and decisions is used by world leaders in automobile industry (VW, Audi, Porsche etc.) the leading companies in telecommunication, IT, healthcare and energy fields.

Some examples of application of the practice of building new production on the principles of smart enterprises exist in the field of agribusiness, engineering and pharmaceutical industry.

Regarding the policy of central authorities, the Government of Ukraine has already outlined priority actions in the field of economy for the period till 2020 [23], which can concern the smart industry as well. In addition, at the end of October 2017, the Ministry of Economic Development and Trade of Ukraine announced the launch of pilot project of the smart specialization in industry in three regions [24]. However, as opposed to action plans of the USA, China, core EU countries and other industrial leaders, Ukraine still does not have any strategic document, which would determine smart industry as the national strategic initiative. Ukraine also does not have the authorities, responsible for the forming of such a policy.

Challenging issues of the planned development of smart industry in Ukraine are the questions of limited financial resources for the development of an appropriate infrastructure, lending and holding of SRDV in critical areas for the country. Also, the shortcomings in the system of training and retraining of STEM staff are known. Ukraine has one of the highest education rates in the world, but cannot provide the suitable way of personnel training due to outdated programs and teaching methods in the development of modern techniques and technology areas.

Conclusions

Modern fast-growing industrial cyber-physics systems are already contributing to the increase of labour productivity, meeting the ever-increasing needs of people and improving the quality of life far beyond ever imagined. Obviously, the economic sectors which include mainly standardized manufacturing processes will be radically changed in the upcoming years in the framework of new online models of global value chain’s creation. Worldwide mega-

trends, such as globalization, urbanization, demographic change and transformation of energy sources, will undergo significant changes under the influence of forward-looking development of IIoT as well.

Due to the fact that manufacturers face increasing pressure on costs and volatility of markets and accelerating scientific and technological progress, test phases and life cycles of products become shorter and more informative. Modern world experience of industry development and the innovation tendencies of reshoring testify the fact that material production without "advanced" information is bad and inefficient. However, the information without “advanced” material production is also bad and inefficient, although it is digital technology of manufacturing systems (in conjunction with 3D printing, bio-, nano-, and other disruptive methods and instruments) that mainly define the specifics of what is now called smart industry. It is important to take into account the fact that through IIoT technologies there are no unpromising areas of production today. Every area has enterprises capable (or non-capable) to provide the transition of production according to the smart principles.

Smart enterprises, as components of the smart industry, can be very different in size (small, large, medium) and activity types. These features are not of fundamental importance. The main thing is that all of them represent high-tech flexible cyber-physics production, which provides the accurate adjustment to the individual customers’ demands (delivery time, quantity, quality, costs of production) and are based on the use of big data and advanced digital management methods. So now the top entrepreneurs no longer believe that the transfer of production to countries with cheap labour is an efficient and successful way of doing business. The reason is that now the products must correspond to the production configuration, aimed at satisfying the individual needs and demands of consumers (customers). On the one hand, from now on, the industry can become more localized. On the other hand, development of smart industry means qualitative leap in cooperation and coordination between enterprises, researchers, developers, suppliers, distributors and end users from all over the world through the global computer networks.

In today's world there are different approaches to building of smart industry, that take into account the features of countries’ path dependence, geo-economic positioning, level of R&D, institutional environment etc. Ukraine also needs to consistently develop its own model of IIoT formation and implementation that will be capable to overcome traditional crisis in industry. Besides, as shown by the analysis of the foreign experience in the paper, it is inappropriate to do a "blind" copying of foreign strategies, but Ukrainian government should form its own plan for the transition of national production on a “smart” ground.

Taking into account the current state of affairs, for Ukraine a combined model of building the smart industry, which provides a combination of profitable assets’ optimization (according to the US experience) and the support for the national small and medium-sized business (according to the German experience), can become congruent. Indeed, it is small and medium-sized businesses that are able, under the prevailing conditions, to quickly integrate into the global smart environment, to provide the development and export of the necessary advanced technologies and products for the network industry. The large business differs from the medium and small ones with the possibility to lobby their interests inside and outside the country. That is why the development of large business on the smart principles demands the legislative framework and practical support of "long game rules" to protect property rights, minimize political influence on eco-

nomic processes and exclude rent-based behaviour of dominant owners. All this should ensure the long-term investments in re-equipment of the basic sectors of industry, as well as investments in conducting SRDV.

A priori, it may be noted that the strategic national document on the formation of the national smart industry in Ukraine should contain the following principles, goals, organizational and economic mechanisms:

- definition of smart specialization of Ukraine in the world, taking into account the regularities of the co-evolution of socio-economic, technical, technological, socio-cultural and ecological spatial systems. These patterns are not universal, but depend on the individual circumstances of the country's development in space and time. They are defining the specifics of setting goals and ways to achieve them at this stage;

- formation of a favorable institutional environment for the development of smart industry for acceleration of progressive organizational and managerial, techno-technological and structural-branch transformations through the integration into European Digital Single market and in Digitalizing European Industry [25, p. 9];

- formation of a holistic complex of financial sources and effective lending algorithms for the small and medium-sized enterprises to provide their transition on the "smart" basis;

- a radical increase of the amount of state allocations for holding SRDV and creation the favourable conditions for financial opportunities to involvement of business structures in their implementation;

- development and introduction of upgraded training and retraining STEM-staff programs in accordance with modern technologies, considering the demands of development of smart-industry;

- ensuring the implementation of a set of measures to strengthen national and regional innovation systems, which supports the development of small and medium-sized enterprises for which it is more difficult to compete with international corporations than for the big ones.

But a more detailed substantive content of these proposals requires further, more comprehensive studies.

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РОЗВИТОК СМАРТ-ПРОМИСЛОВОСТІ ЯК ЕФЕКТИВНИЙ ШЛЯХ РЕАЛІЗАЦІЇ ПОЛІТИКИ НЕОІНДУСТРІАЛІЗАЦІЇ У СВІТІ

Розкрито особливості промислового смарт-підприємства (як гнучкого кіберфізичного виробництва, що забезпечує точне налаштування на споживача і ґрунтується на використанні великих даних), а також старт-промисловості. Проаналізовано етапи реіндустріалізації провідних країн на шляху до розбудови смарт-промисловості. Визначено нові перспективи, можливості та проблеми, пов'язані з розвитком смарт-промисловості.

Ключові слова: смарт-промисловість, Індустрія 4.0, Консорціуму промислового Інтернету, смарт-підприємство, промисловий інтернет речей, кіберфізичні виробничі системи, інформаційно-комунікаційні технології, великі дані.

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РАЗВИТИЕ СМАРТ-ПРОМЫШЛЕННОСТИ КАК ЭФФЕКТИВНЫЙ ПУТЬ РЕАЛИЗАЦИИ ПОЛИТИКИ НЕОИНДУСТРИАЛИЗАЦИИ В МИРЕ

Раскрыты особенности промышленного смарт-предприятия (как гибкого киберфизического производства, которое обеспечивает точную настройку на потребителя и базируется на использовании больших данных), а также смарт-промышленности. Проанализированы этапы реиндустриализации ведущих стран мира на пути к построению смарт-промышленности. Определены новые перспективы, возможности и проблемы, связанные с развитием смарт-промышленности.

Ключевые слова: смарт-промышленность, Индустрия 4.0, Консорциум промышленного интернета, смарт-предприятие, промышленный интернет вещей, киберфизические производственные системы, информационно-коммуникационные технологии, большие данные.

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ANALYSIS OF THE WORLD EXPERIENCE OF ECONOMIC AND MATHEMATICAL MODELING OF SMART ENTERPRISES

The paper shows the inevitability of technological mode shift driven by the Industry 4.0, which implies the ubiquitous implementation of information technology, total automation of various processes and creation of cyber-physical systems with artificial intelligence. This requires a complete restructuring of manufacturing systems and production relations, especially in the economies of those countries that want to take a decent place in the new international division of labour of the digital future.

An analysis of the world experience of such changes connected with smart industrialization, digital transformations of the economy, the emergence of the industrial Internet of Things and big data processing made it possible to draw the conclusion that it is necessary to apply economic and mathematical methods to justify the expediency of such transformations: economic validity, as well as physical viability of newly created systems. The use of the apparatus of economic and mathematical modeling allows studying properties of the smart system that is being designed, evaluating its effectiveness and risks, anticipating the emergence of problems and errors – without the risk of incurring significant losses which is inevitable when making direct changes in the object of research.

Therefore, the purpose of this paper is to study the world experience in the economic and mathematical modeling of smart enterprises and to substantiate its use in the conditions of Ukraine.

The review of publications, reflecting the aspects of economic and mathematical modeling in these areas, allowed to conclude that the methodical and methodological apparatus for modeling these processes is unsystematic and inefficient, as well as to formulate recommendations on the economic and mathematical modeling of smart enterprises in Ukraine. In order to take into account the specific features of Ukraine's technological and institutional development, a number of economic and mathematical modeling tools based on the use of production functions, models of inter-branch balance, network optimization models and simulation models based on stochastic dependencies were offered to support the creation of smart enterprises.

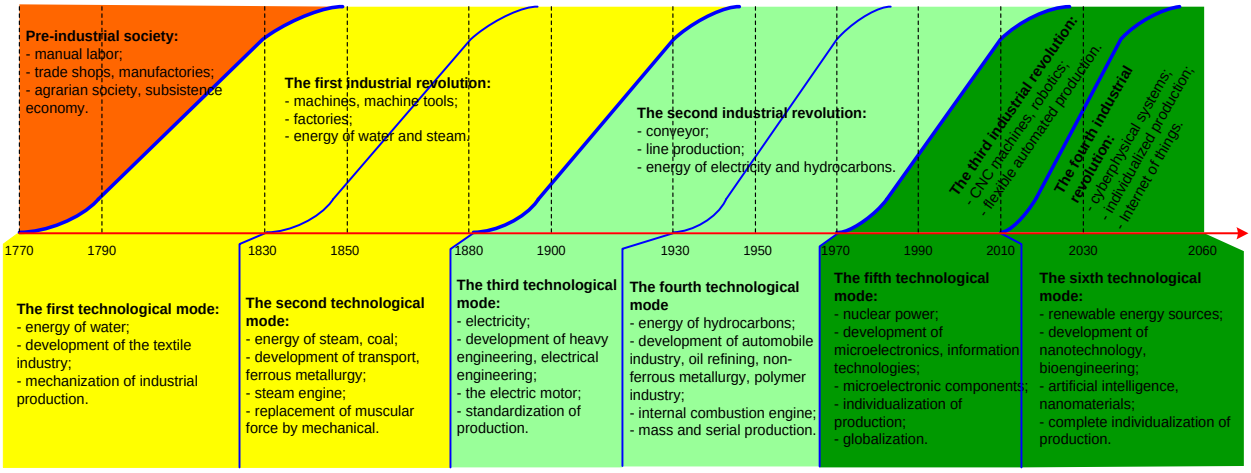
Keywords: Industry 4.0, digital technologies, smart enterprises, big data, economic and mathematical modeling.

JEL codes: C00; C60; C67; C69; O12; O14.

In 2011, at the Hanover Fair, a group of German researchers, businessmen and public figures from the Industry-Science Research Alliance for the development of strategic principles of high-tech production, offered the term "Industry 4.0" and its principles [23].That event marked the comprehension and the beginning of the transition

to a new industrial revolution, based on the ubiquitous application of "smart" technologies that can completely exclude humans from the process of making routine decisions in the area of manufacturing. For several years, these ideas have spread so much in the scientific and business environment that the Fourth Industrial Revolution became the main and dominant topic at the 46th World Economic Forum in Davos [6].

Fig. 1 shows the evolution of world industry development and its relationship with the change of technological modes. The Third and the Fourth Industrial Revolutions are considered by many researchers as two different ones: the Third revolution is the digital revolution associated with the digitization of all processes and the Fourth one is a revolution of cyber-physical systems, associated with the emergence of machines with artificial intelligence. At the same time, there are publications, in which these revolutions are not separated [19], and introduction of technologies of the 5th and 6th technological modes is considered to be the Third industrial revolution, and the key factor in that revolution is the significant change in the role of information and informatization of production processes.



Source: compiled from [5, 22].

Fig. 1. Evolution of the world industry development and its relationship with the change of technological modes

There's certain logic behind that as, firstly, the term the "Third industrial revolution" appeared just 5 years before the "Fourth" one and the principles of manufacturing organization, associated with it, are only beginning to spread across the Western countries (and are still in their infancy in Ukraine). Secondly, it's obvious that the emergence of cyber-physical systems is an evolutionary development of the digitalization process. Therefore, we believe that the concepts of the Third and Fourth revolutions most probably will eventually be combined into a single one, "digital revolution".

In any case, the spread of information technology, comprehensive automation of a wide variety of processes, the discovery of fundamentally new materials and non-waste ways of using them, success in the creation of cyber-physical systems that have artificial intelligence – all that has revolutionized the opportunities in the organization of industrial manufacturing. Ukraine, whose industry uses technologies of the 3rd and 4th technological modes [3], is far behind the Western

countries in its development, and the chances of catching up with them in an evolutionary manner seem doubtful. Nevertheless, while being on the periphery of the world economic processes, Ukraine has no right to remain aloof from these major transformations. The creation of new enterprises, operating the technology of the 6th mode, might allow Ukraine to occupy a worthy niche in the new international division of labour of the digital future.

However, any project, even a local one, requires careful justification of its suitability. First of all, from the point of view of the physical viability of the designed system in the environment in which it will exist. The creation of the most modern smart enterprise in the conditions of a corrupt system, undeveloped institutions, contractors working according to old principles, undeveloped culture of using information technologies, might actually lead to nonviability of such an enterprise. Another aspect is the economic feasibility: the costs of creating such enterprises should be justified, and the efficiency of their operation has to exceed the efficiency of the current ones. However, in the above mentioned conditions, such efficiency is not always achieved. Therefore, the transition to a new smart production system and measures to transform production relations should be carefully justified, and economic and mathematical modeling is the most effective tool for describing the systems and processes being designed. The use of the apparatus of economic and mathematical modeling makes it possible to conduct any experiments with the system being designed, study its properties, evaluate efficiency and anticipate the occurrence of problems and errors without the risk of incurring colossal losses that are unavoidable in the case of direct experiments.

The apparatus of economic and mathematical modeling is currently developed enough to describe any, even the most complex processes and systems, however, the novelty of the tasks to be solved when creating smart enterprises does not allow making an unequivocal choice in favor of using certain specific tools. In order to choose the most effective and expedient tools of economic and mathematical modeling, it makes sense to study the foreign experience of applying these methods in the creation of smart enterprises, since the developed countries are way ahead of Ukrainian reformers and already have certain empirical knowledge in this field.

Therefore, the *purpose of this article* is to study the foreign experience of economic and mathematical modeling of smart enterprises and the rationale for its use in Ukrainian conditions.

The following concepts, associated with the digital revolution can be distinguished, which have a certain synonymous character:

– «*the Fourth industrial revolution*» [35], practical manifestations of which are the intensification of information exchange in production, the Internet of Things, cyber-physical systems and cloud computing [38];

– «*Industry 4.0*» (German"Industrie 4.0"), which is used in Germany to describe the Fourth industrial revolution [33];

– «*smart factory*» or «*smart enterprise*» – modular, structured factories, in which cyber-physical systems control physical processes, create a virtual copy of the physical world, and make decentralized decisions [34];

– *«cyber-physical systems»* (CPS) – hardware and software systems, being a close interlacing of the physical and virtual world. Such systems are formed by network of embedded systems that are connected to the outside world using sensors and drives, receiving data streams from the physical world and creating and constantly updating the virtual copy of the physical world [29; 44];

– «*Internet of Things*» [24] (IoT) – information networks of physical objects (objects, goods, machines, cars, buildings and

other objects) that ensure the interaction and cooperation of these objects for achieving common goals;

– «*Industrial Internet of Things*» [36] (IIoT) – an information network that, among other things, connects transport and industrial production (digital product views, cyber-physical systems of smart factories, etc.).

Before analyzing the economic and mathematical models of smart enterprises, it is necessary to classify all the variety of publications, concentrated on the problems of their implementation and functioning, and to highlight the areas that make sense studying within the scope of the scientific research on identifying the smart industry development directions in Ukraine.

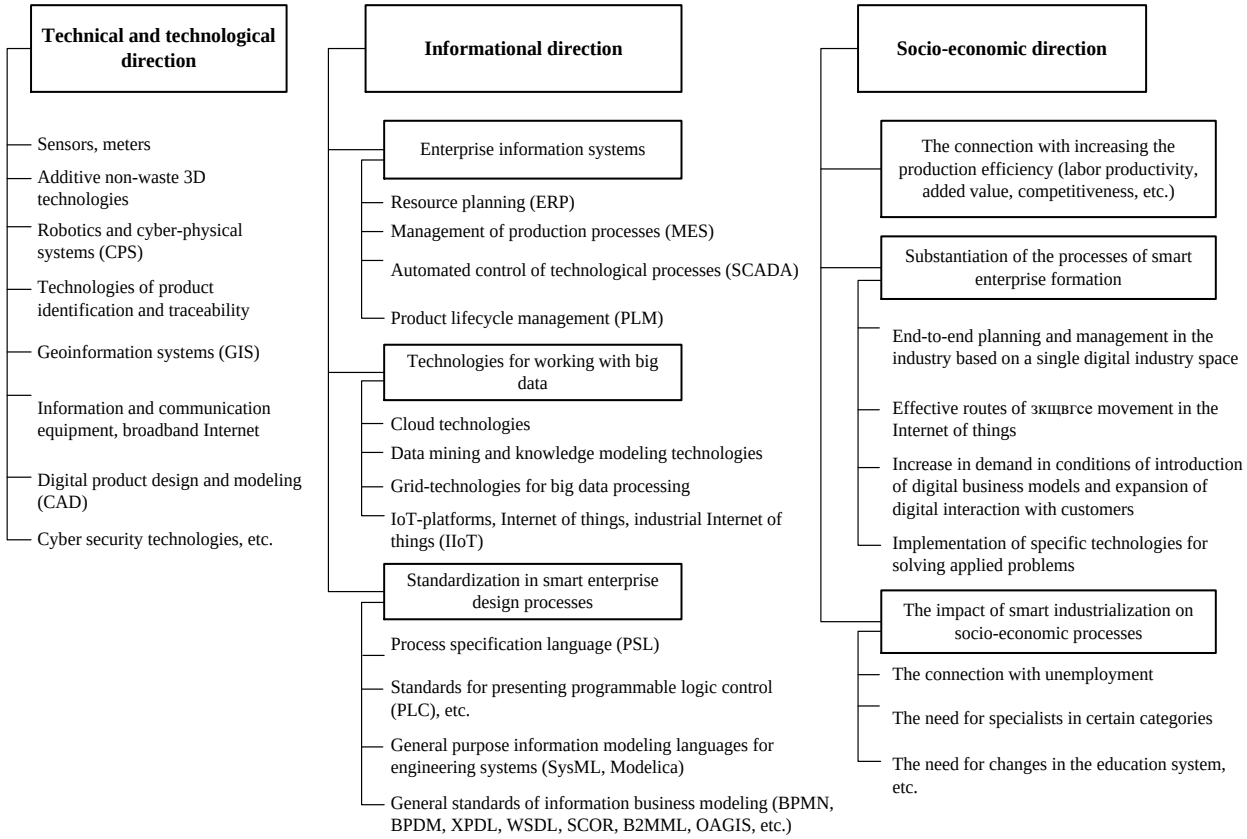
According to the ***objects of research***, the following directions of such publications can be highlighted:

1) technical and technological direction, associated with the design and implementation of high-tech physical systems;

2) information direction, associated with the accumulation, processing and transmission of information;

3) economic direction, associated with changes in the provision of benefits and economic interests of individuals and social groups.

In a closer look, the following objects of study can be identified in these areas (fig. 2).



Source: compiled by the authors

Fig. 2. The main focus objects in the publications on smart industry

Also, all the variety of publications, concerned smart enterprises, depending on the goals that are pursued in a publication, can be divided into following ***tasks to be solved***:

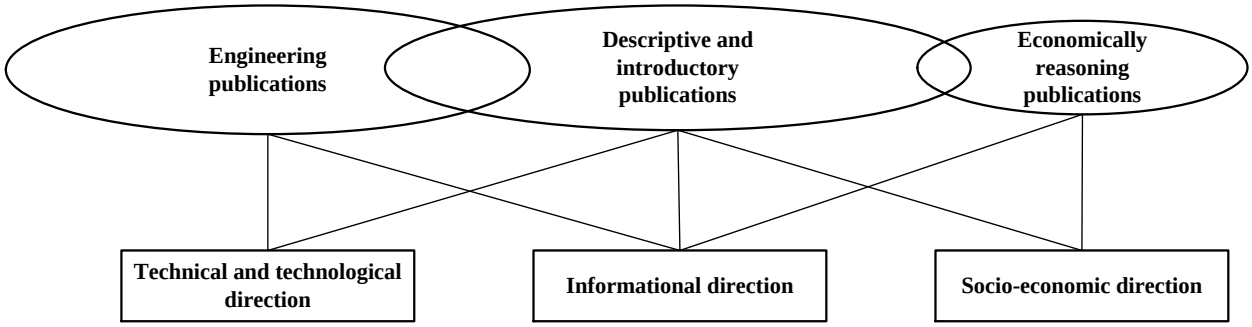
1. *Descriptive and introductory* – the purpose of which is to familiarize the reader with certain objects or phenomena in the smart industrialization. Such publications are not relevant to economic and mathematical modeling, but their subject enables identifying problems that can be solved using such methodological tools.

2. *Engineering* – the purpose of which is to describe the processes. Such publications present numerous descriptions of various models, including mathematical ones, but these models are of engineering nature and solve no economic problems. However, as in the previous case, their analysis enables identifying the occurrence of accompanying economic problems.

3. *Economically reasoning* publications, which confirm the economic feasibility of implementing certain processes, associated with smart industrialization, or substantiate the emergence of new tasks, representing economic and social problems. Such publications directly relate to the subject of this study, but are scarce in number, often inconsistent and are unable to adequately solve the problems.

The publications of the second and third groups usually also include a descriptive-introductory part and thus may overlap with the publications of the first group. However, we were unable to find publications that would represent an intersection of the first and the third group, which would have considered the problem of the engineering design of smart enterprises through the prism of solving economic problems.

Fig. 3 shows the relationship of the nature of publications according to the tasks they solve with their directions according to the objects of research.



Source: compiled by the authors

Fig. 3. Relationship of the nature of publications according to the tasks they solve with their directions according to the objects of research

Let's begin the overview of publications on smart enterprises with *descriptive and introductory studies* related to the identification of objects and their functioning, since these publications form a basic representation of the way such enterprises function.

According to [31], 4 principles of "Industry 4.0" design are distinguished:

– *interaction*: the ability of machines, devices, sensors and humans to connect and interact with each other via the Internet of Things or the Internet of People;

– *information transparency*: the ability of information systems to create a virtual copy of the physical world by filling digital models of enterprises with sensor data. This requires aggregation of raw sensor data into context information with a higher level of usefulness;

– *technical assistance*: firstly, the ability of support systems to help humans by

aggregating and visualizing information to make informed decisions and quickly solve urgent problems in a short time; secondly, the ability of cyber-physical systems to physically support humans by performing a number of tasks that are unpleasant, physically exhausting or dangerous to humans;

– *decentralized decision-making*: the ability of cyber-physical systems to independently make decisions and perform their tasks as autonomously as possible. These tasks are transferred to a higher level only in case of abnormal situations, interference or conflicting goals.

Authors of [34] mention three areas of "smart enterprises" that distinguish them from traditional ones:

1. *Monitoring and control*– monitoring and control systems implemented at smart enterprises in real time collect and transmit a wide range of data on the status of enterprise facilities, their operation, the use of resources, and the state of their environment, which allows them to react quickly to changes.

2. *Information exchange and interaction*– the modern information infrastructure allows exchanging large volumes of information between humans and humans, humans and physical objects, as well as between physical objects without human intervention. Often the components of information exchange and cooperation are combined with monitoring and management components, initiating the exchange of information or certain actions in the event of a certain situation detected by sensors. Such capabilities allow production management automation, when human intervention will be necessary only in cases of certain events' occurrence, and rest of the time the exchange of information is limited to physical objects.

3. *Big data and data analysis*– collecting large amounts of data on the status of objects, processes and the environment, and increasing the capacity of data processing systems make it possible to expand the use of analytical tools to improve business processes at all stages, including the development, production and sales.

Given this, the following criteria can be used to classify an enterprise as a smart enterprise: the use of intelligent sensors for monitoring and processes control; automation of information exchange processes and interaction of workers with each other, workers with physical objects (mainly with machines and computer systems), as well as physical objects with each other; use of big data for continuous analysis and process improvement.

Thus, the key factor in the modeling of smart enterprises is the work with big data, the research of which is the topic of a large number of publications, related to smart industrialization.

The use of big data, which, along with the software of cyber-physical systems, forms the basis of information support for the smart industry, is associated with significant difficulties in their processing using traditional methods. Such a complexity is explained not only by the large amount of data, but also by their unstructured nature (the collected data is not generated initially in accordance with the rules for database design), the lack of centralization of collection and processing (data from a variety of different sources can be used), and the weak relationship within the data itself (data from different fields of activity). In [40], big data is defined as data sets with sizes beyond the capabilities of typical database management software to collect, store, manage and analyze data.

In a review article [32], the lifecycle of big data consisting of four stages (generation, collection, storage and analysis) was analyzed, and the main approaches and tools that can be used at each stage are considered. Similar to other publications on this topic, the main problem of analyzing big data is defined as their initial absence of pattern (which not only makes it difficult to collect and store such data, but also makes it

impossible to use traditional structured databases), and modeling, visualization, optimization and forecasting are mentioned as the main areas of using big data in practice.

Analysis of big data to obtain practical conclusions is directly related to data mining technologies. Data mining is a collective name, served to denote a set of methods used for detecting previously unknown, nontrivial, practically useful and accessible interpretations of knowledge that is required for decision-making in various areas of human activity [15].

In [48], the following main areas of development of big data and the scope of big data use in the industry are offered:

– new and improved methods for analyzing big data and data mining;

– cloud solutions, related to the storage and transmission of big data;

– use of big data in control and monitoring;

– data-driven optimization and forecasting within manufacturing systems;

– data-driven solutions for supply chain development and risk management;

– the use of the theory of big data in modern industrial applications;

– big data-based solutions for intelligent power transmission networks and clean energy systems.

As a part of implementing data mining in manufacturing management, the authors of [30] propose a platform for advanced manufacturing analytics to eliminate such shortcomings in existing approaches, as isolated consideration of individual data sets, limited tools, insufficiency of reporting and visualization tools, the lack of mechanisms for obtaining specific recommendations, based on results of analysis. Such platform includes three levels:

1. *Process optimization* – involves the use of analytical findings, obtained at level 2 to improve manufacturing processes.

2. *Process analysis* – includes various ways of processing data, collected at level 3, including data mining. The results are stored in the manufacturing analytics repository.

3. *Data integration* – includes a manufacturing data warehouse, which reflects all the data, obtained during the manufacturing process (all aspects of the manufacturing process).

The authors offer two approaches to improving manufacturing processes using big data: optimization of manufacturing processes based on indicators (involves changing the parameters of processes, taking into account the conclusions derived from the analysis) and the optimization of manufacturing processes on the basis of templates (represents the development of the approach to the optimization of manufacturing processes on the basis of indicators by using templates that include sets of indicators for a particular application in the context of time and elements of the manufacturing process).

As a tool for data analysis, it is proposed to use standard models and methods, such as *neural networks, reference vectors, decision trees, Bayesian classifications* and the creation of *decision making rules*. The main advantage of the abovementioned approach is the accentuation of levels of big data use in the improvement of manufacturing processes and the emphasis on the need to create repositories of manufacturing analytics. The shortcomings include the absence of specific models or authorial ways of decision-making support.

With regard to the processing of big data, the main approach, currently used for the distributed processing of large amounts of data and promoted by such major companies as Google and IBM, is the MapReduce architecture [18]. Within the framework of this architecture, the array of input data is processed using the user-defined "map" function (that assigns a value to each attribute called a "key", for example, the frequency of attribute’s occurrence in a specific document) and "reduce" function (folds the "key-value" pairs by summarizing the key values for each characteristic from an array

of intermediate data). The user has to specify the data sources, specify the required attributes (keys), the rules for assigning values to the keys (the map function), and folding rules (the reduce function). In turn, the data processing systems form data packets and distribute the execution of these functions on the data packets among the hardware. This approach allows processing data arrays, which even theoretically cannot fit in the RAM or hard drives of individual computers, creating a basis for distributed processing and analysis of big data.

In [41], the use of big data in manufacturing is analyzed, and the conclusion is made that data has become an important production factor along with tangible assets and human capital, and big data allows companies to create new and improve existing products and services, and invent completely new business models.

This conclusion is backed by empirical studies of the McKinsey Global Institute, which provides the following facts about big data as of 2011 [40]:

– the volume of data created increases by 40% each year, while the IT infrastructure spending increases by only 5%;

– the additional need for advanced data analytics professionals in the US alone is about 200 thousand people, and the need for senior specialists with data processing skills is about 1.5 million people;

– big data allows increasing the profitability of retail enterprises by 60%;

– the potential economic effect of the comprehensive use of big data in the US healthcare system is USD 300 billion.

The same paper distinguishes the following mechanisms, by means of which big data creates economic value [40, *p.* 5]:

– *ensuring transparency* – the very fact of relevant stakeholders being able to access big data in a timely manner makes it possible to obtain a significant economic effect;

– *the ability to conduct experiments* to identify needs, analyze variability and increase productivity – by digitally collecting and storing large amounts of data about their activities, organizations can collect more accurate and detailed data in real or near real time about all areas: from inventory to staff sick leave days, which creates the conditions for modeling and forecasting the relevant aspects;

– *customer segmentation* and individual solutions – big data allows organizations to segment and adapt their products and services with high degree of precision to meet the needs of specific customers;

– *replacement / support of human decision making* using automated algorithms – in-depth analytics can significantly improve the decision-making process, minimize risks and discover valuable ideas that are hidden from the attention of a researcher, who is not armed with big data;

– *development of new business models, products and services*– manufacturers can employ data on the use of existing products to improve and develop the next generation of products and create innovative offers in the field of after-sale services.

The general conclusion is that in the near future the use of big data will be a key factor of competitiveness in all sectors of the economy, including industry.

Analysts of the McKinsey consulting company [25] indicate that industries with the maximum potential for the introduction of analytics, based on big data, are pharmaceutical, chemical and mining. In these industries, in the opinion of the authors, minor changes in the characteristics of the process can significantly affect the result, which creates the conditions for the application of "advanced analytics" – the processing of economic data with the help of statistical and other mathematical tools for evaluating and improving various areas of activity.

A number of publications, which will be discussed below, are of engineering nature and consider the models of the functioning of smart enterprises or certain aspects of their functioning, the mechanisms

of transforming regular enterprises into smart ones, and the methods of economic and mathematical modeling associated with these processes. We will omit the analytical part of the publications, which is devoted to purely technical aspects, associated with the introduction of cyber-physical systems (see the technical and technological block in the Fig. 2), and will review the most informative publications of that group.

Traditional approaches to centralized control and rigid management are unable to cope with the vast ecosystem of networked systems that are becoming increasingly widespread in the economy as a whole and in the manufacturing sector in particular, which requires the use of modeling tools to predict the behavior of such systems in certain situations and develop optimal control inputs. However, since simulation and modeling tools are usually created for application in a particular field, it's difficult to develop such models, since both physical and cybernetic aspects of such systems need to be modeled [28]. The modeling of cyber-physical systems uses simulation tools such as *hybrid Petri nets, hybrid automata and hybrid processes, aggregated modeling techniques (including such tools as Dymola and gPROMS)* [44].

It should be emphasized that in this case we are talking about the modeling of cyber-physical systems, and not about modeling the economic aspects of the functioning of enterprises, which use such cyber-physical systems in their manufacturing processes.

One of the main modeling trends in the last few years has been the use of the advantages, provided by the modern programming languages and development tools [4]: object orientation, class libraries and visual design environments. Modelica, which is one of the most popular tools at the moment, is a visual modeling environment that includes the Modelica universal object-oriented language for modeling complex physical systems and such tools as Dymola or MathModelica. The Dymola (Dynamic Modeling Laboratory) package supporting Modelica modeling language is a complex tool for modeling and research of complicated systems in such areas as mechatronics, automatics, aerospace research, etc. [27]. The ability to combine components of a different physical nature in one model makes it possible to build models of complex systems that better mirror the reality and to obtain more accurate and transparent results.

The critical importance of the development of cyber-physical systems was noted in [13] from the point of view of national interests and, first of all, for the creation of new digital products with unprecedented economic efficiency. However, calculations of the consequences of the influence of digital technologies on the economy are carried out on the basis of individual, practical experience of functioning of existing digital manufacturing systems, without using the tools of economic and mathematical modeling. The paper emphasizes that the model, used in the management system, is the key one in cyber-physical systems, the viability and functionality of cyber-physical system depends on how that model relates to reality. The reality of the world is embodied in the form of models and data populated in them, so in order to create systems that can work in the real world, a new discipline is required – *model engineering*. With the purpose to understand the new ideology of product lifecycle management (PLM), it's necessary to combine the building information model (BIM) with the manufacturing information model (PLC), which forms a completely new quality. As we can see, the authors of [13] pay considerable attention to the modeling of cyber-physical systems, but mainly to engineering modeling.

The Chinese authors in [50] argue that the modeling of digital manufacturing (which in the context of the work in question is equal to smart manufacturing or manufacturing at smart enterprises) doesn't require any specific approaches to model-

ing – it uses standard modeling methods. The lifecycle of the digital manufacturing model includes data collection, data processing, data transmission, monitoring, interaction management and decision support. It consists of an ordered series of models, which typically includes a product development model, a resource model, an information model, a control and management model, an organizational model, a decision-making model, etc. "Ordered" means that these models are built at different stages of the lifecycle of the digital manufacturing system [50, *p.* 24]. Objects of modeling are products, resources, information, organizational aspects, decision making, production process and network environment (interaction models). Thus, the authors suggest using standard modeling tools and models, *including process models, object models, structural models, Petri net models* [49], *optimization models*, etc.

Petri nets are used to model asynchronous systems that function as a set of parallel interacting processes. Analysis of Petri networks allows obtaining information on the structure and dynamic behaviour of the simulated system. However, the prospects for the practical application of Petri nets in the modeling of smart enterprises belong to the technical rather than the economic field, in particular, in the field of modeling manufacturing processes, as well as the processes of data collection and processing.

Optimization modeling [12] has a significant potential for practical application both in substantiating general directions of introducing smart technologies, and in selecting and planning specific measures. Its application enables designing mathematical models for solving a wide range of both technical and economic problems, involving the allocation of limited resources to alternative uses, choosing from a list of alternative options, scheduling certain measures in time, etc. The optimization model consists of an objective function capable of taking values within an area, limited by the task conditions (areas of admissible solutions), and constraints, characterizing these conditions. The objective function consists of three elements: controlled variables, parameters (that can't be controlled, for example, those depending on the external environment), and the shape of the relationship between them (the shape of the function). In general, an optimization model is represented as follows:

$$\begin{cases} U = f(x_i, y_j) \to max \ \ or \ min; \\ x_i = A, x_i > A \ or x_i < A. \end{cases}$$

where

U – the objective function, for which a maximum or a minimum is sought, depending on which indicator is chosen as the criterion;

x_i – controlled variables, for which there are optimal values at which the objective function would reach the desired extremum, $x_i \in \{X\}$ – the set of controlled variables;

y_i – parameters, used in calculations in the form of fixed values (constants), $y_i \in \{Y\}$ – the set of constants.

When modeling smart enterprises, optimization models can be used to select technologies for implementation, to determine the optimal parameters of technological processes or investment projects, and to solve other problems related to the choice of available alternatives.

In [1], models of *digital transformation of the industry* at the macro-level are presented in the framework of process, sectoral and technological approaches. The model of the process approach is based on viewing the industry as an industrial chain – from the development of industrial products to their sale and service. The elements of digital transformation of the industry include: digital R&D center, digital factory, digital storage and transportation, electronic commerce and digital services. It's noted, that the creation of the Eurasian technology transfer network and the Eurasian network of industrial cooperation and subcontracting

can become effective tools for digital transformation of industry.

The industry-specific approach to digital transformation of industry is based on the industry's connection with other sectors of the economy and includes the following digital industrial markets: food and water production and delivery systems, intelligent resource extraction systems, digital (smart) factories, distributed power systems, unmanned automobile systems, unmanned aerial vehicles, digital railway, telemedicine, personal medicine, smart houses, smart roads, digital financial technologies, safety systems, e-commerce, e-education, digital culture and the media.

The model of the technological approach to the digital transformation of the industry includes a set of technologies that form a digital agenda in the industry: IoT and industrial Internet, digital design and modeling, quantum technologies, big data, element base (processors), robotics, sensors, meters, additive 3D technologies, cloud technologies, supercomputer technologies.

This set of technologies is open and can be expanded. At the heart of virtually all technologies are software and hardware, the core of which is software and microelectronics. Broadband Internet access is of key value for the development of digital transformation of the industry. According to Swedish scientists, doubling the average speed of the broadband Internet access in a country increases its GDP by 0.3%. According to the authors of the study [1], an increase in GDP by 0.3% in OECD countries will lead to an increase in the world economy by USD 126 billion. Historically, this is about 1/7 of the average annual growth rate in OECD countries over the past ten years.

It should be noted, that in paper [1] the models of digital transformation of industry within the framework of process, sectoral and technological approaches are presented only in an object form. It lacks economic-mathematical models of digital transformation of industry, but is devoted to the ways of supporting such initiatives in the field of modeling:

– through the introduction of information modeling in the field of industrial and civil construction (BIM-systems). In such way authors offer to encourage projects, aimed at creating and implementing automated process control systems (ACS) in the industrial sectors, including supervisory control and data collection systems (SCADA);

– through the development of mathematical modeling and design of mathematical models for use in industry and engineering.

As for micro-level models, the so-called "S-Model" of digital manufacturing is proposed in [43], where "S" symbolizes statistical processing and simulation (modeling). Within the framework of this model, a closed cycle digital manufacturing system with an autonomous statistical analysis module and an autonomous modeling module for discrete events is offered to create a flexible and efficient value chain. To interact with personnel in this model, it was suggested to use the forecast panel and an interactive production planning interface. That model is not an economic-mathematical model, but rather the author's vision of the use of econometric models in manufacturing control: for example, based on the analysis of statistical information it’s proposed to predict crises (equipment failure), demand, and other factors, and make manufacturing planning interactive and adjust it in real time, using the appropriate interface.

Pharaos Navigator [46] is one of examples of practical implementation of the smart enterprise concept, intended for enterprises of various areas of activity (manufacturing, services, etc.). It allows visualizing the operation of a smart enterprise, displaying in a visual form the results of data collection from smart sensors on all equipment and thus allowing the management to receive real-time information about the operation of the enterprise.

In the paper [14], the main focus is on standardizing the processes of digital transformation of industry, as well as the matters of information modeling of manufacturing systems. And the standards are considered as a link between information models and manufacturing at a factory through design systems. Two sets of international standards, specific for modeling manufacturing systems and data exchange are described: the standards of manufacturing resources and processes and the standards of construction/facility modeling. The paper describes the characteristics of standards and their purpose for information modeling. The analysis of paper [14] showed that the main focus is on *standardization of information and engineering modeling of manufacturing systems* for the purpose of digital transformation, but the matters of standardizing economic and mathematical modeling of smart enterprises and economic problems solved at the stage of their formation are not sufficiently investigated.

The paper [21] investigates the consequences of introducing new technologies and creating of smart enterprises, such as technogenic catastrophes, serious manufacturing problems, caused by stealing of confidential data, as well as complete collapse of manufacturing process. The authors of the paper note that new cyber defense tools can't be tested in real manufacturing conditions, since this may entail a slowdown and even stop manufacturing processes, which is completely unacceptable for business. For this reason, this kind of work includes a stage of applied research, at which engineers use special equipment that simulates real manufacturing processes to the best possible extent. Research [21] deals not only with the issues of ensuring information security, but also assessing the impact of cyber defense tools on the productivity of industrial enterprises, which also needs to be taken into account in the economic and mathematical modeling of smart enterprises.

The most interesting from the point of view of economic and mathematical modeling are the papers, devoted to the economic justification of the efficiency of the introduction of the smart industry and its impact on the economy of the country and socio-economic processes.

Let's begin analyzing this direction with paper [45], in which, based on a survey of a number of Dutch companies operating in various areas, it's concluded that companies are actively engaged in the implementation of elements of the smart industry, and the larger the company, the more actively it works in this area. It focuses on the fact that the introduction of digital technologies affects all aspects of a company's operation: products, manufacturing processes, etc. Nevertheless, the work doesn't provide any calculations or even assessments made by the interviewed companies regarding the qualitative or quantitative indicators of the introduction of smart technologies or the economic effect of their implementation. This work is indicative, as it illustrates a whole layer of works on this topic, in which it is possible to distinguish several elements: a short or a more extensive listing of smart industry definitions, such as digital technologies, big data, etc.; a set of statements declaring that it is very important and promises various advantages; if a model or system is declared, in most cases, it's represented by a rather abstract drawing. At the same time, there are no calculations, economic and mathematical models or analysis of statistical data. Thus, the overwhelming number of works on smart industry, in the same manner as the abovementioned paper [45], are devoted to convincing the reader in the importance of this direction, but lack any scientific or practical novelty.

The following few works are a rare exception to the indicated trend.

For example, in a Korean study on the impact of the smart industry on urban development and the country's economy in general [37], the following approach was

used: the main industries are picked which are suppliers and consumers of smart products (primarily computer equipment, microcircuits, industrial automation, communication equipment, etc.) and on the basis of input-output tables, the impact of demand for such products on the production volumes in the city, employment, added value, etc. was analyzed. An unconditional advantage of this work is an attempt to give a numerical assessments of smart manufacturing (as opposed to the abstract approach seen in many other works), as well as the fact that a specific list of smart products was compiled. On the example of the implementation of the smart cities development program in Korea, the corresponding economic effect is shown – an investment of USD 10 million in such a program allowed increasing output by USD 19 million due to an increase in demand in related industries. The drawback of this work is that there has been no comparison of investments in the smart industry with investments in other industries, as a result of which there was no answer to the question of whether a USD 1 investment in the smart industry gives a greater or lesser effect than a USD 1 investment in traditional industries.

Based on the statistical data on the US industrial enterprises, paper [26] analyzes the impact of data-driven decision-making on the value-added created by an enterprise and concludes that the introduction of data-driven decision-making increases the value added by 3% on average. Such an estimation is made using *regression analysis on the basis of a production function (similar to the Cobb-Douglas function)* with the added value as the dependent variable and labour productivity, capital, labour resources, energy consumption, IT-capital (in the form of cost of hardware and software), measure of structured management (the degree of autonomy of mid-level staff in decision-making) and data-driven decision-making as factors.

Authors propose the following model:

$$Y_{it} = A_{it}K_{it}^{\propto}L_{it}^{\beta}E_{it}^{\gamma}IT_{it}^{\lambda}e^{\mu SM_{it}}e^{\eta X_{it}}e^{\delta DDT_{it}},$$

where

Y_{it} – actual value added (output – material costs);

A_{it} – productivity;

K_{it} – capital value at the beginning of the period;

L_{it} – labour (number of employees);

E_{it} – consumption of energy resources;

IT_{it} –value of IT assets (hardware and software) at the beginning of the period;

SM_{it} – measure of structured management;

X_{it} – additional factors, such as the industry and the level of education;

DDD_{it} – measure of data-driven decision-making.

Among the advantages of the approach is the attempt to analyze the impact on production efficiency, based not just on investments in the IT infrastructure, but specifically on the use of data analysis results in decision-making. Among the shortcomings of the offered approach is the abstractness of the very concept of "data-driven decision-making", as well the fact of using data-driven decision-making as a factor in the model (for each particular enterprise this parameter can be estimated as 0 or 1) that is established according to the results of the survey carried out at enterprises, therefore the question of the intensity and directions of using such an approach remains unanswered. In addition, one of the disadvantages is the inclusion in the function of such poorly assessable factors as structured management and data-driven decision-making, as well as the use of the number of employees as the indicator of labour resources.

From the point of view of the prospects for the introduction of smart technologies in specific industries, worthy of interest is the vision of such perspectives by management of the metallurgical industry, as reflected in the results of a survey, conducted by the PwC consulting agency

among more than 2,000 respondents from the nine main industrial sectors and 26 countries [17]. According to the management of metallurgical enterprises, the introduction of digital technologies increases the maneuverability of supply chains, promotes a deeper understanding of processes and increases the level of capacity utilization. Automation combined with data analysis is used to ensure flexibility and manufacturing efficiency. To improve productivity, algorithms are used to trace the relationship between the physical properties of raw materials, used for manufacturing and manufacturing costs, as well as factors that limit the production activity of enterprises. Then, integration of previously specified processes is performed, which allows reducing heat losses, energy consumption, manufacturing time, stock level, and optimizing prices. In general, the management of metallurgical enterprises expects that in 2016-2021 the introduction of digital technologies would be increasing revenue by an average of 2.7% per year and reducing costs by an average of 3.2% per year. All that confirms that the introduction of digital technologies is in demand in industry in general and in metallurgy – in particular, and the management of enterprises places high hopes in it.

In conclusion, the study proposes the following sequence of steps to turn the enterprise into a smart one:

1. Development of an individual strategy for implementing the concept of "Industry 4.0".

2. Development of the first pilot projects.

3. Assessment of the necessary resources.

4. Implementation of data analysis.

5. Transformation of the company into a digital enterprise (comprehensive implementation of digital technologies).

6. Active planning of the ecosystem approach (cooperation with the market environment – suppliers and consumers).

In paper [7] attention is paid to the impact of digital transformation (digital technologies, the Internet) on the labour market and labour productivity. It is noted that some of the perceived benefits of digital technology are compromised by the risks that arise. Many economically developed countries are facing increasing polarization of labour markets and growing inequality – in part because new technologies complement more skilled work and, at the same time, replace standard labour operations, requiring many workers to compete with each other for low-paid jobs. In the absence of accountable institutions, public investment in the development of digital technologies strengthens the influence of the elites, which can lead to subordination of policy to the interests of the establishment and to increased state control. The digital revolution can generate new, profitable business models for consumers – but not where the established companies control the entry to the market. Technology can increase the productivity of workers – but not where they do not have the skills and knowledge, necessary for its application. Digital technology can help control the presence of tutors in the workplaces and improve academic performance – but not where education system is not accountable.

Despite the fact that a fairly modest number of jobs are created directly in the area of digital technologies, these technologies contribute to the creation of a considerable number of jobs in other areas. This way, in Kenya, the digital payment system M-Pesa provides additional income for more than 80,000 of its agents. And according to the China State Information Center, the recent rapid growth in the e- commerce sector in the country has led to the creation of 10 million jobs in online stores and related services, which is about 1.3% of total jobs in the country.

If digital technologies promote economic growth, how are these benefits allocated on the labour market? Although digital

technologies increase productivity and overall well-being, labour market turmoil can turn out to be unhealthy and lead to increased inequality. Thus, another area for the use of economic and mathematical modeling of digital and smart enterprises is to assess the impact of digital technology on the labour market, employment structure and labour productivity.

In general, the nature of publications on the modeling of the smart industry and the processes of its implementation, is unsystematic, fragmented and incomplete. That is a consequence of the fact that this scientific direction is still on the early stages of its development, there are no established concepts for the introduction of the smart industry and its modeling, and existing examples of practical implementation of smart enterprises are based more on heuristic methods, rather than on accurate mathematical justifications. As can be seen from the above analysis, most of the publications, devoted to the development of the smart industry, are either descriptive and introductory, or view this process from the engineering point of view, which mainly covers technical, technological and informational directions (Fig. 2). A few mathematical models, which are mentioned in them (but are not given explicitly) are strictly of applied nature and solve technical problems.

Publications, which consider the economic aspects of Industry 4.0, are generally scarce. At the same time, even if certain mathematical justifications for some conclusions are present, most often they're of empirical descriptive nature, based on existing observations, and the methodological variety of economic and mathematical models used at best covers correlation-regression analysis.

However, it should also be noted that the conditions for smart industrialization in Ukraine are significantly different from those in the countries of the West. This not only includes technological lagging, but also the weakness of state institutions, insecurity of capital and investment, unpredictability of state policy (in such areas as taxes, finance, trade, international relations, etc.), the virtual lacking of financial support from the government, corruption in all areas of potential stakeholders' activity. More details about the peculiarities of technological and institutional development of Ukraine can be found in [2; 8-11; 16; 20; 42; 47].Thus, the peculiarities of the functioning of the Ukrainian economy, the specifics and the level of development of its institutions make it senseless to directly use the Western experience of smart industrialization in Ukraine and requires a more thorough scientific justification for the feasibility and cost-effectiveness of implementing measures for the development of the smart industry in Ukraine.

As noted in the study of the Commonwealth of Independent States (CIS) Executive Committee on the status, problems and prospects for the development of the information society, it's necessary to develop new methods to ensure the efficiency of informatization processes in the Commonwealth states that will allow a person to correctly understand and explore the new highly dynamic information picture of the world that opens before them [20].Undoubtedly, methods of economic and mathematical modeling, which allow obtaining objective and unbiased quantitative justification, should play a prominent role among such methods.

Based on the carried above analysis of the current trends in the study of smart industry development in the West and taking into account the peculiarities of the Ukrainian economy, the following promising areas of economic and mathematical modeling of smart enterprises can be highlighted.

1. First of all, we are interested in the development of the macroeconomic production function in connection with the transition to the neo-industrial smart economy. The use of methods of economic and mathematical modeling makes it possible to theo-

retically substantiate the qualitative changes of this function in connection with the emergence of new technological combinations of classical factors of production, and the possible emergence of a new production factor in the form of informatization or artificial intelligence.

It is possible to propose several specifications of the enterprise production function with the account for the effect of this new factor (denoted by *I* below) using:

– multiplicative function (similar to the Cobb-Douglas function):

$$y=\alpha_0 K^{\alpha 1} L^{\alpha 2} I^{\alpha 3},$$

where production factors are presented in the natural form;

– additive-multiplicative shape:

$$y=a_1 K+a_2 L+a_3 I+a_4 KL+a_5 KI+a_6 LI+a_7 KLI,$$

where the factors of production are presented in a standardized form.

The second version might be more informative for static models, since it's able to reflect the various multiplicative effects, obtained from different combinations of factors. If we consider the development of the production function in the dynamics, the first variant might be more informative, since there are reasons to believe that the parameter $\alpha 3$ is described by a time-dependent S-shaped curve, for example, the Gompertz curve or the logistic curve:

$$\alpha 3 = \frac{1}{1+be^{-at}}.$$

The choice of the *S*-shaped curve is due to the avalanche-like character of informatization processes, and, possibly, the development of artificial intelligence, when increments depend on the level reached, and in the beginning they increase with the acceleration of development, and then, upon saturation, they decelerate.

Parametrization of models in the first and in the second cases is possible using the standard methods of regression analysis, namely using the method of least squares (in the first case, the equation must be transformed by logarithm).

Another direction in the use of economic and mathematical models of smart enterprises has a more practical focus. They make it possible to do the following.

2. Different variations of the Leontief input-output model and the inter-branch balance which can be used to solve at least three problems:

- end-to-end planning and management of the industry, based on a common digital industry environment;
- selecting enterprises that require priority digital integration, estimating losses from retaining "unsmartized" participants in the value chains, etc.;
- increasing demand in the context of introducing digital business models and expanding digital interaction with customers by reducing transaction costs.

Both natural and monetary values can be used as the coefficients of the technological matrix of the input-output model. When using monetary terms of the cost factor, it's possible to distinguish certain cost components, for example labour costs (l_{ij}), transport costs (tr_{ij}), transaction costs, associated with intermediate and final consumption of products (z_{ij}). In the same way, the time factor (t_{ij}) can be considered to be a cost element, associated with the value chain.

That opens a whole block of optimizing tasks that allow identifying the interconnected industries and consumers that are most in need of integration on the basis of a common digital industry environment.

Let's consider one of the versions of the general mathematical formulation of such problems.

We'll assume that the costs z_{ij} in the inter-branch balance model can be lowered by virtue of smartization of the manufacturing in branches *I* and *j*:

$$z'_{ij} = z_{ij} (1 - S_i S_j),$$

where S_i, S_j – a certain level of enterprise smartization, measured by a value in the range (0; 1).

(Moreover, we'll note that if one of the interacting parties is not a smart enterprise, the effect of reducing costs will not be observed). The level of enterprise smartization is presented using an *S*-curve function of investment spending *K*, connected with the transformation of a traditional enterprise into a smart one:

$$S_i = \frac{1}{1+b_i e^{-m_i K_i}}, \quad S_j = \frac{1}{1+b_j e^{-m_j K_j}}.$$

There's a reason to assume that within one industry the relationship between investment costs and the level of smartization is described by the same function (parameter *b* is the same), and differs only in the production scale parameter (m_i, m_j), since it's obvious that the larger the enterprise, the more smart equipment has to be installed in order to achieve the same level of production smartization.

Thus, the task of reducing production costs through the introduction of smart industrialization within the framework of limited investment resources can be presented in the following way:

$$\sum_i X_i \sum_j z'_{ij} \Rightarrow \min$$

$$X = (E - A)^{-1} Y,$$

$$z'_{ij} = z_{ij} \left(1 - \frac{1}{1+b_i e^{-m_i K_i}} \cdot \frac{1}{1+b_j e^{-m_j K_j}}\right),$$

$$\sum_{\forall i} K_i \le K_{\lim}.$$

Where $A=(a_{ij})_{n\times n}$ – a technological matrix, the elements of which $a_{ij} = x_{ij}/X_j$ show how many units of *i* industry products should be spend for the production of one unit of industry *j* products, $Y_{n\times 1}$–column vector of the final product.

Work on the creation of digital business-to-business (B2B) platforms is already being carried out not only in the countries of the West, but also in Eurasian Economic Union (EAEU) countries [1]. The interaction of smart enterprises within these digital platforms significantly reduces transaction costs, creates conditions for the development of an end-to-end planning and management system in industry, frees resources that increase national income (quadrant 2) and, accordingly, the volume of the final consumption, which can also be estimated by balance models.

3. The third direction of economic and mathematical modeling of smart enterprises is represented by variations of network models, transport tasks, assignment tasks, etc. Building a network graph of interactions between consumers, manufacturers and other counterparties, for example, in a particular industry will help finding solutions to the following problems:

– substantiation of network effects in the creation of smart enterprises in the industry and assessing the minimum necessary level of digitalization of the network, in which the costs from the further introduction of smart technologies will be compensated for by the increase in the efficiency of the network as a whole;

– within the limits of the amount of available investment resources, selecting enterprises that require the digitization of their production the most, so that the path from order placement to order receipt would be associated with minimal possible costs;

– optimization of the movement of products (from their design to consumption by end customers) in the conditions of the IoT and smart infrastructure.

The standard objective function in such problems is aimed at minimizing the costs of moving from the initial to the final vertex:

$$Z = \sum_i \sum_j c_{ij} x_{ij} \to \min,$$

where x_{ij} – the volume of products, moved from vertex *i* to vertex *j*; c_{ij}– cost of moving them (for different arcs can be either constant or dependent on the volume of the products being moved).

Standard constraints: the demand of all consumers must be satisfied, the total production is equal to the total consumption:

$$\sum_j x_{ij} = a_i, \quad \forall i,$$

$$\sum_i x_{ij} = b_j, \quad \forall j,$$

$$\sum_i a_i = \sum_j b_j.$$

An obvious extension of this task is to determine the effective path in the conditions of the possibility of smartization of individual enterprises that form part of this network. The following restrictions will be added:

$$c'_{ij} = c_{ij}\,(1 - \frac{1}{1+b_i e^{-m_i K_i}} \cdot \frac{1}{1+b_j e^{-m_j K_j}}),$$

$$\sum_{\forall i} K_i \le K_{\lim}.$$

Digitalization and the IoT can virtually eliminate the cost of traffic through some intermediate vertexes, associated with transactional and organizational costs. In addition, they expand the number of vertices, available for analysis, by increasing the dimension of the graph, and accordingly, making the choice more valid and effective. The accessibility of some vertices mathematically in this task can be regulated by the restriction on the throughput of the vertex. For some vertices that determine the known trunk path, it will be a constant value, for others – a value, proportional to the degree of integration of the enterprise into the IoT, that is, proportional to the value

$$S_i = \frac{1}{1+be^{-mK_i}} \in (0;1):$$

$$\sum_i x_{ij} \le P_j S_j, \quad \forall j,$$

$$\sum_j x_{ij} \le P_i S_i, \quad \forall i,$$

where P_i – nominal (basic, potential) vertex throughput.

4. Another topical area of economic and mathematical modeling is the evaluation of social effects, associated with the impact of digitalization of the economy on the employment. The replacement of human labour by cyber-physical systems has the potential risk of massive job losses in manufacturing, which is the area of primary income distribution. In this case, the effects of lowering transaction costs in the conditions of the IoT may turn out to be lower than the negative effects of a decrease in effective demand, associated with a decrease in the primary incomes of the employed in manufacturing population. This problem becomes especially urgent in the conditions of Ukraine, when the potential superprofits from smart manufacturing will not be redistributed into the economy and stimulate domestic demand, but will accumulate in the pockets of oligarchs and then moved to offshore.

Stochastic modeling, in particular correlation-regression models for estimating stochastic dependencies, as well as simulation models for assessing the consequences of various scenarios of smart industrialization consequences for employment, income of the population and the economy as a whole, can be instrumental in assessing such effects.

Here are some dependencies that require evaluation, specification and parametrization within this research area:

1) labour costs (L_i) in industry *i*, depending on the smartization of that industry(S_i) (assessment of job losses);

2) demand for labour (L) in the region, depending on the degree of smartization of various industries in this region (assessment of the emergence of new vacancies);

3) production volumes (Q) in the region, depending on the degree of smartization of various industries in the region (assessment of changes);

4) taxable incomes of the population, depending on the possible growth of production volumes and changes in labour costs (assessment of changes);

5) deductions from income of the population (assessment of changes in relevant funds j);

6) volumes of consumption of households depending on the income of the population (assessment of changes);

7) burden of social security funds, depending on the number of population (N) and employment level.

These (and, probably, many more) dependencies can be combined into a single simulation model, the analysis of which will allow assessing the balance of the development of the smart economy, at least along two contours: the balance of household incomes and expenditures for expanded consumption; balance of revenues, raised to budgets and social funds, and the need to spend money from them.

The use of the apparatus of economic and mathematical modeling in substantiating the programs of smart industrialization of Ukrainian economy will make it possible to obtain scientific explanations for solving problems of the formation of smart enterprises and to increase the efficiency of these processes.

Conclusions

1. The Fourth Industrial Revolution (which, in the opinion of some scientists, is the stage of development of the Third one, the digital revolution) is based on the achievements of the 6^{th} technological mode, characterized by the massive introduction of additive production technologies, nanotechnology and bioengineering, full digitalization of manufacturing, implementation of cyber-physical systems that have artificial intelligence, creation of a global information network of products, transport, buildings and industries, capable of interacting with each other independently without human intervention. Ukraine, whose industry uses technologies of the 3^{rd} and 4^{th} technological modes, is lagging far behind in its development from Western countries, and chances of catching up with them in an evolutionary manner seem doubtful. At the same time, the creation of new enterprises that operate the technologies of the 6^{th} mode can enable occupying certain niches in the world's digital production.

2. The most effective way of justifying the economic feasibility of creating smart enterprises and their viability in Ukraine is the use of tools of economic and mathematical modeling that allow conducting experiments with the system being designed, studying its properties, evaluating efficiency and anticipating the occurrence of problems and errors. Despite the rather good development of the modern economic and mathematical modeling apparatus, the novelty of the tasks to be solved when creating smart enterprises prevents from making an unequivocal choice in favor of the use of certain specific tools. To justify such a choice, it seems useful to study the foreign experience of applying economic and mathematical methods in the creation of smart enterprises, since certain empirical knowledge has already been accumulated in that area.

3. The objects of research, which are given attention in the publications devoted to the Fourth industrial revolution and the functioning of smart enterprises, can be classified in three directions. The first one, *technical and technological direction* describes the operation of sensors, meters, robotics and cyber-physical systems, technology of product identification, cyber defense, data transmission, etc. The second direction is the *informational* one, describing the operation of information systems of various levels at enterprises, technologies for working with big data, and approaches to standardizing the development processes of smart enterprises and their elements. Finally, the third one– the *economic direction*–is connected with the rationale for the economic expediency of digitization of certain segments of the economy, or with its impact on socio-economic processes.

4. Most of the publications devoted to the development of the smart industry are either descriptive or introductory, or view this process from the engineering point of view, which mainly covers technical, technological and information directions. A few mathematical models mentioned in them (but not shown in explicit form) are of strictly applied nature and solve technical problems. Publications, which affect the economic aspects of Industry 4.0, are generally scarce. At the same time, even if certain mathematical justifications for some conclusions are present, they are, in most cases, empirically descriptive, based on existing observations, and the methodological variety of economic and mathematical models used at best covers correlation-regression analysis.

5. A separate large segment of publications, devoted to smart enterprises, is connected with the big data, which along with the software of cyber-physical systems form the basis of information support for the smart industry.

6. The analysts of the McKinsey consulting company indicate that the industries with the maximum potential for the introduction of analytics, based on big data, are pharmaceutical, chemical and mining. In those industries, in the opinion of the authors, minor changes in the characteristics of the process can significantly affect the result, which creates the conditions for the application of "advanced analytics" – processing of economic and technical data using statistical and other mathematical tools for assessing and improving various fields of activity. PwC consulting agency emphasizes the positive prospects for the introduction of smart technologies in the metallurgical industry: the introduction of digital technologies increases the maneuverability of supply chains, promotes a deeper understanding of processes and increases the level of capacity utilization. All these industries are well developed in Ukraine, and these conclusions would be useful to take into account, when forming smart industry here.

7. A large number of analyzed publications are of engineering nature, and reflect the design features of certain objects of the smart industry and cyber-physical systems. Modeling objects include products, resources, information, organizational aspects, decision making, manufacturing process and network environment (interaction models). In general, they use standard modeling tools including process models, object models, structural models, Petri net models, optimization models, hybrid automata, queuing systems, balance input-output models, aggregated modeling techniques, including tools such as Dymola and gPROMS, etc.

Nevertheless, the actual models, presented in these publications, are usually limited to object representation in the form of diagrams and graphs, which makes it impossible for them to be directly used in practice, which gives a wide range of possible interpretations about how these models can be specified for solving specific problems.

8. The few publications that reason the economic consequences of the introduction of smart enterprises are devoted to the economic feasibility of such measures. In particular, in a Korean example of investing in the development of the smart industry, it has significantly increased output due to increased demand in related industries. At the US enterprises, the use of big data in decision making was accompanied by a 3% average growth in value added. Despite the fact that a fairly modest number of jobs are created in the area of digital technologies, many publications confirm that these technologies help create jobs in related areas, which helps alleviate the reduction of jobs, caused by the automation of manufacturing processes.

9. In general, the nature of publications on the modeling of the smart industry and the processes of its implementation is unsystematic, fragmented and incomplete.

That is a consequence of the fact that this scientific direction is still quite new, there are no established concepts for the introduction of the smart industry and its modeling, and existing examples of practical implementation of smart enterprises are based more on heuristic methods, rather than on accurate mathematical justifications. The overwhelming number of papers on the topic of the smart industry focuses on convincing the reader of the importance of this direction, but lacks any scientific or practical novelty.

10. The peculiarities of the functioning of the Ukrainian economy, the specifics and level of development of its institutions make it senseless to directly apply the Western experience of conducting smart industrialization to Ukraine and require a more thorough scientific justification for the feasibility and cost-effectiveness of implementing measures to develop the smart industry in Ukraine. However, based on a review of foreign experience, the economic and mathematical modeling of smart enterprises in Ukraine does not require creating any fundamentally new types of models. It can be performed through the evolution of well-known models, with additional parametrization of specific conditions, specific to Ukraine's institutional features, the level of development of its industry and the information technologies used.

In particular, among the promising areas of economic and mathematical modeling of smart enterprises in Ukraine are the following:

– the use of modifications of *production functions*– to justify the qualitative changes in the factors of production, the emergence of new factors of production, their new technological combinations;

– the use *of modifications of Leontief input-output models* and *optimization models* for end-to-end planning and management of the industry, justification of enterprises requiring priority digital integration, reduction of transaction costs in the context of introducing digital business models and expansion of digital interaction with customers;

– the use of modifications of *network models* and *optimization models*– to optimize the movement of goods (from their design to consumption by end customers) in the conditions of the IoT and smart infrastructure, and also to justify the primary candidates for digitalization in conditions of restrictions on the amount of available investment resources;

– the design of *correlation-regression models*– for assessing economic stochastic dependencies, as well as *simulation models* for assessing the consequences of certain scenarios of smart industrialization, that allows assessing the consequences of these scenarios for employment, incomes of the population and the economy as a whole.

The concretization of the formulation of these models and approaches to their implementation requires an in-depth study of the specifics of the tasks being solved and the formalization of specific institutional factors. All of that is the subject of further research.

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АНАЛІЗ СВІТОВОГО ДОСВІДУ ЕКОНОМІКО-МАТЕМАТИЧНОГО МОДЕЛЮВАННЯ СМАРТ-ПІДПРИЄМСТВ

Показано неминучість зміни технологічного укладу у зв'язку з промисловою революцією 4.0, що потребує кардинальної перебудови системи виробництва і виробничих відносин. У результаті аналізу зарубіжного досвіду подібних змін, пов'язаних зі смарт-індустріалізацією, цифровими трансформаціями економіки, становленням промислового інтернету речей, обробки великих даних, встановлено необхідність застосування економіко-математичних методів для обґрунтування доцільності подібних трансформацій: як пов'язаної з їх економічною обґрунтованістю, так і з фізичною життєздатністю новостворюваних систем. Огляд публікацій, які відображають аспекти економіко-математичного моделювання в зазначених сферах, дозволив зробити висновок про несистемність і неопрацьованість методичного і методологічного апарату моделювання даних процесів, а також сформулювати рекомендації щодо економіко-математичного моделювання смарт-підприємств в Україні. Для врахування особливостей технологічного та інституційного розвитку України при обґрунтуванні створення смарт-підприємств запропоновано ряд інструментів економіко-математичного моделювання, заснованих на використанні виробничих функцій, моделей міжгалузевого балансу, мережевих оптимізаційних моделей, імітаційних моделей на базі стохастичних залежностей.

Ключові слова: промисловість 4.0, цифрові технології, смарт-підприємства, великі дані, економіко-математичне моделювання.

JEL codes: C00; C60; C67; C69; O12; O14.

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АНАЛИЗ МИРОВОГО ОПЫТА ЭКОНОМИКО-МАТЕМАТИЧЕСКОГО МОДЕЛИРОВАНИЯ СМАРТ-ПРЕДПРИЯТИЙ

Показана неизбежность смены технологического уклада в связи с промышленной революцией 4.0, что требует кардинальной перестройки системы производства и производственных отношений. В результате анализа зарубежного опыта подобных изменений, связанных со смарт-индустриализацией, цифровыми трансформациями экономики, становлением промышленного интернета вещей, обработки больших данных установлена необходимость применения экономико-математических методов для обоснования целесообразности подобных трансформаций: как связанной с их экономической обоснованностью, так и с физической жизнеспособностью вновь создаваемых систем. Обзор публикаций, отражающих аспекты экономико-математического моделирования в перечисленных сферах, позволил сделать вывод о несистемности и непроработанности методического и методологического аппарата моделирования данных процессов, а также сформулировать рекомендации по экономико-математическому моделированию смарт-предприятий в Украине. Для учёта особенностей технологического и институционального развития Украины при обосновании создания смарт-предприятий предложен ряд инструментов экономико-математического моделирования, основанных на использовании производственных функций, моделей межотраслевого баланса, сетевых оптимизационных моделей, имитационных моделей на базе стохастических зависимостей.

Ключевые слова: промышленность 4.0, цифровые технологии, смарт-предприятия, большие данные, экономико-математическое моделирование.

JEL codes: C00; C60; C67; C69; O12; O14.

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PROBLEMS OF ECONOMY OF INDUSTRIAL ENTERPRISES AND MANUFACTURING COMPLEXES

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ANALYSIS OF THE FINANCIAL RISKS OF THE UKRAINIAN RAILWAY TRANSPORT

The object of the paper is the financial risks of the railway transport. Today the financial situation of Ukraine's railway transport tends to deteriorate due to the systemic crisis of the national economy, the severance of existing economic ties, the critical wear and tear on non-negotiable assets, as well as an ineffective financial management. This led to the complexities of the formation of sufficient financial resources, the growth of financial risks and, as a result, the reduction of the international ratings. It is shown that little attention is paid to the risks, arising in the course of operating activities in the JSC 'Ukrzaliznytsia'.

The paper analyzes financial risks of Ukrainian railway transport (financing of operating activities, liquidity, interest, credit and currency). The analysis showed that the industry is facing problems related to the financing of operating activities, providing the necessary level of liquidity and, consequently, the cost of the resources involved. This leads to a decrease in the ability of Ukrzaliznytsia to carry out the operational activities, reduce its effectiveness and, as a result, further deterioration of the financial condition.

In order to improve the financial situation and reduce the financial risks of railway enterprises, the directions of their reduction are offered: optimization of the structure of financial resources by reducing the share of borrowed funds, limiting the amount of high-risk financial transactions, limiting the volume of current assets in the form of low liquid and illiquid assets, rationalizing the policy of managing financial instruments, implementation of scientifically sound financial management system. The strategy and tactics for managing financial risks of the railway enterprises should be based on the balance between expected benefits and possible risks.

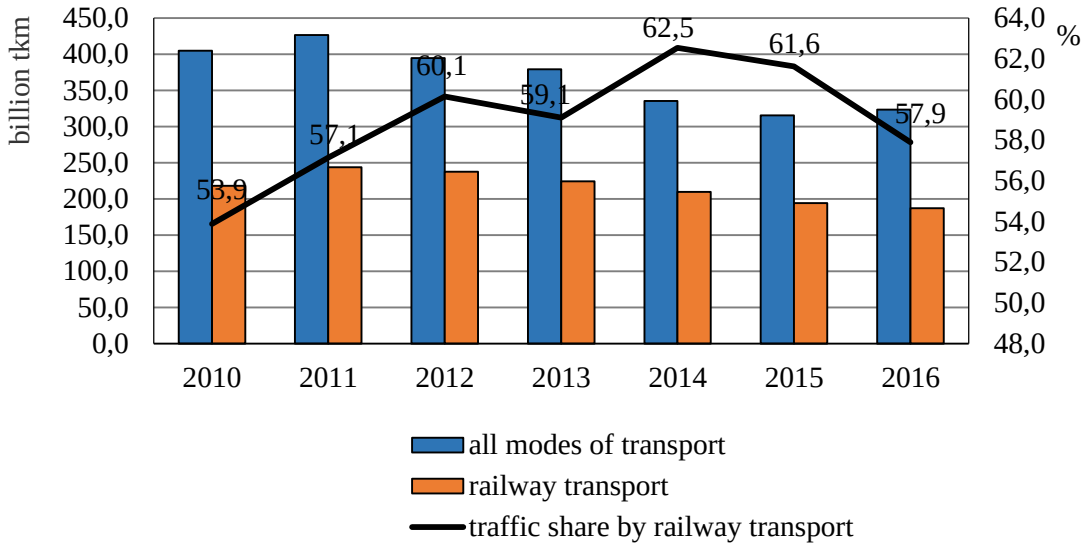
Keywords: financial condition, financial resources, financial risk, analysis, railway transport.

JEL codes: G 320, G 390, L 920

After the global financial crisis of 2008, the processes, associated with the development of the "new industry", took shape politically and organizationally. One of the priority directions of the proclaimed policy of "the industrial renaissance" is the introduction of qualitatively new approaches to cooperation within the framework of the formed economic order. In this context, in 2013 China offered the concept of "One belt – one way", involving the mutually beneficial integration of developing and developed countries, the introduction of new mechanisms for the regional economic partnership, the stimulation of economic prosperity of the states, and the promotion of their sustainable development [1]. Implementation of this concept is impossible without

the creation of a developed infrastructure, including railway transport, which is the "circulatory system" of any economy that allows overcoming territorial gaps between producers and consumers of goods and services, strengthen the economic ties between enterprises, and ensure the free movement of the population. In this unified infrastructure, the Ukrainian railways can act as a connecting element between the countries of Europe and Asia: the main trans-European corridors (East-West, Baltic and Black Sea) pass through Ukraine; the Ukrainian railways directly interact with the railways of Hungary, Slovakia, Poland, Romania, Russia, Belarus, and Moldova.

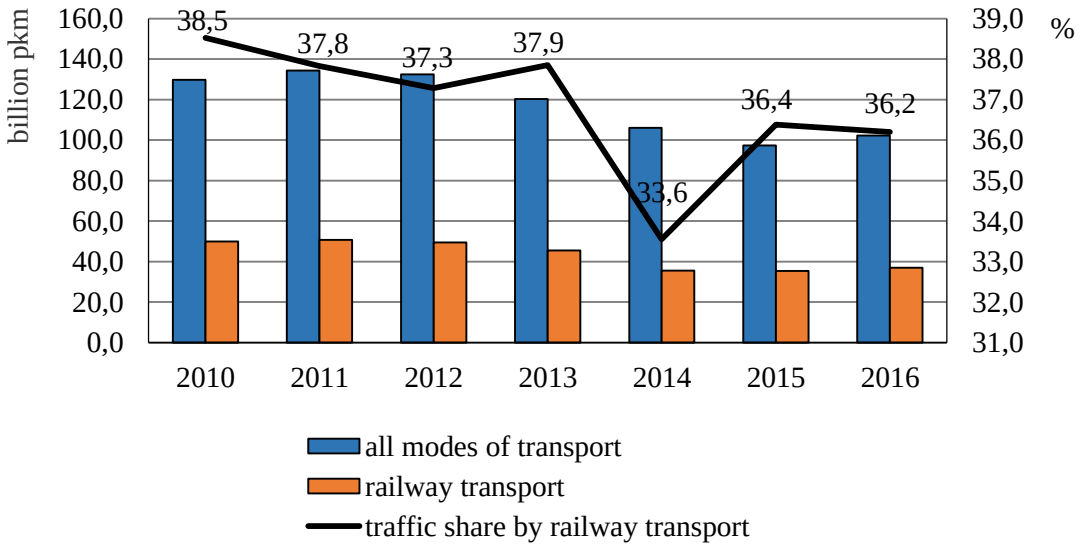
For the economy of Ukraine, railway transport also retains "a paramount importance" [2] due to high speed, reliability, rhythmicity, the possibility of transporting large volumes of cargo, a low cost of transportation and relative independence from the weather conditions. The transport capabilities of the industry and the carrying capacity of the railway network directly affect the functioning of not only individual industrial enterprises, industries, but also the national economy as a whole. The railways account for more than 50% of freight traffic by all modes of transport and more than 30% of the passenger traffic (Figure 1-2). For the leading industries, they [railways] are a non-alternative mode of transport, which carries up to 90% of their output. In conditions of poor quality of highways, as well as the factual insignificance of the river and sea fleet, railway transport remains the most competitive and popular mode of transport for both the shippers and passengers.



Source: data from the State Statistics Service of Ukraine [3]

Fig. 1. Dynamics of freight traffic in 2010-2016.

The systemic crisis of the national economy, the disruption of existing economic ties both within the country and with foreign partners, primarily – Russian ones, the lack of effective reforms in the industry, ineffective management in the JSC 'Ukrzaliznytsia', and the critical wear and tear on the non-current assets of its structural divisions led to a significant deterioration in their financial results. A comprehensive assessment of the financial situation in the industry based on the five-factor



Source: data from the State Statistics Service of Ukraine [3]

Fig. 2. Dynamics of passenger traffic in 2010-2016

model "Credit-Men" by Depalyan, J. (Table 1) shows that during 2010-2014, there was a significant deterioration in the financial situation in Ukrzaliznytsia, which resulted in problems of providing sufficient financial resources not only for investment activities, but also for operating and financial ones. The artificial increase in the value of non-negotiable assets in 2015 made it possible to significantly increase the assessment of the financial condition of railway enterprises, but this did not give the expected result, that is, did not lead to an increase in the investment attractiveness of the industry.

Table 1

Assessment of the financial situation in the railway transport of Ukraine

Indicators	At the end of the year						
	2010	2011	2012	2013	2014	2015	2016
Standardized quick liquidity ratio	0.11	0.18	0.04	0.07	0.08	0.21	0.29
Standardized debt ratio	1.64	1.49	1.44	1.37	0.61	3.93	3.76
Standardized equity immobilization ratio	0.67	0.66	0.63	0.63	0.41	0.84	0.84
Standardized inventory turnover ratio	1.17	1.17	1.04	0.88	1.01	0.93	0.80
Standardized receivables turnover ratio	0.81	0.96	1.21	1.57	1.21	0.72	0.51
Assessment of the financial situation	90.01	90.98	88.32	91.44	65.81	144.92	135.85

Source: data from the consolidated financial statements of the JSC ‘Ukrzaliznytsia’ [4]

The worsening of the financial situation immediately affected the international ratings of Ukrzaliznytsia. Thus, long-term credit rating in the foreign currency from the consulting company Standard & Poor's was determined at the level of SD

and Fitch Ratings – RD; credit rating of LPN by Standard & Poor's – CCC +, Fitch – CCC [5]. Such low ratings are indicative not so much of the technical default already occurred in 2016, but rather of potential default in the future and, as a consequence, the possible suspension of the railway transportation, which will have catastrophic consequences for the national economy. To avoid such a situation, special attention should be paid to analyzing and assessing the risks of Ukrzaliznytsia functioning, especially financial risks, in order to increase its adaptive capacity for abrupt changes in the external environment, and improve the results of production, economic and financial activities. In addition, the stabilization of the financial situation will help to increase the investment attractiveness of the capital investments in the development of the industry.

The questions of assessing financial risks were investigated in the researches of leading Ukrainian and foreign scientists, among whom Andersen, T.G., Blank, I.A., Bollerslev, T., Brealey, R.A., Brehmer, B., Vitlins′kyy, V.V., Christoffersen, P.F., Diebold, F.X., Vickers, J., Wengler, J., Gradoboyev, V.V., Karchik, V.G., Myers, S.C., Stulz, R.M., Taran, O.V. [6-15] should be noted. At the same time, it should be mentioned that this problem with the regard to railway transport is not actually considered. This can be explained by the fact that until recently, the railway transport was viewed as something integral, unchanging and outside the laws of a market economy. This resulted in insufficient attention to the difficulties, especially financial ones that arose in the process of the adaptation of the industry to new economic realities, which led to "negative results of the railway...", the true reason for which, according to V. Medvid, director of the consulting company "Invest-Expert", has become an ignorant financial policy, and not operational activities [16]. Increasing difficulties, associated with the formation of the sufficient financial resources for the implementation of the operational, investment and financial activities, cause the urgency of the problem of the financial management of the railway enterprises, as well as emerging risks as a necessary condition for not only its development but also effective functioning.

With this regard, the *aim of the article* is to analyze the financial risks of Ukraine's railway transport.

The functioning of any business entity, including railway transport, in a market economy is always accompanied by the risks of different nature, the outcome of which is the failure to receive the expected financial results, loss of profits or additional costs. Ukrzaliznytsia noted that four groups of risks can affect the efficiency of functioning of the industrial enterprises, namely [17]:

(1) economic risks caused by a change (decrease) in freight traffic as a result of the further deterioration in the state of the national economy and a decrease in the volume of industrial output. As tools for leveling these risks, it is proposed (a) to work out a flexible investment program for the development of the industry; (b) to introduce a set of measures aimed at reducing costs and increasing labor productivity as the factors for enhancing the profitability of operating activities; (c) use the tactics of rolling stock diversification in accordance with the needs of the customers to improve the quality of the services provided;

(2) significant investment are needed for the renewal of rolling stock and infrastructure due to the critically high moral and physical depreciation of non-negotiable assets resulted from the extremely low intensity of their renewal. Thus, during the period of 2010-2016, the largest increase in assets was observed in 2011 (3.6%) with retirement of 0.4%, in 2016, the increase was already 0.2% with a retirement of 0.1% [18, p. 25]. According to

I.V. Volovelska, this situation was caused by an irrational policy of the formation of an amortization fund, the amount of which is insufficient for the simple reproduction of completely worn out non-negotiable assets. The lagging of the book value of these assets from the real assets was more than 4 times, which resulted in a decrease in depreciation charges and unreasonable overstating of the accrued profit, more than 75% of which is transferred to the budgets of various levels in the form of tax deductions [19, p. 179]. The revaluation of the value of non-negotiable assets by more than 4 times in 2015 did not significantly affect the situation, since its goal was not so much the formation of its own investment resources, sufficient for gradual improvement of the situation, but only an artificial increase in the financial indicators, earnings before interest, taxes, depreciation, amortization (EBITDA), to attract the foreign investors. At the same time, it was not taken into account that railway transport is an industry with low investment attractiveness not only in Ukraine, but also in the world;

(3) a large proportion of staff costs, which adversely affects the cost of services and, as a consequence, financial results. So, in 2016, the structure of the operating expenses for wages and deductions for social security accounted for 32.8% (for comparison, for material expenses – 26.7%, for depreciation – 24.6% [4]). As the factors to reduce this risk, it is offered to implement a set of measures to increase labor productivity and staff optimization, as well as to carry out professional retraining of the workers;

(4) currency risk, associated with the fact that part of the expenses and liabilities of Ukrzaliznytsia are denominated in the foreign currency. It is determined that this risk can be reduced due to (a) the "natural hedge" of exporters, that is, the weakening of hryvnia rate increases the competitiveness of the goods of the Ukrainian producers and, thereby, will increase the need for transportation of their products; (b) the denomination of part of the transit proceeds in the US dollars; (c) reporting on a permanent basis the results of monitoring by the Treasury of Ukraine of the magnitude of market risks;

(5) refinancing risk and interest risk, associated with short-term liabilities of Ukrzaliznytsia. To eliminate these risks, it is expected (a) to intensify the work to increase the maturity of debt obligations of railway enterprises, including Eurobonds; (b) to develop a funding and refinancing strategy.

The consulting company Ernest & Young recognizes the main reasons for the occurrence of these risks and the increased riskiness of the functioning of Ukrzaliznytsia in general, in the instability of the political and economic situation in Ukraine, as well as in the shortcomings of the national economy, namely – low liquidity in the capital markets, high inflation and a significant deficit in the balance of the state finance and foreign trade [4]. At the same time, little attention is paid to the financial risks, arising in the course of the operating activities, which led to deterioration in its liquidity, solvency and financial stability indicators (Table 2).

Since 2010, the current assets of the railway enterprises do not cover their current obligations, which impede the normal operation of the industry and indicate the need to develop emergency measures to reduce the accounts payable. The situation is complicated by the fact that Ukrzaliznytsia is experiencing significant problems with the repayment of short-term obligations. At the same time, due to a significant increase in equity capital, the industry retains financial independence and has a reserve of raising financial resources from the external sources. The low level of the equity ratio is a consequence not so much of the cautious attitude of the industry management to external sources of financing, but the low investment prospects of the railway enterprises. However, at the

Table 2

Indicators of the financial condition of the railway transport in Ukraine

Indicators	At the end of the year						
	2010	2011	2012	2013	2014	2015	2016
Coverage ratio	0.508	0.711	0.534	0.599	0.180	0.539	0.415
Absolute liquidity ratio	0.009	0.138	0.015	0.033	0.056	0.155	0.220
Equity ratio	0.666	0.713	0.684	0.649	0.377	0.797	0.790
Debt ratio	0.334	0.287	0.316	0.351	0.623	0.203	0.210
Financial stability ratio	0.745	0.765	0.762	0.788	0.505	0.885	0.890
Financial leverage ratio	0.611	0.697	0.720	0.728	1.650	0.254	0.266

Source: data from the consolidated financial statements of Ukrzaliznytsia [4]

to a significant increase in short-term liabilities. In 2015, the situation improved, primarily due to enhancing in the cost of equity capital by 7.9 times. High values of the equity ratio are "normal" for the railway transport, which is a capital-intensive industry (the ratio of non-negotiable and working capital in 2016 was 16.0). The consequence of this was a significant excess of the level of the financial stability ratio, which determines the solvency in the long term. At the same time, low financial leverage ratio indicates a missed opportunity to increase profitability of equity by attracting additional resources to the activities of Ukrzaliznytsia. Thus, railway enterprises have significant problems in managing their finances and ensuring a balance of the financial activity.

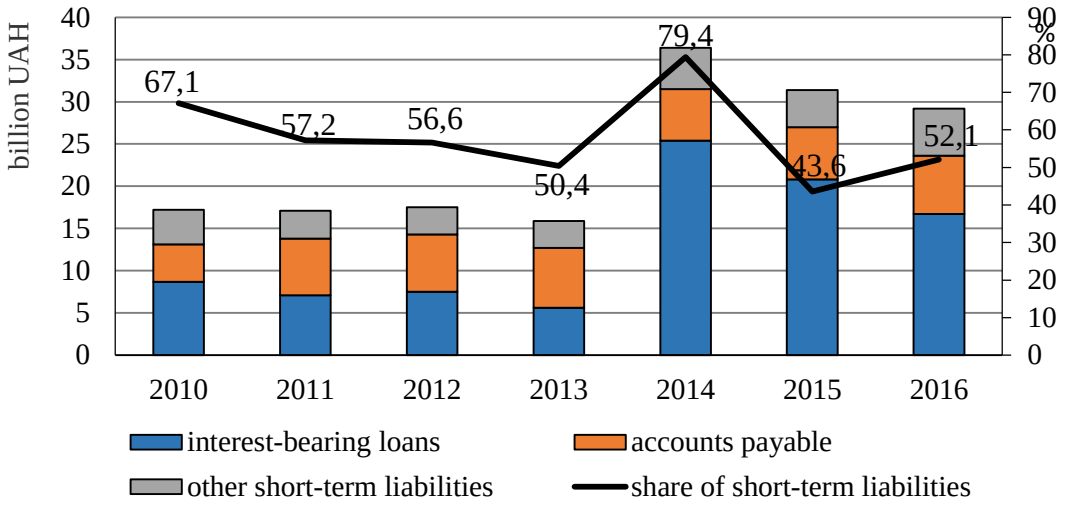
The risk of financing operating activities. The conducted researches show that the main financial risk of the operating activity of Ukrzaliznytsia in the industry is the growing deficit of the current assets for financing the transportation activity [18, 20, etc.]. This was the result, on the one hand, of a decrease in the profitability of operating activities (Table 3). With an average profitability of 10% in 2014, the profitability of operating activities decreased to 7.1%. In 2015, to improve the situation, tariffs for transportation were increased, which made it possible to increase profitability while reducing the volume of transportation (in the period from 2010 to 2016 freight transport decreased by 30.4%, passenger transportation by 8.7% [3]). Secondly, over the past decades, the process of laundering of money from the economic turnover of Ukrzaliznytsia has been taking place. The resulting shortage of the financial resources of the railway enterprises is liquidated due to short-term obligations (Figure 3).

Table 3

Financial results of Ukrzaliznytsia's operating activities in 2010-2016, billion UAH

Indicators	Years						
	2010	2011	2012	2013	2014	2015	2016
Freight transportation, million tons	432.5	468.4	457.5	441.8	387.0	350.0	344.1
Passenger transportation, million people	426.6	430.1	429.6	425.4	389.1	389.8	389.5
Total revenues from sale	42.6	51.6	52.7	51.0	49.5	60.1	66.6
Operating expenses	(38.4)	(44.6)	(47.5)	(46.1)	(46.2)	(54.3)	(64.7)
Operating profit	4.2	7.0	5.2	4.9	3.3	5.8	1.9
Profitability of operating activity,%	10.9	15.7	10.9	10.6	7.1	10.7	2.9
Net profit	6.7	2.1	0.8	0.6	(15.4)	(16.7)	(7.4)

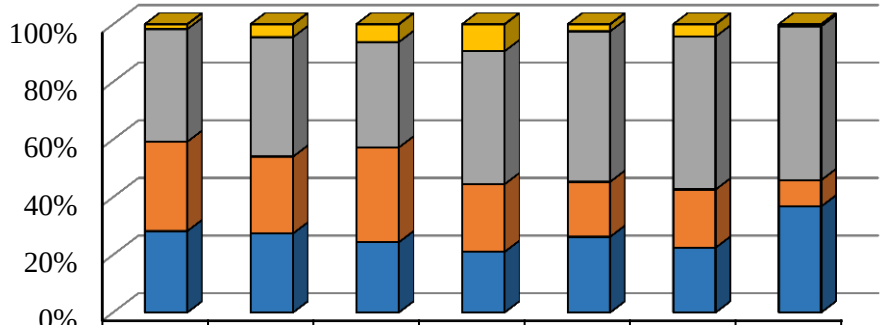
Source: compiled on the basis of data from the State Statistics Service of Ukraine [3] and data from the consolidated financial statements of Ukrzaliznytsia [4]



Source: data from the consolidated financial statements of Ukrzaliznytsia [4]

Fig. 3. Dynamics of the short-term liabilities of Ukrzaliznytsia in 2007-2016

The main instruments for regulating the amount of available financial resources in Ukrzaliznytsia are short-term interest-bearing loans and liabilities, as well as accounts payable, obligations under finance leases, etc., arising directly in the operating activities. With the exception of 2015, the share of short-term financial liabilities was more than 50%, reaching a maximum in 2014 (79.4%). The largest part is accounted for interest-bearing credits and loans, used to eliminate the current shortage of the financial resources. In 2014 there was a significant decrease in the volume of freight (by 12.4%) and passenger (8.5%), which was accompanied by a 2.9% decrease in revenues and twice increase in short-term loans and borrowings. At the same time during 2010-2016 3-months financial liabilities augmented to 36.8%, while long-term loans (more than 5 years) –decreased to 0.7% (Figure 4). This structure of liabilities of Ukrzaliznytsia is not normal for the railway enterprises.



	2010	2011	2012	2013	2014	2015	2016
more than 5 years	1,7	4,4	6,1	9,3	2,4	4,2	0,7
1-5 years	39,1	41,5	36,6	46,2	52,2	53,1	53,4
3-12 months	31,0	26,7	32,9	23,5	19,1	20,2	9,1
less than 3 months	28,3	27,4	24,4	21,1	26,3	22,5	36,8

Source: data from the consolidated financial statements of Ukrzaliznytsia [4]

Fig. 4. Structure of obligations of Ukrzaliznytsia by maturity terms in 2010-2016

The present situation is explained by the management of Ukrzaliznytsia, using the funds raised to "smooth out the effect of unpredictability and inefficiency of Ukrainian financial market and is aimed at reducing its potential negative impact on financial results ..." [4]. At the same time, the real target of increasing tariffs for transportation and the formation of short-term obligations is the liquidation of the deficit of the current assets to finance operating activities, as well as the repayment of the existing obligations. This not only has a negative impact on the financial sustainability of railway enterprises, but also has a deterrent effect on the national economy and the leading industries in times of crisis.

The liquidity risk is derived from the risk of financing operating activities. As noted by the management of Ukrzaliznytsia, one of the main tasks of managing financial risks of railway enterprises is to maintain a balance between continuous financing and flexibility in the use of the funds received from operating activities and the terms of lending that are put forward by the suppliers and banks. At the same time, as of June 30, 2017, the current liabilities of Ukrzaliznytsia exceeded the current assets by 14.66 billion UAH (as of December 31, 2016 – 13.4 billion UAH) [4]. This is accompanied by a violation of the deadline for fulfilling obligations under long-term credit agreements, which were not corrected until the end of the reporting period, which led to cross defaults on certain types of loans. In the meantime, it is noted that railway enterprises may not be able to liquidate a possible violation of the conditions for placement of Eurobonds of Shortline P-L-C in the amount of 500 million US dollars.

Given that as of December 31, 2016, no credit resources were used for the amount of 6.5 billion UAH, in early 2017, Ukrzaliznytsia received confirmation from the Ukrainian banks for new long-term loans for the amount of 5.5 billion UAH to refinance a portion of loans and borrowings included before current liabilities, as well as to finance the capital expenditures. Also by the end of 2017, it is planned to issue domestic bonds worth 2.0 billion UAH and the possibility of a new issue of Eurobonds is being considered.

During the period 2010-2016, the book value of undiscounted payments on the financial liabilities increased by 2.2 times, including interest-bearing loans – by 3.5 times (Table 4), while the volume of freight traffic increased by 7.4%, and passenger – decreased by 6.0%. This indicates a growing number of problems with servicing financial liabilities of Ukrzaliznytsia. At the same time, the obligations under the finance leases agreement in the period 2010-2016 decreased by 3.6 times, that is, the railway enterprises are forced to abandon actually the only possibility to update the part of their non-current assets (primarily rolling stock) by getting them through leasing. This will result in a decrease in the operating cash flow, worsening of the financial situation, the further decline of liquidity indicators, an increase in negative expectations of the potential investors regarding investments in the development of railway transport, and boosting other financial risks, primarily credit and interest.

The increase in **interest rate** risk in Ukrzaliznytsia is associated mainly with interest-bearing loans and loans with floating interest rates. In 2015-2016 years the loans of railway enterprises mainly had fixed and floating interest rates linked to the London interbank offered rate ("LIBOR").

Increases in the percentage risk can be explained by such factors: (a) instability of interest rates on the external liabilities and (b) high sensitivity of the profit of Ukrzaliznytsia to a change in basis points.

Table 4

The book value of the undiscounted payments on financial liabilities of Ukrzaliznytsia in 2010-2016, billion UAH

Indicators	Years						
	2010	2011	2012	2013	2014	2015	2016
Interest-bearing loans	11.6	14.6	16.8	17.9	31.1	42.0	40.5
Obligations under finance leases	5.8	4.2	3.3	2.4	3.4	2.0	1.6
Trade and other payables	4.4	6.7	6.8	7.1	6.1	6.2	6.9
Total	21.8	25.5	26.9	27.4	40.6	50.2	49.0

Source: data from the consolidated financial statements of Ukrzaliznytsia [4]

The instability of the interest rates on the liabilities and loans, as well as high sensitivity to their change is primarily due to the negative expectations of investors regarding maturities, which results in an increase in the cost of raising funds in the economic turnover of the enterprises. So, even in the relatively prosperous 2013 it was noted that the initial cost of interest-bearing loans and loans attracted by both Ukrzaliznytsia and individual roads is significantly higher than the average market one, reaching 30% per annum for certain assets [21] (for reference: according to the data of Prostobank Consulting in August 2013 the average interest rate on loans for the acquisition of the non-current assets in UAH was 21-22% per annum). Such "distrust" to the railway enterprises was explained by the difficult situation in the financial markets, very low profitability and non-transparent management of cash flows. The current financial condition of Ukrzaliznytsia also does not contribute to the lowering interest rates to the average market level. In addition, the failure to meet maturity terms leads to an increase in their value: in 2016, the annual interest rate on Eurobonds increased from 9.5% to 9.875% [22].

The problem of high profit sensitivity to changes in basic points (Table 5) is a consequence of an inefficient financial policy in the industry, irrational structure of the financial resources, lacking of sound development strategy. In 2014, the forecast interval of fluctuations of the basic points was small: according to LIBOR – [-0.02; +0.02], according to EURIBOR – [-0.02; +0.02]. This predetermined the possibility of minor fluctuations in profit: [-1.0; 1.0] and [-0.3; 0.3]. The deterioration of the financial condition of Ukrzaliznytsia resulted in a greater spread of the probable changes in the basis points, as well as their impact on the profit of railway enterprises (with the elimination of the influence of other factors). So, in 2016 the spread of possible fluctuations according to LIBOR was [-0.08; +0.60], according to EURIBOR - [-0.08; +0.12] and, accordingly, the profit -– [-4.3; 32.0] and [-0.8; 1.2]. Despite the management's remarks that this does not affect the equity capital of Ukrzaliznytsia and it does not participate in hedging of interest rate risks, the current situation intensifies the negative expectations of the potential investors and provokes an even greater increase in the cost of attracting resources from the external sources.

The credit risk. The financial instruments that can lead to a potential increase in the credit risks of railway enterprises include mainly cash and its equivalents, deposits, trade and other receivables, as well as loans provided. The management of Ukrzaliznytsia states that the funds are placed in the "big reliable banks of Ukraine", the credit risks are monitored and analyzed in each specific case, and also properly displayed in the reserves for depreciation of assets [4]. At the same time, the maximum credit risk at the end of 2015 and 2016 equaled the book value of all financial instruments. In addition,

Table 5

Sensitivity of profit before taxation of Ukrzaliznytsia to changes in interest rates in 2014-2016, million UAH

Lending rates	At the end of the year					
	2014		2015		2016	
	change in basis points,%	impact on profit	change in basis points,%	impact on profit	change in basis points,%	impact on profit
LIBOR	+0.02	1.0	+0.50	29.5	+0.60	32.0
LIBOR	-0.02	(1.0)	-0.12	(7.1)	-0.08	(4.3)
EURIBOR	+0.04	0.3	+0.17	1.1	+0.12	1.2
EURIBOR	-0.04	(0.3)	-0.05	(0.3)	-0.08	(0.8)

Source: data from the consolidated financial statements of Ukrzaliznytsia [4]

when assessing credit risks for all customers that are granted with the loans or deferred payment exceeding the established limit, railway enterprises do not require pledge for their financial assets, which only in 2016 led to an increase in receivables by 22.9% compared to 2015. Such a policy in the conditions of worsening the financial condition of Ukrzaliznytsia and the growing scarcity of available resources is irrational and provokes the further deterioration of the situation.

The currency risk. This risk is significant for Ukrainian railway transport, since more than 80% of its liabilities are in foreign currency. In addition, the payments for transit and interstate transportation are also carried out in currency. This risk relates to monetary assets and arises from fluctuations in rates in the foreign exchange market, as well as in transactions for the purchase/sale of transportation services, the value of which is calculated in foreign currency. Instability of the national currency (from January 1, 2015 to January 1, 2017, the devaluation of the UAH against the US dollar was 68.2%, the Swiss franc - 70.5%, the euro - 62.4%, the Russian ruble - 49.8% [23]) negatively affects the sensitivity of profit to the likely change in exchange rates (Table 6).

Table 6

Sensitivity of profit before taxation of Ukrzaliznytsia to changes in the exchange rate in 2014-2016, million UAH

Currencies	At the end of the year					
	2014		2015		2016	
	change in UAH, %	impact on profit	change in UAH, %	impact on profit	change in UAH, %	impact on profit
UAH / dollar	+28.9	(7892.6)	+67.0	(24344.5)	+53.0	(20117.8)
UAH / dollar	-28.9	7892.6	-18.0	6540.3	-13.0	4934.6
UAH / Swiss franc	+28.9	(19.9)	+67.0	(96.7)	+53.0	(21.3)
UAH / Swiss franc	-28.9	19.9	-18.0	26.0	-13.0	5.2
UAH / EUR	+29.0	(108.3)	+67.0	(366.8)	+53.0	(289.3)
UAH / EUR	-29.0	108.3	-18.0	98.5	-15.0	81.9
UAH / Russian Ruble	+39.9	(1.5)	+50.0	(1.9)	+58.0	(0.9)
UAH / Russian Ruble	-39.9	1.5	-33.5	1.3	-22.0	0.4

Source: data from the consolidated financial statements of Ukrzaliznytsia [4].

The greatest impact on profit of Ukrzaliznytsia has UAH to US dollar rate, which is connected with the binding of tariffs for transportation to this currency. During 2014-2016 years the impact of UAH exchange rate on the Swiss franc and on the Russian ruble is significantly reduced, which is associated with a fall in transit, intermodal and multimodal transport due to the severance of economic ties with the Russian Federation and the creation of artificial barriers to the international transportation by the territory of Ukraine. At the same time, the impact of currency risks on profits is reduced due to a decrease in transportation activity. This, on the one hand, is a positive point, as the expected profits of railway enterprises become more predictable, which allows more efficient distribution, including the renewal of non-negotiable assets. On the other hand, a decrease in the volumes of transit and international transportation, which are the most profitable, leads to a decrease in profits and, as a consequence, a deterioration in the financial condition of the branch enterprises.

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Conclusions. The favorable geographical position of Ukraine, its developed transport infrastructure, including the railway infrastructure, stipulate its inclusion in the integration processes taking place on the Eurasian continent. Thus, when implementing the concept of "One belt – one way", connecting European and Asian countries in a single economic space, the significance of Ukraine as a transit state through which territory the main trans-European corridors pass is significantly growing. At the same time, the existing network of railways retains its importance as a "locomotive" for the national economy.

The systemic crisis in Ukraine, the lack of effective reforms, the breakdown of established economic ties, and the irrational financial policy in Ukrzaliznytsia led to a significant deterioration in its financial condition. The result was an increase in the financial risks and, as a consequence, a significant decline in the international ratings.

Analysis of the financial risks of Ukrainian railway transport has shown that the industry is facing problems, related to the financing operating activities, providing the necessary level of liquidity and, in effect, the cost of the resources involved. This, along with systemic problems of the national economy, leads to a decrease in the ability of Ukrzaliznytsia to carry out the operational activities, reduce its effecttiveness and, as a result, further deterioration of the financial condition. In addition, a decrease in the transportation capacity and capacity of the railway network adversely affects the functioning of the leading industries due to the fact that it is impossible to carry out transportation activities in the required quantities and with sufficient quality.

It is impossible to improve the financial situation and reduce the financial risks of railway enterprises and Ukrzaliznytsia as a whole without the implementation of a set of measures aimed at increasing the volumes of transportation, primarily freight, improving the efficiency of transportation activeties, developing a scientifically sound financial management strategy, policy of management of the formation of the financial resources. In this case, the main areas for reducing the financial risks should be the following:

(1) optimization of the structure of the financial resources by reducing the share of borrowed funds, primarily in the form of the short-term obligations. The decrease in the share of borrowed funds will help to reduce the dependence of industrial enterprises on the external sources of financing and increase their financial stability. At the same time, a predominant focus on own financial resources will lead to a decrease in the level of the financial leverage;

(2) restriction of the financial transacttions having a high level of risk. The shortage of the financial resources of Ukrzaliznytsia does not allow to completely exclude such operations, as they are used for a prompt liquidation of cash gaps and repayment of the current liabilities, as well as financing of the continuous transportation activities, as a result of which own financial resources are formed;

(3) limitation of the volume of the current assets in the form of low liquid and illiquid assets (stocks, overdue or bad trade and receivables, etc.). This will limit the washing of own financial resources of their economic turnover of Ukrzaliznytsia, reduce the risk of insolvency to an acceptable level. However, the introduction of the strict limitation of the current assets on their liquidity can lead, on the one hand, to an increase in the amount of lost profits from the failure to provide services for the transport of goods or passengers, and on the other hand, to a disruption in the rhythm of transportation activities due to an excessive reduction of the insurance stocks;

(4) streamlining of the policy of managing the financial instruments. This will allow (a) the issuance of the domestic and foreign loan bonds: borrow funds in necessary (sufficient) volumes, manage the interest rate risk; (b) when placing temporarily free resources: correctly determine the direction of the investment of funds and, thereby, reduce the losses from ineffective investments in short-term financial instruments, as well as reduce the risk of loss of profits;

(5) the introduction of a financial management system based on the principles of integrated management, integration with production and economic management systems, the continuity of monitoring changes in the external and internal environment of Ukrzaliznytsia, as well as the balance in making the financial decisions.

The development of a strategy and tactics for the management of the financial risks of the railway enterprises should be based on the balance between the expected benefits and possible risks, namely – the need for additional financial resources for the implementation of the operational, investment and financial activities and the likely deterioration of the financial condition, reduced liquidity and solvency. This involves the use of the modern methods of forecasting risks, based on the economic and mathematical modeling.

The complex implementation of these measures in the management of the financial risks of Ukrzaliznytsia will not only reduce unforeseen losses due to changes in the external and internal environment, but will also help to improve the financial situation in the sectorial enterprises, generate sufficient financial resources for continuous transportation activities, update non-negotiable assets, as well as to enhance the efficiency

of the railway transport in Ukraine as a whole.

The complexity and multifaceted nature of the problem under consideration causes the need for the further research, aimed primarily at developing methodological bases for forecasting the dynamics of risks, taking into account the specifics of the financial resources' formation in railway transport and changing the demand for them, as well as the development and justification of a complex of fast response measures to a threat of an increase in external and internal risks for the timely neutralization of their negative impact on the financial situation in Ukrzaliznytsia.

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АНАЛІЗ ФІНАНСОВИХ РИЗИКІВ ЗАЛІЗНИЧНОГО ТРАНСПОРТУ УКРАЇНИ

Доведено, що погіршення фінансового стану підприємств залізничного транспорту призвело до дефіциту фінансових ресурсів. Визначено, що наслідком неефективного управління фінансами стало збільшення ризиків «Укрзалізниці». Проведено

аналіз динаміки основних фінансових ризиків залізничного транспорту та їх впливу на формування фінансових ресурсів галузевих підприємств.

Ключові слова: фінансовий стан, фінансові ресурси, фінансовий ризик, аналіз, залізничний транспорт.

JEL codes: G 320, G 390, L 920

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АНАЛИЗ ФИНАНСОВЫХ РИСКОВ ЖЕЛЕЗНОДОРОЖНОГО ТРАНСПОРТА УКРАИНЫ

Показано, что ухудшение финансового состояния предприятий железнодорожного транспорта привело к дефициту финансовых ресурсов. Определено, что следствием неэффективного управления финансами стало увеличение рисков «Укрзализныци». Проведен анализ динамики основных финансовых рисков железнодорожного транспорта и их влияния на формирование финансовых ресурсов отраслевых предприятий.

Ключевые слова: финансовое состояние, финансовые ресурсы, финансовый риск, анализ, железнодорожный транспорт.

JEL codes: G 320, G 390, L 920

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INDUSTRIAL INTEGRATED STRUCTURES AS ROBINSON CRUSOE ECONOMIES

A model, formulated by the Lausanne school of economics in the 30s of the XX century and known as the economy of Robinson Crusoe, forms a compulsory course in microeconomics at various universities of the world. Though it basically corresponds to the pattern of vertically-integrated system, it was undervalued by the industrialists.

Keeping in mind that when the economy of Robinson Crusoe is in a state of equilibrium, a graph of the consumer indifference curve touches a graph of the manufacturer's production function in the point, which reflects the maximum of company profit, the analysis of operating efficiency of the system on the whole can be carried out by studying the operating mode of the producer of good only.

To adapt the classical model of Robinson Crusoe economy to the modern conditions of company operation it was offered to use a single-factor production function with an argument in the form of multi-resource equivalent (MRE), which is a hypothetic resource, combining the inputs of labour, electrical energy, fuel, materials, etc. and having the entire cost, which is equal to the entire company expenses.

Based on the analysis of profit fluctuations of coal mining enterprises (coal mines), which have various production characteristics and operate in various market conditions, a conclusion is drawn that the worse the operating conditions of the coal mine are the more intensive its production load should be to make it more cost-effective. At the same time, coal mines, working in favourable operating conditions, need to limit their production load.

It is worth to use the developed methodology to analyze and substantiate the methods of improving the operation of vertically-integrated systems in the sphere of coal washing, coke chemistry, metallurgy, power engineering and other branches of industry. At the same time, its introduction into practice requires further study of company production functions.

Keywords: Robinson Crusoe economy, integrated structures, industry, model, the Lausanne school.

JEL codes: D5.

Vertical integration is an essential factor, if not a cornerstone, in the industrial development. Ronald Coase (Ronald Harry Coase) called vertical integration the basic structural characteristic of industry [1, p. 388]. The importance and universal character of this notion was noted in his time by Bengt Karlof: 'Advanced vertical integration is a problem that troubles Mikhail Gorbachev in Kremlin as much as Directors of General Motors in Detroit' [2, p. 110]. In the planned economy the structure of industry was based on the branch principle, inter-branch enterprises were scarce. In the post-Soviet Ukraine inter-branch industrial groups started coming into being in the period of L. Kuchma presidency [3]. They remain indispensable of today's industry.

The notion about vertical integration was changing in the course of the historical

development. For Rudolf Hilferding, the 19th century economist, it was a link between industrialists and traders, who increased their trading profit at the expense of the production profit of industrial enterprises [4, p. 246]. The Japanese Power energy company J-Power is an example of vertically-integrated fuel-and-power corporation which annually delivers about 8 mln tons of coal, extracted at open-cast mines of their Australian branch company Idemitsu Australia Resource, for the use at their power stations, situated in the Japanese islands.

"Integrated corporate body", "bound and diversified system", "interglomerate", "integrated business group" are the synonymous terms, united by the feature, common to all of them. This is an interaction of enterprises in production, sales and consumption of the same final product.

Vertical integration as a theoretical discipline attracts attention of researchers, representing different scientific schools: neoclassical, institutional, dynamic comparative advantage school, corporate finance school, etc. At the same time, there are some aspects, integral character of which lacked everybody's attention. This is the Robinson Crusoe economy, developed by the marginalists of the Lausanne school (a mathematical school). Léon Walras (Marie-Ésprit-Léon Walras) and Vilfredo Pareto alongwith the English marginalists William Jevons (William Stanley Jevons) and Francis Edgeworth (Francis Ysidro Edgeworth) initiated the introduction of mathematical methods into economics. The other distinctive feature of the Lausanne school was an express mechanistic approach: they showed the economy in a state of equilibrium like a sort of a mechanism.

A Robinson Crusoe economy, also called "one manufacturer, one consumer and two commodities" (1x1x2), is a mandatory section of microeconomics course in all leading universities of the world. But neither world famous Californian scientists Hal R. Varian [5] and a Nobel Prize winner Daniel McFadden [6], nor Jeffrey Miron from Harvard and Yossi Spiegel from Tel Aviv make it clear what is the link between theoretical conclusions based on ideas of Léon Walras and modern practical knowledge.

The same is understood from the very title of the famous Russian economist A. Nekipelov's monograph – "Foundation and functioning of economic institutions: from Robinson Crusoe to market economy, based on the individual production": mathematical apparatus is getting more and more elaborated, but *per se* it remains the very same combination of coconuts and leisure [7, pp. 32-64].

This predetermined *the purpose of this paper*: to demonstrate the essence and functioning details of vertically-integrated corporations as Robinson Crusoe economies and to substantiate the possibility of using the model to estimate the optimum operation mode of integrated production systems and to evaluate the efficiency of investment projects, involved in their development process.

The Lausanne model's legend has it that one and the same person – Robinson Crusoe – acts as a producer and a consumer of the product. By labour inputs he produces a useful product – grows yams for his own consumption as described by D. McFadden or harvests coconuts as described by Hal R. Varian, which makes no difference as far as the model is concerned.

Suppose in this case coconuts act as the first commodity. The second commodity is leisure, i.e. Robinson Crusoe's spare time. If we denote the first commodity as x_2, then the second commodity (x_1) is equal to the difference

$$x_1 = L - z \qquad (1)$$

where L – is a time (factor, which is a constituent part of a commodity cluster);

z – working time, spent on production of commodity x_2.

Production function $f(z)$, inherent to the company, – is a numerical correlation

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between an output (produced commodities) q and resource input (labour time) z. The production function reflects the fact that the more time Robinson Crusoe spends working, the more coconuts he obtains. At the same time, amount of useful marginal product, which Robinson Crusoe obtains by investing a marginal labour hour, is decreasing. This statement corresponds to neoclassical economics' concept of diminishing return or increasing marginal costs.

A company is a price-taker by definition (i.e. it sells its products at prices, which are formed by forces that are not under the influence of the company): price of a commodity is denoted as p, a labour price – w.

It is supposed, that production activity results in accumulation of profit π:

$$\pi = pf(z) - wz \qquad (2)$$

where π – is a profit of a company.

The main goal of a company – obtaining a maximum profit – can be denoted in the following way:

$$\pi = pf(z) - wz \mapsto \max_{z \geq 0}, \qquad (3)$$

In this case an optimal output depends on the following parameter – a price ratio between the commodity and the resources:

$$z^* = \arg\max_{z} \pi(z, p) = z^*(p). \qquad (4)$$

Robinson Crusoe's preferences as a customer are characterized by function of utility $u(x_1, x_2)$, having the form of indifference curves.

The bigger crop Robinson Crusoe harvests, the more food he will get and less time will left, as Hal R.Varian indicated, "to improve his suntan". Due to this, the goal of a consumer is to achieve a maximum welfare standard:

$$u(x_1, x_2) \mapsto \max; px_2 \leq w(L - x_1) + \pi(p, w). \qquad (5)$$

Complete satisfaction by maximum criteria is obtained when Robinson Crusoe works and consumes in the state of equilibrium, which can be shown in the following way: the curve of operation set $f(z)$ correlates with one of the indifference curves' assemblage.

At this very point the most preferred combination of labour and consumption is achieved if this particular technology is used. And in this case the Pareto-efficiency is achieved, which means that welfare improvement of one person is impossible without detrimental effect to another person.

The process of achieving an optimum or efficiency by Pareto means finding the point at which an inclination of indifference curve is equal to the inclination of production function (as per the standard postulate on convexity of curves). If situation cannot be described as Pareto-efficiency, then curves will intercept, which means that there is another point, more preferable than this one, and one of the parties can improve its welfare without deteriorating the situation of another party. If the marginal product exceeds the marginal substitution rate then refusing from some leisure in order to get additional coconuts will bring advantage to Robinson Crusoe. If the marginal product is less than a marginal substitution rate, Robinson Crusoe will benefit more if he works less.

Thus, Robinson Crusoe economy has some patterns, defining the optimum mode of system's production functioning, which includes a consumer and a manufacturer of some good.

The fact, that optimal point by Pareto is the same for a manufacturer and for a consumer of goods, allows defining the abovementioned optimum by finding the highest profit conditions for a company. As they say: "What is good for General Motors is good for America". And it is much easier to determine the way, how to achieve the highest profit for the company than to evaluate preferences of a consumer.

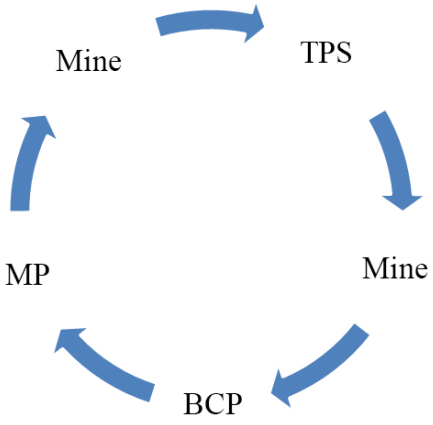
Thus, the task of system's optimization may be limited to constructing a production function of a company and determining its highest profit in the conditions when prices of a final product and the resource inputs, used for its production, are not stable.

A book under the title of "Robinson Crusoe's Economic Man: A Construction and deconstruction" interprets the Lausanne school Robinson Crusoe adventures as a sort of schizophrenia as the criticists considered him a person with a split mind, who urged to improve his personal welfare to the maximum in both categories of a consumer and a manufacturer [8].

But the degree of schizophrenia may increase, if we try to bring the model nearer to the modern industry. Lack of attention to the Robinson Crusoe economy from the part of modern industrialists is caused not just by its basically demo character, its deliberately chosen title and a presence of two specific commodities, such as coconuts and leisure. The model itself is very complex and hard for proper identification.

Suppose Robinson Crusoe discovered coal deposits on his island and started excavating fuel for the use at his farm instead of harvesting coconuts. This is another format of Lausanne model: he himself produces a fuel resource as a good and he himself consumes it. At the same time, he has some leisure in the form of his free time, i.e. the period when he is not excavating coal.

But the modern technology of excavating the fossils is far more progressive than mining of coal with a pick. A modern coal mine uses electric and thermal energy, generated from coal, it requires metal to hold the roof of mine headings and make tools. In the meantime, metal is also an embodiment of coal in the form of coke and electric power. The complexity of this interaction is shown on the diagram on Figure 1 as an interaction "Electric power station – Thermal power station (TPS), by-product coke plant (BCP) – metallurgical plant (MP)".



Source: compiled by the authors.

Fig. 1. Integrated system of coal mining and coal processing

Using electric power as a resource, Robinson Crusoe as a miner excavates coal and delivers it to the consumer, Robinson Crusoe as a power engineer. The abovementioned is not just an economy of "1x1x2" but a clearly defined vertical integration scheme. Even if a holding is not formalized institutionally the communication between the enterprises is rather strong. According to our assessments, the efficiency of energy enterprise affects greatly the efficiency of a coal mining enterprise: even a narrow-range fluctuation in specific consumption of solid fuel at the thermal power station can result in increase of EROI index[1] in national industry from 8 to 10:1.

[1] EROI – energy return on investment. EROI is a ratio of generated energy to consumed one, energy profitability.

For comparison: this index in the US coal mining industry constitutes 80:1 (data as of 1990), an average worldwide index is 46:1 [9].

On the other hand, Robinson Crusoe as an energy engineer generates electrical power using coal as a fuel source and then delivers it to the consumer, Robinson Crusoe as a coal miner. This scheme also corresponds to the Lausanne model and forms an embodiment of vertical integration.

Examples, indicated above, can be extended to a metallurgical branch as well.

The Ukrainian business group System Capital Management (SCM) in addition to coal-energy division (DTEK) and coal metallurgical division Metinvest owns a coal machine building division (Corum Group) as well. The latter supplies machines and equipment for mechanization of coal mining processes and consumes electricity and metal on a large scale.

A number of schemes and the complexity of classification increases since the other group of enterprises, called horizontally-integrated, should also be referred to Robinson Crusoe's economy. An example of such enterprises is the Pavlogradugol – company, which is a part of DTEK group. Production units (coal mines), forming this company, are not directly involved in the sales of their products. They have no market entry and delegate these functions to the parent company.

Such isolation of economic space is an inherent feature of not only a majority of the national companies, but the corporations of the countries with advanced market economies. The same operating pattern is used by the private company DTEK Pavlogradugol, state-owned enterprise Krasnoarmeyskugol (both are from Ukraine) and the American coal mining company Walter Energy, etc. There is Robinson Crusoe, who produces and the one who accepts the products – this is a pattern of vertical integration of industrialists and traders by Hilferding.

Fragment of vertically-integrated company DTEK is represented by a horizontally-integrated Pavlogradugol (10 mines) on the lower level of technological chain and a horizontally-integrated power-generating company Vostokenergo (3 thermal power plants) on the upper level of technological chain. Neither coal mines (power plants), nor coal mining (electricity generation) companies conduct business on their own and supply their products to the parent company (business group). And what makes them close to Robinson Crusoe economy is managing a company output (operating modes) according to the product and resource prices.

To adapt a classical Lausanne model to modern production conditions the authors of this paper offered a single-factor production function with multi-resource equivalent (MRE) – a sort of hypothetical resource, which includes not just a direct labour as in the case of Robinson Crusoe, but electricity, materials, fuel, etc. costing as much as the production costs at actually operating business [10].

Production function of the enterprise is written as:

$$s = k \cdot Ln(r) + 1, \qquad (6)$$

where s – an annual output of the enterprise, standardized by its production capacity, unit fractions;

r – a standardized MRE input (relative to the total costs at full production capacity), unit fractions;

k – a regression coefficient, which reflects the internal parameters of the enterprise, based on mining and geological conditions of coal deposit, technological state of production, etc.

$$s = \frac{q}{P} \qquad (7)$$

$$r = \frac{z}{z_P}, \qquad (8)$$

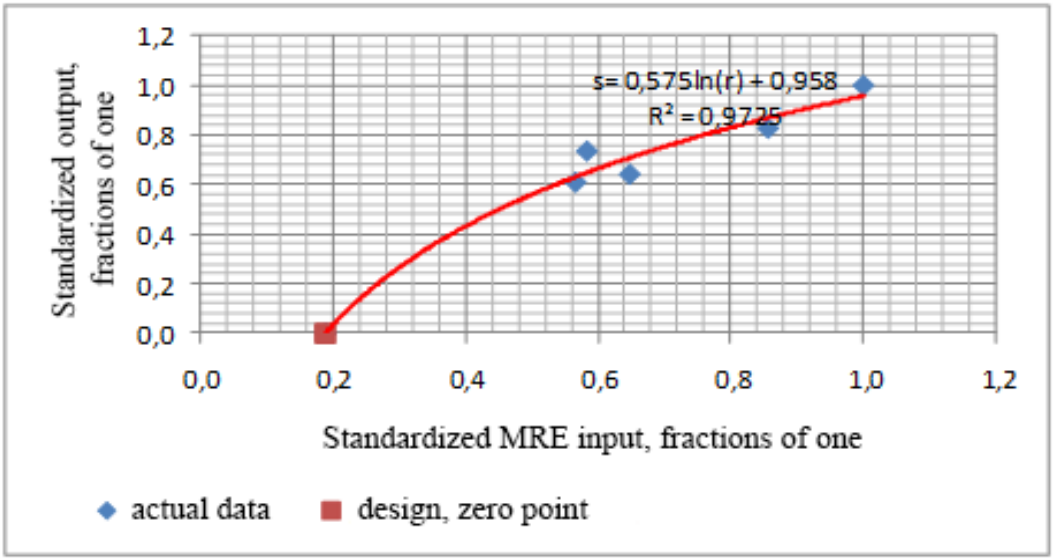
where q – annual output, in physical terms;

P – production capacity of an enterprise;

z – current annual inputs of MRE;

z_p – annual MRE input, when the enterprise operates at full capacity.

The production function of the Pokrovskoye Colliery Group, owned by PJSC "Donetsksteel", is given here as an example (Figure 2).



Source: compiled by the authors.

Fig. 2. Standardized production function of the Pokrovskoye Colliery Group

According to the classical model, the good x_2 is a coal in quantity s; when p and w are respectively: the cost of the extracted coal and the cost of inputs, when coal mine operates at a full capacity (s=1); the good x_1, by analogy with the Robinson Crusoe's leisure L-z, is a value z_p-z, i.e. production resource savings (1-r).

The formula of profit standardized by coal value takes the form:

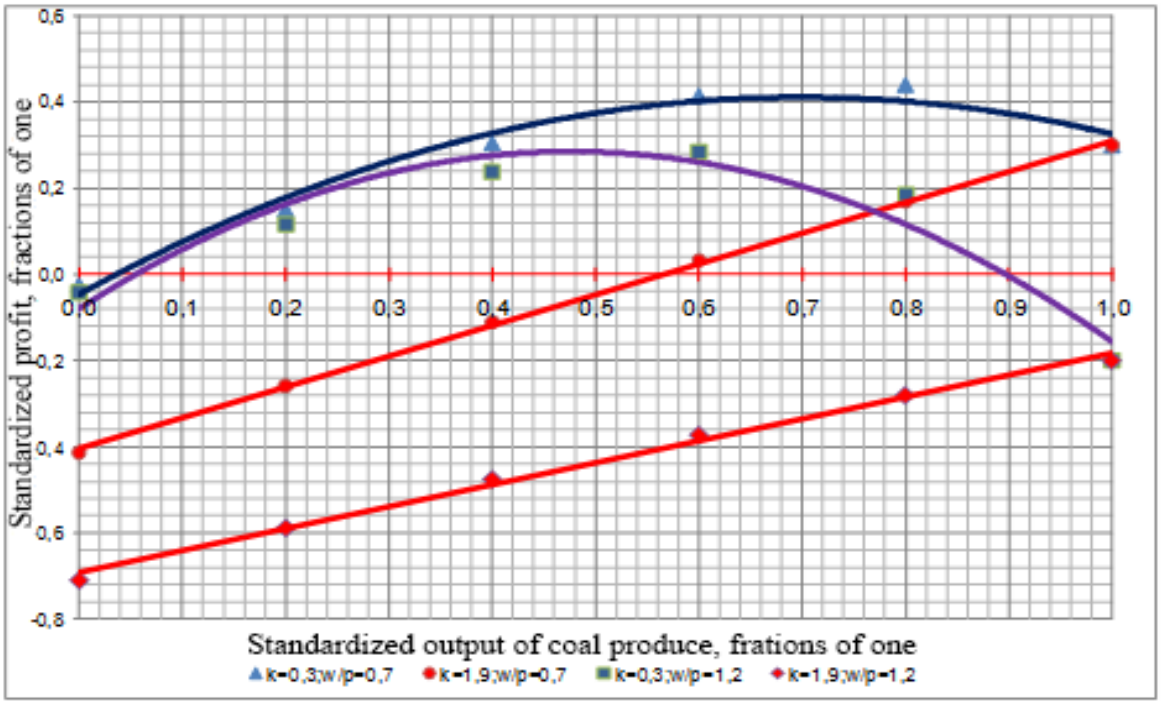
$$\frac{\pi}{p} = s - \frac{w}{p} r. \qquad (9)$$

Fig. 3 shows the calculated profit fluctuations at the enterprises having different operational characteristics, characterized by value k, in various market conditions, which can be described by the ratio w/p.

The higher the k value, the more complicated the operational characteristics of the enterprise are (very deep horizons, high gas content), and the higher (due to economic considerations) a coal production at the collieries should be in order to compensate for high dead expenses (resource input for mine drainage, ventilation, degasification). At shallow mines with a low level of output coal production needs to be adjusted since clean-up costs are decisive in the overall resource inputs. Fig. 4 demonstrates the difference in the elasticity of the production functions.

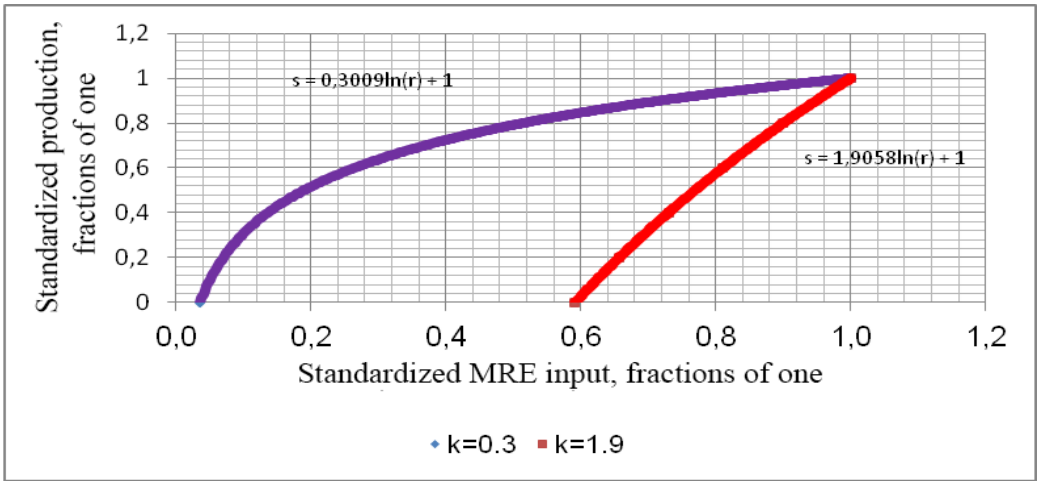
The less the value of w/p ratio, the better a market situation is for a colliery.

If a coal price is low compared to price of multi-resource equivalent (w/p>1), then collieries with difficult operating conditions have no chance to make profit: a Graph line on fig. 3 goes completely below the x-axis. In this situation it makes sense to increase output, which will help to minimize the losses. On the whole, the abovementioned tactics is in the interests of vertically-integrated power and energy groups as well as metallurgical corporations.



Source: compiled by the authors.

Fig. 3 Graph of standardized profit fluctuation at collieries having various operating conditions and at various market situations.



Source: compiled by the authors.

Fig. 4. A production function of collieries operating in various geological conditions.

If market conditions are favourable for coal production ($w/p<1$), even collieries having difficult operating conditions can achieve a break-even point (BEP). This happens when a standardized profit graph crosses an x-axis (at around $s=0.6$). Thus, a calculated future development of production promotes an increase of a profit.

On the contrary, the situation at the collieries, operating in good geological condition, is absolutely different. Even if the market situation is unfavourable ($w/p=1,2$), a cost-

effective operation of colliery can be ensured when its fixed assets are used to achieve 0,1 to 0,9 of its rated capacity. The higher production loads may bring about losses.

If market situation is favourable, i.e. coal prices are high and resource costs are low, colliery of this type will quickly exceed the level, at which BEP is achieved, and will remain profitable, when the colliery's basic production assets are used at full capacity.

Condition (10) forms the Robinson Crusoe's economics efficiency criterion: production loads at the colliery should not exceed its optimum value:

$$s \leq s_{opt}, \qquad (10)$$

where s_{opt} – is an optimum production load for the existing production technology.

A previous experience proves the appropriateness of the above stated academic points. The period of rather low coal prices was prevailing in Australia till the middle of 2016. One half of the local collieries, which covered one third of a thermal coal production, worked at a loss. "In the last 2 years we lost 21,000 working positions" – Mr. Michael Roche, a director-general of Queensland Resources Council (QRC) announced [11].

At the same time, as referred to in the report of Wood MacKenzie agency [11]: 'While demand remains for thermal coal, so that all product continues to sell, the price has remained soft... The market remains oversupplied and a focus on efficiency has seen some producers increase their production rates in a bid to lower their unit costs by spreading their fixed capital costs over a larger volume of production'.

But this is an example of how exactly the Robinson Crusoe economy should work when the operating conditions are difficult. And for the Japanese power company J-Power the best approach to managing its Australian branch coal company is to ensure the stable production, when resource input costs are dropping and the cost of their basic product – electric power – remains stable.

There are examples of another kind. In view of unfavourable market conditions in 2012, coal production at the Maple colliery was reduced by its owner – Walter Energy Inc. – by one third [12]. The same approach was chosen by the majority of the US mining companies, including all the major ones, though vertical integration pattern was usually not used in the US mining industry.

And this is an example of how exactly a corresponding Robinson Crusoe economy should act, when the resource input prices remain stable and a price of the final product is decreasing.

Still, the possibilities of using the Robinson Crusoe economy as an economic pattern are not confined to the abovementioned examples.

The explained approach was used by the authors of the paper to evaluate the investment project, aimed at introduction of vent wells massive boring technology at the Pokrovskoye Colliery Group. Though the innovative degassing method involves significant additional expenses, it is recommended for implementation in order to achieve a high production rate and to improve mine safety [13].

In this case vertical integration means the "colliery – drilling module" combination. The elements of the mentioned combination represent different branches of industry, but both of them are the property of the PJSC "Donetsksteel".

The use of Robinson Crusoe economy concept is substantiated by the necessity to study the effect of boring operation costs, carried out by a specialized body on the fluctuations of production function of a colliery. In this case the calculated costs of boring operations exceeded the actual expenditure of the colliery group since the calculations included the expenses of the parent company for procurement of a costly technological complex.

The research, carried out by the authors of the paper, showed the following: if the degassing technology by boreholes drilled from the surface is not implemented,

the condition (10) will not be fulfilled, i.e. the achieved output will surpass the optimum level at the given conditions of coal mine functioning.

Implementation of the innovative degassing technology will create necessary conditions for the economically attractive development of coal production and the group as a whole even though boreholes' drilling involves high additional costs. Practice confirmed these conclusions.

Since the Donetsksteel owns some other vertically integrated structures, such as "colliery and coal preparation plant", "coal preparation plant and by-product coking factory", "by-product coking factory and metallurgical plant", it is worth doing further researches to determine an optimum operating mode of such enterprises in cases of considerable fluctuation of input costs and final product prices.

Based on the national and international experience, a conclusion can be drawn that the current situation does not facilitate the intensification of business.

Low prices for metal and coal triggered a wide-scale restructuring in the most of vertically-integrated structures [14].

Robinson Crusoe economy in the form of "metallurgical corporation having coal assets" as in the case of other related entities can be analyzed by the same pattern: by developing a production function of the enterprise in the form of dependence of its output from MRE inputs and by evaluating the optimum operating conditions.

Conclusions

A model, formulated by the Lausanne school of economics in the 1930s of the XX century and known as the economy of Robinson Crusoe, forms a compulsory course in microeconomics at various universities of the world. Though it basically corresponds to the pattern of vertically-integrated system, it was undervalued by the industrialists.

Methodology, used for describing the economies of "1x1x2" pattern, which means "one producer, one consumer and two commodities" can be used for defining the optimum operating modes of vertically-integrated systems as well as for evaluating the efficiency of investment projects, aimed at their development.

Keeping in mind that when the economy of Robinson Crusoe is in a state of equilibrium, a graph of the consumer indifference curve touches a graph of the manufacturer's production function in the point which reflects the maximum of company profit and the analysis of operating efficiency of the system on the whole can be carried out by studying the operating mode of the producer of good only.

To adapt the classical model of Robinson Crusoe economy to the modern conditions of company operation it was offered to use a single-factor production function with an argument in the form of multi-resource equivalent (MRE), which is a hypothetic resource, combining the inputs of labour, electrical energy, fuel, materials, etc. and having the entire cost, which is equal to the entire company expenses.

Based on the analysis of profit fluctuations of coal mining enterprises (coal mines), which have various production characteristics and operate in various market conditions, a conclusion is made, that the worse the operating conditions of the coal mine are the more intensive its production load should be to make it more cost-effective. At the same time, coal mines, working in favourable operating conditions, need to limit their production load.

As the Australian and US experience proves, hypothetic constructs satisfy the coal mining practice in different countries, which allows asserting that it is possible to use the principles of Robinson Crusoe economy in respect of real enterprises.

In order to test this concept in Ukraine, we used a production data of the Pokrovskoye Colliery Group, which is a vertically-integrated structure with a drilling company, providing services for making degassing boreholes.

Conclusions, drawn on the basis of enterprise production function analysis, show the efficiency of innovative degassing technology and a possibility of using it in the development of an enterprise. The practical results of massive boring technology introduction at coal mining production of the Pokrovskoye Colliery Group proved the validity of theoretical analysis.

It is worth using the developed methodology to analyze and substantiate the methods of improving the operation of vertically-integrated systems in the sphere of coal washing, coke chemistry, metallurgy, power engineering and other branches of industry. At the same time its introduction into practice requires further research of company production functions.

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ІНТЕГРОВАНІ СТРУКТУРИ У ПРОМИСЛОВОСТІ ЯК ЕКОНОМІКИ РОБІНЗОНА КРУЗО

Модель, розроблена у 30-х роках XX ст. економістами лозаннської школи, відома як економіка Робінзона Крузо, є обов'язковим елементом університетських курсів з мікроекономіки, але виявилася недооціненою промисловцями, хоча за своєю природою відповідає схемі вертикально інтегрованих систем.

Методологія опису економіки формату «1×1×2», що означає «один виробник, один споживач і два товари», може бути використана для розрахунку оптимальних режимів роботи інтегрованих виробничих систем та оцінки ефективності інвестиційних проектів, пов'язаних з їх розвитком.

Ключові слова: економіка Робінзона Крузо, інтегровані структури, промисловість, модель, лозаннська школа.

JEL codes: D5.

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ИНТЕГРИРОВАННЫЕ СТРУКТУРЫ В ПРОМЫШЛЕННОСТИ КАК ЭКОНОМИКИ РОБИНЗОНА КРУЗО

Разработанная в 30-х годах XX в. экономистами лозаннской школы модель, известная как экономика Робинзона Крузо, является обязательным элементом университетских курсов по микроэкономике, но оказалась недооценена промышленниками, хотя по своей природе соответствует схеме вертикально интегрированных систем.

Методология описания экономик формата «1×1×2», что означает «один производитель, один потребитель и два товара», может быть использована для расчета оптимальных режимов работы интегрированных производственных систем и оценки эффективности инвестиционных проектов, связанных с их развитием.

Ключевые слова: экономика Робинзона Крузо, интегрированные структуры, промышленность, модель, лозаннская школа.

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MACROECONOMIC AND REGIONAL PROBLEMS OF INDUSTRIAL DEVELOPMENT

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WORLD MONETARY CENTRES AT THE STAGE OF GLOBAL FINANCIAL INSTABILITY: RISKS, CHALLENGES AND PERSPECTIVES

The paper analyzes origins, challenges and risks, associated with global financial transformations and the aggravation of the national currencies competition, in order to improve the understanding of the changes, taking place in this sphere, and to determine prospects for the development of the world financial system. It is substantiated that, taking into account the actions of global fundamental factors (populational, civilizational, technological, allocative and financial) in the long term, the financial situation on the planet will remain unstable.

Based on the application of the developed concept of the economic and monetary potential, it is grounded that in the medium term the world is likely to be generally divided into (if you ignore the British pound and the Japanese yen) the unstable predominant areas of US dollar (relatively stable), euro (decreasing), and RMB (increasing). The Russian ruble will remain on the world periphery and the potential growth of its influence will only be of a regional character. In general, the world will move to a multipolar financial architecture, the formation of which is connected with the "warming up" of new hotbeds of financial strains.

Nevertheless, the US dollar will still remain the world's leading currency for a long time (at least until the 2030s), due to the high political, military and economic influence of the USA, the relatively balanced monetary flows sources, the orientation of the economy on the large internal market, rather than on volatile external markets, as well as taking into account the "path dependence", in this case – the benefits of using the US dollar from the minimizing transaction costs standpoint.

The paper also substantiates, that in the medium-term agenda, despite the fact that the leading central banks managed to pacify the global crisis of 2007-2008, to improve the prospects for the developed economies and to begin the processes of normalizing the monetary policy, there remain the following questions of: distorted financial asset values and high risks in the non-financial sector, which is being restructured on cyber-physical technologies; persistently low interest rates in many developed countries; overheated credit and securities markets; high levels of global and national debts; targeted use of national currencies in order to achieve unilateral trading advantages, new challenges, related to the restructuring of the financial intermediation sector under the influence of fintech, etc. This is exactly the modern "financial normality", under which turbulent processes of shaping the new political and economic structure of the world will take place in the forthcoming years.

Keywords: global financial instability; monetary policy; currencies struggle; new "financial normality".

JEL codes: E52, E58.

Rather than declining, according to the International Monetary Fund (IMF), global financial risks are only increasing in the medium term, which, combined with the transformation of the global industrial structure and aggravating political contradictions, makes countries and markets more vulnerable to external and internal shocks [1]. Moreover, the situation can be exacerbated in view of recent events involving accusations against a number of world's leading countries of using their national currencies in order to achieve unilateral trade advantages [2].

The global financial instability must have become chronic. At first, during the Scandinavian banking crisis in the early 1990s it was seen as an accident, later on during the Asian financial crisis in 1997-1998 it showed as a symptom, and finally it became a dangerous disease in time of the financial crisis of 2007-2008 in North America, that shortly developed into global recession. In terms of the slow global economic growth (less than 3% in 2014-2016) the current outrunning of the credit growth in the US, EU and Japan, as well as in a number of developing countries, aimed at maintaining the consumer demand, can cause yet another financial turmoil at any time. According to the experts from McKinsey&Company, "Seven years after the bursting of a global credit bubble resulted in the worst financial crisis since the Great Depression, debt continues to grow. In fact, rather than reducing indebtedness, or deleveraging, all major economies today have higher levels of borrowing relative to GDP than they did in 2007. Global debt in these years has grown by $57 trillion, raising the ratio of debt to GDP by 17 percentage points. That poses new risks to financial stability and may undermine global economic growth" [3].

It is becoming yet more obvious, that recurrent financial crises are not a random problem, emerged under unfortunate occurrences, but is the intrinsic property of the modern world at current stage of its development.

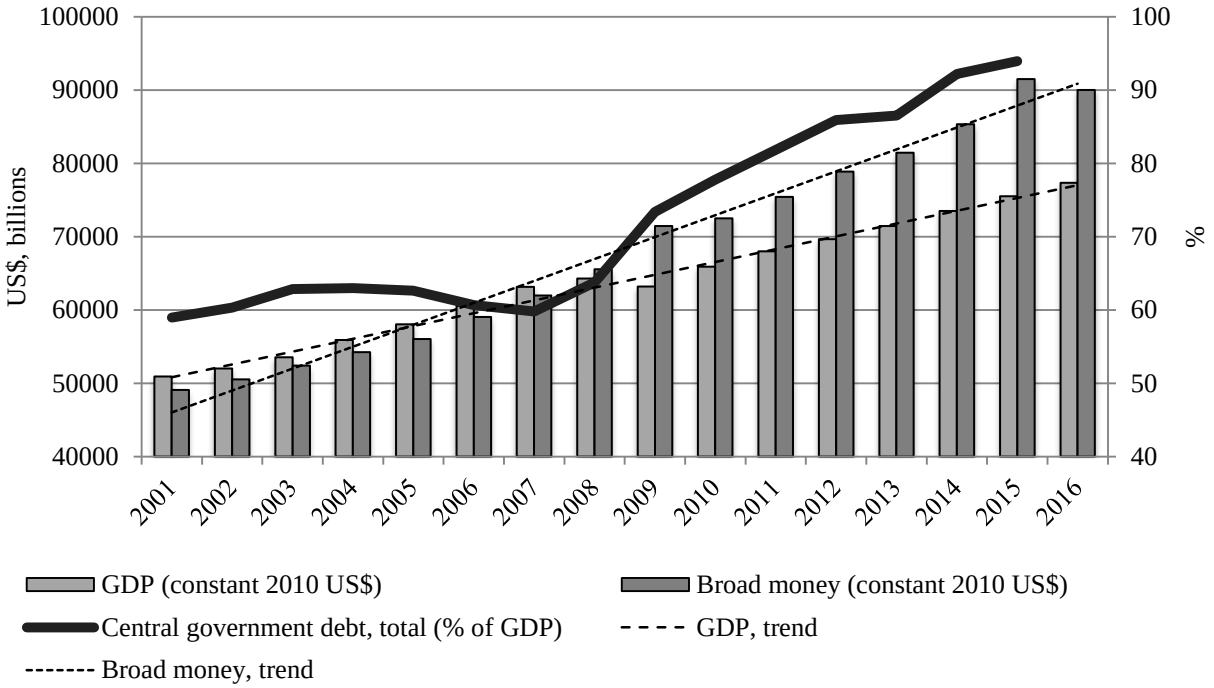
The root of this lies in the following fundamental factors of global instability: populational factor – limitations in human development with the growth of population and the depletion of natural resources, necessary for its sustainable reproduction [4, p. 45]; civilizational factor – an uneven global demographic dynamics, decreasing potential of Western civilization and increasing potential of non-Western civilizations (the Chinese, Hindu, Islamic civilizations) [5, pp. 46-60]; technological factor – a change of dominant technological modes with the transition to the production, based on the cyber-physical systems and blending of enabling technologies, blurring the boundaries between physical, digital and biological spheres [6]; allocative factor – shifting global production capacities to developing countries, which led to fundamental shifts in savings and investment [7, pp. xi-xii]; financial factor – rapid development of global financial markets and a dramatic increase in the mobility of international capital flows [4, pp. 46-47].

The abovementioned factors are, obviously, of different time, field and power of influence, and their impact is ambiguous, but in a complex and taking into account the growing gap between global production growth rates and money supply, they form, as the experts note, such a situation of a "new normal" [8; 9], in which there is no

chance for the situation in the global finance to be alleviated in medium term [1].

In order to find possible solutions to this set of problems it is necessary to continue the special study of the new financial normality phenomenon, given the particular significance of the relationships in the real and monetary spheres. To this end, the paper presents the analysis of the origins, challenges and risks, associated with the global financial instability and the national currencies struggle, aimed at improving the understanding of the changes, taking place in the global financial system in the face of new technological revolution.

Over the recent years, despite the slowdown in the world GDP growth, the money supply and central governments debts have been increasing rapidly (Fig. 1).



Source: The World Bank, World Development Indicators

Fig.1 Comparative dynamics of the global economy, money supply growths and central government debt

In reality, we should prepare for new manifestations of global financial instability, and to find appropriate responses to emerging circumstances of the world, regional (regions of the world), and national economies development.

Cash and liquidity (highly liquid assets) are, metaphorically speaking, the blood of the economic system. And like human blood examination helps to identify the disease correctly, an analysis of cash and those monetary arrangements of economic development, applied by the world's major players, is an important step on the way to the correct conclusion about the state of the issue, the essence and ways of solving emerging problems in the global economy, where the civilizations clash, countries fight for power and limited resources, financial bubbles appear and collapse, sending the waves of financial instability all over the world.

Nowadays there are several influential centres, which generate cash and liquidity flows of different capacity and quality – these are the leading countries of the West and East, but in this paper we deal only with those, which, in our opinion, are of greater interest from the economic diagnostics standpoint. Those are the leaders of global West – the USA (the dollar area) and the EU (the euro area), global East – China (RMB area), and also the huge Eurasian country– Russia (the ruble area).

Now the leaders of the global west – the US and the EU – are the centres of global capitalism as well as the world's leading monetary centres. It is the West where main international financial institutions were established, such as IMF and the International Bank for Reconstruction and Development (IBRD, the World Bank) [10]. According to the Society for Worldwide Interbank Financial Telecommunications (SWIFT) the activity share of the US Dollar ($), which is the global most used currency, exceeded 40%, and that of the Euro (€) account for about 30%, that is in total over 70% of global transactions (by costs). The main source of cash and liquidity of these economies is capital in the sense that the middle place in money-commodity-money (M-C-M) chain, which determines natural growth limits of the fiat money supply[1], is mostly taken by capital-intensive products [11, p. 40].

The leading country on the global East – China – is a rapidly developing monetary centre, the growing power of which is based on its leadership in global production of material goods. The RMB (¥) activity share is relatively small and corresponds to nearly 2% (December 2016) and therefore takes the 6th place in the world. However, for example, in operating the documentary credit transactions, which are widely used in Asian trade financing, China has already taken the 2d place after the USA. The main Chinese source of cash and liquidity is labour, because the middle place in M-C-M chain, which determines natural growth limits of the money supply, is mostly taken by labour-intensive products [11, p. 40]. It's not surprising, as long as China is the world labour force leader (more than 800 million people).

And finally, Russia – the link between East and West – is a country of the size of a continent (over 17 billion square km) and has the largest territory on Earth. The Russian Ruble (₽) is not listed among the main currencies, as it operates less than 0.5% of world payments. Nevertheless, the Russian monetary arrangement analysis is of great interest, at least for two reasons.

Firstly, the political and economic reason, that is the growing global influence of Russia. The Russian Federation managed to recover after the USSR had collapsed, to save and upgrade the substantial military force, which is now ranked the second place globally [12]. Russia is among the top 5 of world emerging economies – the BRICS group, positioning itself as an alternative centre of power, including a monetary one[2].

And secondly, the natural resources: Russia is enormously rich in mineral resources, especially in hydrocarbons – highly

[1] On the one hand, it is important to emphasize that there is no direct functional link between real and monetary variables, but, on the other hand, they cannot be considered independently. In philosophical terms, there is more of an essential coordination between them, the indissociability, parameters of which vary depending on the circumstances, time and place, and path dependence. And, moreover, the great importance is given to the restrictions put on a relation sign, i.e. the apparent condition of sustainable economic systems development is such dynamics, in which the monetary variables growth is accompanied by increasing (not decreasing) real variables.

[2] In July 2014 the BRICS countries signed the agreement for setting up the BRICS New Development Bank, which was designed to be an alternative to the World Bank and the IMF [13].

marketable goods of strategic importance for the modern economy. Thus, the main Russian source of cash and liquidity is natural resources, because the middle place in M-C-M chain, which determines natural growth limits of the money supply, is mostly taken by resource-intensive products [11, p. 40].

Traditionally, the largest part of Russian hydrocarbons export goes to the EU countries. Recently, however, things start to change. In May 2014, the Russian PJS Gazprom and China National Petroleum Corporation (CNPC) have signed a 30-year contract for supply of up to 38 billion m3 of the Russian gas to China per year. During the lifetime of this contract over 1 trillion m3 of gas is to be delivered to China which means to be the largest Gazprom deal [14]. Also, intense cooperation is developing in other areas.

Given the vast resources of these countries, eventually new global coalition can challenge the global West, including monetary sphere. As noted by the USA experts, "the Russia-China Alliance – we call it the new Axis – is already extraordinary powerful, as it is evident not only from the new economic and trade agreements and military cooperation, but also from the spheres of nuclear proliferation and cyber warfare. Both together and separately Russia and China seek to undermine social, economical and political foundations of the democratic societies and our unions in a way that is yet to be fully comprehended" [15]. However, China and the Russian Federation themselves believe, that their relations are at the best stage in the whole history [16]. All this, in turn, has a profound and multilateral influence on the global economic processes in general and the trends in the new financial reality evolution in particular.

In political and economic terms, the modern world, for many reasons, has become multipolar, and now the United States and the West in general are not the world's only centres of power. According to Patrick J. Buchanan[1], "Toward the end of the presidency of George H.W. Bush, America stood alone at the top of the world – the sole superpower… Consider now the world our next president will inherit. North Korea, now a nuclear power ruled by a 30-something megalomaniac, is fitting ballistic missiles with nuclear warheads. China has emerged as the great power in Asia, entered claims to all seas around her, and is building naval and air forces to bring an end to a U.S. dominance of the western Pacific dating to 1945. Vladimir Putin is modernizing Russian missiles, sending ships and planes into NATO waters and air space, and supporting secessionists in Eastern Ukraine. The great work of Nixon and Reagan – to split China from Russia in the "Heartland" of Halford Mackinder's "World Island", then to make partners of both – has been undone. China and Russia are closer to each other and more antagonistic toward us than at any time since the Cold War" [17].

However, as for the monetary system, it still remains western-polar, and seems to be stuck in the Bretton Woods system, the western rules-based world order – underpinned by the IMF and the World Bank, with the US dollar in its heart – that emerged after World War II and institutionalized America's geopolitical supremacy [18]. As already mentioned, the major western currencies – the US dollar and the euro – account for the majority of all international payments in the world (at cost). The US dollar and the euro are the leading global reserve currencies – more than 80% of global foreign exchange reserve assets are denominated in them [19]. At the same time, ac-

[1] Patrick Joseph Buchanan (born 1938) is the well-known American politician and political commentator, worked as the special assistant to R. Nixon, as the adviser to G. Ford, and served as Reagan White House Communications Director.

cording to the World Bank, the combined share of the US and the EU engagements in industry, which is the engine of innovative development of the world economy, is now about 30%.

Currently, this monetary world order does not work properly. According to J. Stiglitz, Nobel Memorial Prize laureate in Economics, "Right now, the world suffers from insufficient aggregate demand. Financial markets have proven unequal to the task of recycling savings from places where incomes exceed consumption to places where investment is needed. When being the Chairman of the US Federal Reserve, Ben Bernanke mistakenly described the problem as a “global saving glut”. But in a world with such huge infrastructure needs, the problem is not a surplus of savings or a deficiency of good investment opportunities. The problem is a financial system that has excelled at enabling market manipulation, speculation, and insider trading, but has failed at its core task: intermediating savings and investment on a global scale" [20].

To overcome the consequences of the global financial crisis, to maintain demand and to prevent deflation, the US monetary authorities (and then the EU and Japan) launched new innovative liquidity injection and the money cost reduction for their countries programme. At this time, the US Federal Reserve System’s extensive discretionary actions expanded beyond merely controlling the money stock, so this practically became "… a gigantic, financial central planner" [21, p. 486].

Such monetary policy, on the one part, allowed breaking the unfavourable economic trends: for instance, after the financial crisis of 2007-2008 the USA started creating new jobs, reduced unemployment and raised consumption rate, investment, R&D spending [22]. According to the World Bank’s data, the average economic growth rates in the USA in 2010-2016 were over 2%. In 2014 the EU countries (member states of euro area) also reached the positive growth rates.

Yet, on the other part, it creates new challenges.

The thing is that the value of money is information of fundamental importance for the market economy that regulates business processes, primarily – investments. The planned large-scale money depreciation leads to an artificial rise in the value of assets (low interest rates increase the return on shares, corporate bonds, real estate and other assets, pushing the value), encourages enterprises into critical debts, reduces the borrowers' quality and distorts economic data for investors. All this has long-term negative consequences and increases the possibility of other financial bubble occurrences. In such situation investment flows can be directed to projects which normally would not be considered as attractive, or to dealing for stock prices and speculations. But industry sector with a moderate return for capital employed, which is a built-in innovation generator in the economy, wins little from this. Another reason for that is that financial capital, boosted by the quantitative and credit-easing policy, can choose where to invest, while avoiding excessively risky compared to the expected return investments, when production capital, which depends on the previous path of development, has to seek for technical solutions and financial resources within narrowly defined frames [23, p. 105].

It should also be taken into account, that monetary and other measures of overcoming the recession, taken by the governments of many developed countries, exhausted their supplies of anti-crisis policy tools, because the interest rates of the central banks are of nearly zero value, and the public debt and budget deficits in many countries have not decreased, but increased, reaching the alarming proportions. As noted

in The Economist (2015 "The Bank of England's base rate sits at 0.5%. Records dating back to the 17th century show that, before 2009, it had never fallen below 2%; and futures prices suggest that in early 2018 it will still be only around 1.5%. That is healthy compared with the euro area and Japan, where rates in 2018 are expected to remain stuck near zero. When central banks face their next recession, in other words, they risk having almost no room to boost their economies by cutting interest rates. That would make the next downturn even harder to escape" [24].

Finally, it is important to emphasize, that due to the peculiarities of the current monetary order such actions of the US Federal Reserve System have global impact: "Printing dollars at home means higher inflation in China, higher food prices in Egypt and stock bubbles in Brazil. Printing money means that U.S. debt is devalued so foreign creditors get paid back in cheaper dollars. The devaluation means higher unemployment in developing economies as their exports become more expensive for Americans. The resulting inflation also means higher prices for inputs needed in developing economies like copper, corn, oil and wheat. Foreign countries have begun to fight back against U.S.-caused inflation through subsidies, tariffs and capital controls; the currency war is expanding fast" [25, p. 9].

In general, all this testifies to the fact, that globally the major financial intermediaries appeared to be "short-sighted" and lacking professionalism. They learned well how to solve the current problems of monetary regulation of national economies (from time to time puffing both local and global financial bubbles). Regarding the global real investment financing – in this respect the situation is much worse. This is point one.

Point two is that in the existing world order the new world centres of political and economic power (above all China, the economic and monetary potential[1] of which is growing at a higher rate – Fig. 2) are limited in their international monetary power (Fig. 3).

It appears that in this regard they are dependent on the external forces and the impacting external economic environment, and are unable to control the global situation in accordance to their increased potentials, but each time are forced to seek ways of calming the new emerging from the outside "tsunami waves" of financial and economic instability.

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[1] Economic and monetary potential is an indicator for characterizing the commodity-cash flow capacity of the country, a kind of working capital, which takes into account only the turnover. The latter varies in different countries, because along with the broad money it uses the GDP, resulting from the annual money circulation.

Therefore, the following formula is offered:

$$P_i = (G_i M_i)^{0,5},$$

where G_i is the GDP (the value of final goods produced and sold during the year) of the country i;

M_i is the broad money (M2), which served the production and sale of these products in the country i over the year.

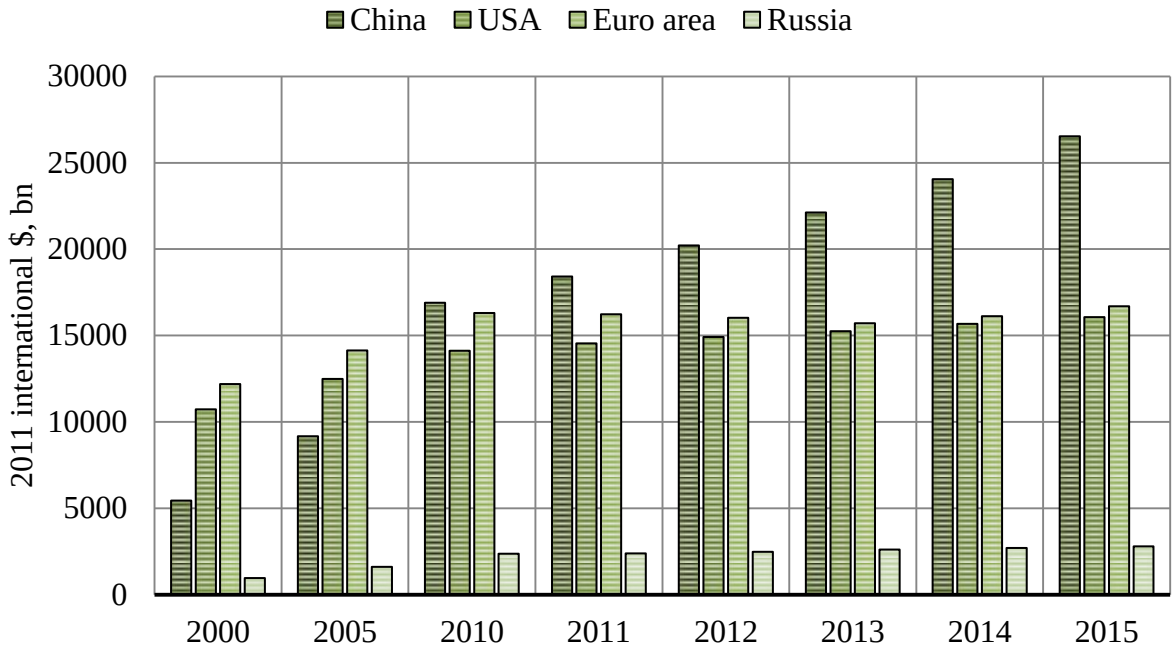
International payments only use the x_i part of the broad money, let it be called $M_{xi} = M_i x_i$. Circulating M_{xi} serves a certain amount of k_i of the total annual value *W* of the international payments sum of

$$M_{xi} v_i = W k_i,$$

where v_i is the broad money circulation speed (circles number) in the country *i*.

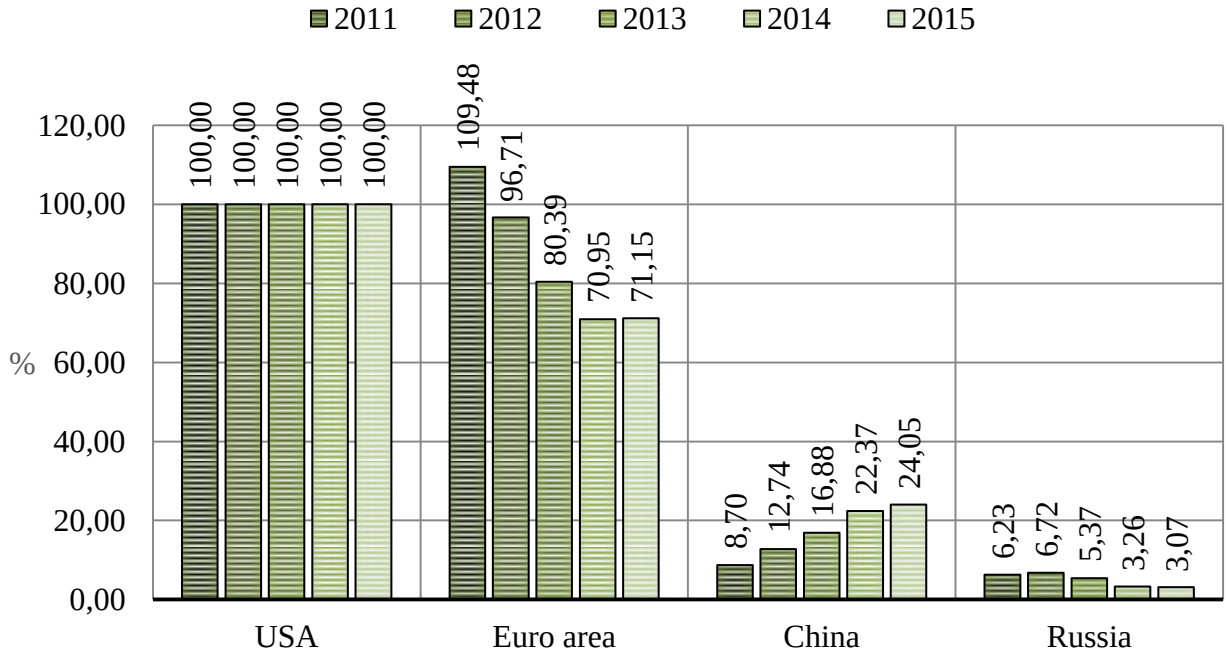
Then the realized potential, taking into account that the currency of the country serves only a part of international turnover, is accounted for $\widehat{P}_i = (G_i W k_i)^{0,5}$, and the comparative economic and monetary potential of the country *a* to the country *b*, considering different levels of international payments involvement is accounted for

$$\widehat{P}_{a/b} = (G_a W k_a)^{0,5} (G_b W k_b)^{-0,5} = \\ = (G_a k_a)^{0,5} (G_b k_b)^{-0,5}.$$



Source: calculated on data from The World Bank, World Development Indicators

Fig.2. The absolute economic and monetary potential of different world monetary centres (the root of the GDP to M2)



Source: calculated on data from The World Bank, World Development Indicators; SWIFT Annual Review.

Fig.3. The comparative economic and monetary potential of different world monetary centres, having regard to the currencies' participation in the international settlements

But the new world centres have been already disagreed with this global state of affairs and will hardly support it voluntarily in the future. Practically it means the currency competition.

The example is the major world commodity-money "USA-China" link.

In the globalized world the production capacities are mostly placed in countries with the lowest costs, trained labour force, access to raw materials and modern technologies (that is now the case in China). In these conditions, the policy of the leading global power centre, which is also the leading global liquidity centre (the US Federal Reserve System), imposes the constraints on the policies of all other power centres, and the consequences are often hard to predict. For example, the "helicopter drop of money"[1] that is the "quantitative easing", used by leading developed countries by repurchasing government obligations on the secondary market (from banks), and the "credit easing" by repurchasing at certain segments of markets the commercial papers, corporate bonds and asset-backed securities, may lead to bringing the inflation to its normal, conduce the reshoring and instigate the issuers' performance, as well as to a deflation and further stagnation of country's industry, only if mass production of commodities is stuck in offshore.

The reasons why it can stay there are as follows:

(1) Inertia. The relocation of production is associated with the costly (including transactional costs) leaving of one production location and entering the other. The productive capital "is basically tied to concrete products, both by installed equipment with specific operational capabilities and by linkages in network of suppliers, customers or distributors in particular geographic locations" [23, p. 105]. So, taking the full costs into account, the relocation process is not so easy to implement, even if the task is set by politicians[2];

(2) Despite the increase in costs in the offshore, a safety margin in the form of lower wage costs (at global competitive prices for equipment, raw materials and their method of connection – technology) can be quite big. For example, the Chinese wages increase, even double, which however would not make it equal to the American level, but with the availability of low-wage labour force would create additional incentives for all the new layers of workers in unproductive areas, to involve in more productive and lucrative sphere of industrial manufacturing, thereby heating up the economy through investments in mass labour force relocation and allocation (which is the case in China, where only over 3 years (2011-2013) more concrete on the new buildings had been spent, than in the United States over the whole 20th century [27])[3];

[1] The metaphor by M. Friedman, characterizing the peculiar monetary policy of combating the deflation, which was used in one of his speeches by the former US Federal Reserve System's chairman B. Bernanke, for which he was dubbed the Helicopter Ben [21].

[2] The typical example is from the USA. In 2012, during the meeting with the heads of the US leading technology companies, Barack Obama asked Steve Jobs, if it was possible to transfer the Apple production back to America. Jobs responded that it was impossible and those jobs would not be coming back ("Why can't that work come home? Mr. Obama asked. Mr. Jobs's reply was unambiguous. "Those jobs aren't coming back," he said"). The main reason for that is the modern USA infrastructure and labour force does not meet Apple's needs, and this situation cannot be changed in a quick way [26].

[3] It should be noted, however, that China's capabilities in this regard also are limited. Countries, with most population living in rural areas, really can steadily develop their economies for years at the expense of the rural workers and low salary rate, as the Nobel Prize winner in economics – A. Lewis – substantiated in the mid-1950s. But China, according to some experts, is showing signs that the economic processes reached the so-called Lewis turning point, when the labour force sources are running short and wages are growing rapidly. At least in 2005-2010 the increase in the number of the migrant workers from the countryside was at 4%, while in 2014 it amounted to only 1.3% [28].

(3) Compensating costs reduction on account of the scientific and technological advance: if technological order (techno-economic paradigm) is in deployment phase in the country, then the enhancements, hindering the imported inflationary costs growth, and/or significantly improving the quality of goods and services can be introduced with relatively low investments and a small-time lag. It should be borne in mind that the location of the generator of such innovations is turned towards the production location: science is gradually drawn to the industry, which forms a symbiosis of research and production. It happened so in the early 20th century, when the R&D moved from Europe to the former "workshop of the world", the United States, and so it happens at the beginning of the 21st century, when the R&D is gradually moving to the current "workshop of the world" – the East and South-East Asia.

In such circumstances, the newly issued currency goes into the hands of the sellers of offshore-originated products and through the adjustable floating RMB rates (which, according to the government, is of the China national interests) becomes the national currency injection, heating up its (China's) economy.

In order to sterilize the money inflows, keeping the inflation within normal range and preventing its conversion into an uncontrollable spiral, the offshore government can use three main options:

(1) to hoard capital into international liquidity, usually presented in form of debt securities issued by foreign governments (especially the US Treasury securities) and in gold [29];

(2) to invest outside China in the projects of critical importance for the national security (the production and supply of raw materials, the creation of new transport corridors for incoming and outgoing goods flows, etc.[1]);

(3) to invest money in the accelerated development of the national economy, involving the production processes (including the production of export goods, which bring increased proceeds in the domestic currency), in new layers of human and physical resources, creating new production facilities and infrastructure for them.

The results of these processes are as follows:

- the inflation export from the country of issue to the offshore production country;
- the inflationary heating-up of the offshore production, coming amid increasing import expenditures, which usually operates for the benefit of the competitive advantages of the issuing country; but, in the case of a particular set of circumstances (an X-case), the offshore production country may even reduce the product's selling price, for example, due to excess investment in the production facilities and infrastructure (which had taken place in China in the aftermath of the global financial crisis of 2007–2008) and/or due to increasing inno-

[1] For example, among such projects is the construction of the Nicaraguan *Canal*, about 300 km in length, the estimated cost of which is $50 billion. With this rival to the Panama Canal, Beijing expects to give a boost to the world shipping, which would stimulate the Chinese economic growth. The 5300-km railroad through Brazilian and Peruvian Amazon is expected to be the next megaproject, financed by China. Another project is the "One Belt, One Road" which should connect 65 countries with a combined population of 4.4 billion people. The railway is expected to begin in Xian, the West of China, where the ancient Silk Road began, and passing through the whole Central Asia, the Middle East, Russia, ending in Western Europe. Rich in mineral resources and raw materials, Africa still remains in the sphere of China's interest. For instance, in April 2015 the state-owned China Railway Construction Corporation (CRCC) signed a $3.5 billion contract in Nigeria and a $1.9 billion in Zimbabwe, in addition to the $12 billion contract to construct a railway through the state CRCC just signed in November 2014 [30].

vation productivity through accelerated development of the "production-science-production'" symbiotic system;

- growth of the public debt of the country of issue, that is, essentially, the transformation of central bank bills in the government bills, which are passed into the hands of external contractors, which get their hands on the levers of political and economic influence[1];
- an X-case – the offshore production country deflation export in form of new flows of bottom-of-the-line products, entering the country of issue [32; 33; 34].

Thus, in a globalized world an attempt to improve national finances in times of financial crisis with 'money helicopters' can in the end result in some national economy warming-up, and/or in the paradoxical offshore production development, the growing welfare of those employed there and offshore economy as a whole; in the growing trade balance deficit of the country of issue, which consumes on account of public debt, to repay which it can become necessary to sell out fixed assets, or to default, or to lose political and economic power (which is the most likely option).

It turns out that a lot of things critically depend not on money and monetary policy *per se*, but on the production location and the material development capabilities. But to let such production develop, it is first necessary to have one. Figuratively speaking, to let a tree grow, expanding its living space, firstly it must be planted and "established". There is always a problem, and, in practice, very few manage to solve it. But China and some other countries of the East and South-East Asia, still managed to do it. First, there appeared some free-trade zones in China, which grown up under a warm foreign investment "rain", which had fallen on the fertile ground of stable political institutions, thousands year old Confucian traditions and cheap labour force, and which now are gradually transforming into "self-fertile" symbiotic systems of research and manufacture: by the volume of financing the Chinese R&D is steadily catching up with the US R&D, surpassing all other countries of the world, and by the number of publications in scientific journals, China has already ranked second globally [35]. Although, of course, in this regard, it is still far from being well and a lot of steps remain to be done: despite the growing financing, improved training of scientific and technical personnel and modern scientific equipment, Chinese scientists have not yet succeeded in making Nobel Prize-worthy scientific breakthroughs, science and production remain disjointed and only a few research findings are brought to the level of innovative industrial technologies and products, and Chinese enterprises, with few exceptions, are still heavily dependent on foreign sources of key technologies [36].

Anyway, current global money helicopter is mainly controlled by one pilot, and the pilot (the US Federal Reserve System) is obviously acting for the interests of a single country, above all, for the interests of the USA, thereby, creating challenges and problems for many other countries. So, there is a fundamental contradiction between new rising power centres, which are of great strength economically and monetarily, but still do not have global monetary authority, and previously-established centres of power, which use their global monetary authority in their own interests because of momentum (but not as effective as before). Therefore, for example, China does not want to sit soaking wet in the foreign monetary rains, and aims to give weigh to the national cur-

[1] Many economists believe that the US dependence on foreign savings exposes the US economy to certain risks, and some also claim that the cheap capital inflows contributed to the property market financial bubble and the subsequent global financial crisis, which began in 2008 [31].

rency (Yuan) in terms of global monetary system. The same also applies to other new centres of power.

This paper investigates the current situation, problems and prospects of the development of the world powerful monetary centres: the US with dollar, the EU with euro, China with Yuan and Russia with Ruble (though there still exist such traditional centres as the UK with Pound, Japan with Yen, as well as the developing Hindu, Muslim and Latin American countries). At the same time, as noted above, with a certain degree of conditionality we can claim that in the US and EU fiat liquidity flows mostly rely upon capital-intensive productions (capital), when in China – upon labour-intensive productions (labour), and in Russia – upon resource-intensive productions (natural resources) [11, p. 40].

Every type of monetary flow in dynamics has its shortcomings: the capital-relying one (industrial and financial) has problems, related to the possible financial capital separation from the material production and the emergence of financial bubbles; the labour-relying one has problems, related to approaching the Lewis turning point; the natural-resource-relying one has problems, related to the prices volatility under technological advances and other factors.

Obviously, to ensure greater stability and liquidity for fiat monetary flows it is better to rely on a balanced set of sources (the available internal or external), that allows to overcome these problems easier and gives these flows the fundamental stability.

In this respect, the USA are in the best position: generally, all three sources are available – capital, labour and natural resources, although it is more of the financial capital (mainly equity-type of capital), than production capital, which, in fact, can result in financial bubbles and a weakening of confidence in US dollar and furthermore, the labour structure is gradually changed, bringing hard to predict, but likely negative consequences for the economy and monetary flows.

This is happening due to the dechristianization processes in the US (as, however, and in the EU countries), the disintegration of society into conflicting ethnic, confessional and other groups [37], the increasing number of Hispanic and Afro-American families, in the structure of the US population, the median income of which is traditionally lower than that of white, non-Hispanic families, and the higher unemployment [38]. By 2050, current non-white minorities (any race other than non-Hispanic, single-race Whites) will become the majority, and the proportion of the Hispanics can dramatically increase from the current 15% to 30% [39].

The situation is a little bit worse in China, which stands among the world leaders in terms of labour force, many of which has sufficient knowledge and skills to participate in the modern industry, and have amassed a capital powerful enough – both financial (as opposed to the US to a greater extent the bank capital, instead of the equity capital) and production, including many contemporary industrial technology, but are in relatively poor situation concerning its own natural resources.

And the situation is even worse in the EU, the member states of which are traditionally in possession of a significant capital, capable of generating innovation, again mostly the financial capital (and, in contrast to the US, mainly bank-type) than production capital, but have well known problems with natural and labour resources (including those related to the growing number of non-assimilated Islamic population [40]), and especially Russia, which has abundant natural resources, but obviously has its chronic problems, both labour issues (difficult demographic situation, the shortage of skilled engineering and working professionals), and capital issues.

The EU-Russia and China-Russia alliances are the speculative rivals to the US dollar. The first is unlikely to be realized in the current reality, including prevailing geopolitical trends and existing social and cultural differences. The potential of the second alliance is growing, but it is also not clear yet how it will be implemented. Russia with its natural resources and central location in the Mackinder's Heartland [41] is likely to maintain, if it is a success, good political relations and economic ties with both the West and the East.

Nevertheless, the improving access even to the part of natural resources and the extending transportation and logistics, scientific-technical and military cooperation with Russia [42] would stabilize Chinese economy and the RMB a great deal, so that over time they will be able to challenge the current monetary order.

The steps in this direction have already been made, e.g. the construction of new oil and gas pipelines, the cooperation between two countries in the fields of space and aviation, the participation of Chinese capital in investing into the Russian Federation [16], newly created international banks (Asian Infrastructure Investment Bank, the BRICS New Development Bank) with the participation of China, the Russian Federation, and others.

However, it is clear, that all this is unlikely to happen soon, especially since the USA and China are in the political and economic clinch, when in the case China sells large amount of the US Treasury securities, owned by them, the cost of the remaining will decrease dramatically, and any negative shocks to the US economy will lead to a drop-in demand for Chinese exports, with all the resulting negative socio-economic and political consequences [31].

Given the evident undesirability of such shock transformations, in the next decade the US dollar is likely to have no serious rivals, although, the euro continues to weaken (due to the lag of EU economy growth rate behind the world rate, natural resources issues and the increasing demographic, ethnic and sectarian tensions), the weight of the Ruble in the future may expand gradually through the Eurasian Economic Union (EEU) potential realization and the expansion of trade with China, but it will remain on global fringes, while RMB weight will continue to grow more quickly and in greater scale, provided that current trends (Fig. 2) last and China manages to maintain the political stability and to use natural resources and transit potential of other countries (including Russia – through the new Silk Road Economic Belt, as well as the countries of Africa and Latin America), and as its production capacity will be transformed into a strengthening of the monetary authorities in international economic relations.

The Chinese monetary system is already becoming yet more and more globalized: more than 50% of non-Chinese companies use RMB for payments outside greater China: in Singapore (74%); South Korea (59%); the euro zone (58%); the UK (57%), and North America (54%) [43, p. 7]. The companies, such as Daimler in Germany, Ford and General Motors in the US, have stated the RMB is now their second most-used currency [44].

Moreover, in October 2016, the RMB was added to the IMF basket of reserve currencies, and its share in the Special Drawing Rights (SDRs) currency basket was 10,92% (this is the third position, the US dollar had about 40%, and the euro's share had declined from 37,4% to 30,93%) [45].

On the one hand, the inclusion of the RMB in the SDR basket secures the process of its internationalization and leads to a further growth in demand for assets denominated in Chinese currency, from public and private investors. But on the other hand, all this is connected with the risks of impeding

control over the exchange rate of the RMB, increasing its value and capital outflows, with all the complex consequences arising for the Chinese and global economy.

Conclusions

In the upcoming decades, the world is likely to be generally divided into (if you ignore the British pound and the Japanese yen) the unstable predominant areas of US dollar (relatively stable), Euro (decreasing), and RMB (increasing). So, apparently, in the next few years, the RMB will not be displacing the US dollar, but the US dollar and RMB will gradually replace the euro. The Russian rubble, as previously mentioned, will remain on the world periphery and the potential growth of its influence (including in connection with the predicted retention of Russia's positions in the top 10 of the world's leading economies for the long term [46]) will only be of a regional character.

US dollar will still remain the world's leading currency for a long time (at least until the 30s of the 21st century, to which the National Intelligence Council's forecast extends [47]), due to the high political, military and economic influence of the USA, the relatively balanced monetary flows' sources, the orientation of the economy on large internal market, rather than on volatile external markets, as well as taking into account the "path dependence" (in this case – the benefits of using the US dollar from the minimizing transaction costs standpoint[1]).

The high US national debt undoubtedly creates great risks to the US economy, but in the relative weakness of the economies of the euro zone and Japan, and strong demand for the reliable financial assets and the accumulation of foreign exchange reserves from the developing countries, this factor may play more to the maintenance of the US dollar leading role in the global financial system, than to its weakening.

The sphere and strength of the euro influence will continue to decline as Europe does not have a balanced source of monetary flows and is too weak politically and militarily, economically heterogeneous and institutionally divided to reliably attract them from outside and be effective at a global level.

With regard to the prospects for Chinese currency unit, striving for a fair representation in the global financial system, the sphere and power of the RMB influence, despite the obvious growth contradictions and difficulties (associated with the excessive debts of enterprises, large scale of shadow banking, stock market development, etc.), will increase[2]. Objectively, this is determined by the fact that China is already the second world economy and consistently expands its access to new technologies and the world's natural resources, in addition to the existing human and financial resources, as through the creation of new global transport corridors. At the same time, the RMB rates of potential realization as a world currency will depend on the China's successful policy in terms of the capital account liberalization, the greater exchange rate flexibility and financial market development, and, of course, the country's political stability and the efficiency of the country's economy.

However, everything indicates that the world will not remain monetary West-polar,

[1] The more popular one currency is, the more useful it is to those, holding it. And even if there is an incentive for someone to switch to the other less popular currency, they must first convince many other agents to switch to it before such a transition has a direct economic sense. These "switching costs" are one of the reasons why, for example, the pound is still widely used for international settlements, although the United Kingdom has long lost its leading position in the world [48].

[2] On the increasing role of RMB monetary power can be judged in how the Chinese decision to devaluate the RMB by several percent in August 2015 caused considerable reaction in the world, resulting in about $5 trillion loss for the global stock markets [49].

and not purely due to monetary, but to the fundamental political and economic reasons, since Western Christian world gradually retreats under the increasing pressure from the renewing themselves East and South, the growing Confucian, Hindu and Muslim civilizations.

In this regard, taking into account the fundamental factors of global instability (populational, civilizational, technological, allocative and financial), it can be expected that in the long term the global financial situation on the planet will not become more stable. In the medium-term agenda, despite the fact that the leading central banks managed to pacify the global crisis of 2007-2008, to improve the prospects for the developed economies and to move to curtailing the measures of the unconventional monetary policy (the US Federal Reserve) [50], there remain questions of: distorted financial asset values and high risks in the non-financial sector, which is being restructured on cyber-physical technologies; persistently low interest rates in many developed countries; overheated credit and securities markets; high levels of global and national debts; targeted use of national currencies in order to achieve unilateral trading advantages, new challenges related to the restructuring of the financial intermediation sector under the influence of fintech, which requires further special studies, etc. This is exactly the modern "financial normality" under which turbulent processes of shaping the new political and economic structure of the world will take place in the upcoming years.

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ВСЕСВІТНІ ГРОШОВО-КРЕДИТНІ ЦЕНТРИ НА ЕТАПІ ГЛОБАЛЬНОЇ ФІНАНСОВОЇ НЕСТАБІЛЬНОСТІ: РИЗИКИ, ПРОБЛЕМИ І ПЕРСПЕКТИВИ

На основі застосування розробленого методичного підходу до оцінки економіко-монетарного потенціалу визначено ключові тренди сегментації світової фінансової архітектури. У середньостроковій перспективі (якщо абстрагуватися від британського фунта і японської ієни) вона буде представлена нестійкими зонами переважного впливу долара США – відносно стабільною, євро – що скорочуватиметься і юаня – що зростатиме. Російський рубль залишиться на світовій периферії, а очікуване посилення його впливу матиме переважно регіональний характер. Також визначено ключові ризики і виклики, що складають нинішню "фінансову нормальність", в умовах якої в майбутні роки буде формуватися нова політико-економічна структура світу.

Ключові слова: глобальна фінансова нестабільність, грошово-кредитна політика, боротьба валют, нова "фінансова нормальність".

JEL codes: E52, E58.

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ВСЕМИРНЫЕ ДЕНЕЖНО-КРЕДИТНЫЕ ЦЕНТРЫ НА ЭТАПЕ ГЛОБАЛЬНОЙ ФИНАНСОВОЙ НЕСТАБИЛЬНОСТИ: РИСКИ, ПРОБЛЕМЫ И ПЕРСПЕКТИВЫ

На основе применения разработанного методического подхода к оценке экономико-монетарного потенциала определены ключевые тренды сегментации мировой финансовой архитектуры. В среднесрочной перспективе (если абстрагироваться от бри-

танского фунта и японской иены) она будет представлена неустойчивыми зонами преимущественного влияния доллара США – относительно стабильной, евро – сокращающейся и юаня – растущей. Российский рубль останется на мировой периферии, а ожидаемый рост его влияния будет иметь преимущественно региональный характер. Также определены ключевые риски и вызовы, составляющие нынешнюю "финансовую нормальность", в условиях которой в предстоящие годы будет формироваться новая политико-экономическая структура мира.

Ключевые слова: глобальная финансовая нестабильность, денежно-кредитная политика, борьба валют, новая финансовая нормальность.

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THE PROFESSIONAL PERSONNEL DEVELOPMENT PROVISION AS A COMPONENT OF THE DECENT WORK CONCEPT

In the paper modern trends of professional development in Ukraine are investigated. The analysis of survey results have defined that there are differences in beliefs of people depending on their age, development level and social status. However, the formation of an effective and sustainable economic growth of an enterprise is impossible without human development of employees, their knowledge and skills. The existence of professional development helps to reduce employee turnover, to increase their commitment and loyalty to the company and to create a favorable social and psychological climate within the collective. Development in an enterprise gives social life a sense of order and stability to workers and additional social guarantees of their employment. This is the main aspect, which allows connect an increase of the staff's qualification level and provision of decent working conditions. In spite of this, an employer often wants to reduce expenses on vocational education and staff training because now the economic situation in the country (Ukraine) is unstable and there is a lack of necessary funds. For this reason, new technologies and development programs of staff are rarely implemented in the labor market. In particular, the disregard for the personnel needs in training leads to decrease in productivity, work motivation, reduction commitment to a company, loss of confidence and positive social interaction with colleagues and top managers. On the other hand, professional development increases business efficiency and competitiveness. Up-to-date methods of vocational training on the labour market of European Union member countries were analyzed with the aim of improving the Ukrainian training system. The experience of foreign companies is important, because they have long realized that the human capital and economy of knowledge become a source of economic growth of the enterprise.

Key words: professional development, decent work, employees, employers, labor market.
JEL codes: J2, I25.

New realities of a modern world require transition to a new level of social relations. The scientific and technological revolution, as well as high technologies and modern standards of management, related to it, dictate existence of professional qualities of workers, their high qualification, mobility and efficiency. In such situation the key to success and competitiveness of each enterprise is qualified personnel, capable to gen-

erate new ideas, to bring expected result and to reach goals set forth, be adaptable to frequent changes, occurring in the world. Therefore, decent work is not only productive, free, safe, established on the principle of equal payment for equal work, but also a kind of work, that doesn't humiliate dignity and develops high potential of a person. However, today in Ukraine, employers frequently ignore the training needs of staff for various reasons. The result is a decrease in the labour share, a decline in employees' motivation, a reduction of devotion to the company, a loss of trust and of personal interaction with colleagues or senior staff etc.

Professional development represents changes of mental functions and personal qualities, which arise at interaction with profession, in the course of vocation education and professional activity [3].

In other words, one should understand that professional development is a personal development as a subject of professional activity. Many researches of outstanding foreign and Ukrainian scientists in the field of economics were dedicated to investigating a set of issues on staff development, notably – M. Armstrong, who conducted a detailed implementation analysis of effective vocational training of personnel [2]; M. Novikova and M. Borovik considered the need for system organization of knowledge management and identified its main constituent elements [5]; O. Grishnova analyzed the complex of organizational and economic actions of the enterprise in the course of personnel professional development and revealed their value for formation of business social responsibility [4]; A. Kolot defined the role of a person, interrelation of economy and human development, socialization perspective of relations in the working sphere [6]; V. Savchenko investigated theoretical principles of system organized process of employees' continuous professional training, their preparation for implementing new production functions and vocational qualification promotion [8]; I. Shvets identified the importance of professional staff development for the formation of a competitive enterprise [10]; S. Shekshnya recognized the development of personnel as the process of employees' training in order to implement new production functions and new challenges by them [11].

Considering historical routes of investigating the subject activity category in psychology, one can notice, that directly an individual development problem has received the greatest development in the works by B. G. Ananiev.

This scientist revealed a concept meaning of the subject and connects it to activity, subject, tools and operative technique, expected output. He emphasized, that the subject was much more, than just subjective phenomena: the structure of human beings as actors integrated individual properties and the identity. It defines readiness and ability to implement activities and to achieve some degree of productivity. A creation of an active subject is not completed, as long as activities are carried out. It's a kind of permanent process which concerns every person of any age. Numerous studies show, that the extending occupational activity and development lead to the overall increase in life expectancy [1]. However, taking into account fast changing economic processes in a country, the system of increase of personnel professional level at enterprises is gradually modified and improved. Therefore, there is a need in more detailed researches.

The aim of the paper is to identify current trends of providing professional development in domestic labor market through a prism of the conducted research and justification of the need to increase the personnel qualification level by ensuring decent work conditions at enterprises.

In modern conditions of employment transformation there is a question of employers' resistance or inability to promote the career and personnel professional development, which makes impossible for them to provide a workplace with decent work conditions [5]. Domination in the world of the concept of economic growth over a long period of time is the reason of such situation. This concept is based on the idea, that the main indicators of the success of socio-economic governance at all levels (country, region or businesses) are high growth, labor productivity, high gross domestic product and average income per capita. The concept dominates in the world via thinking and beliefs of people, because its essence is quite simple and straightforward. The same cannot be said about its effectiveness in practice.

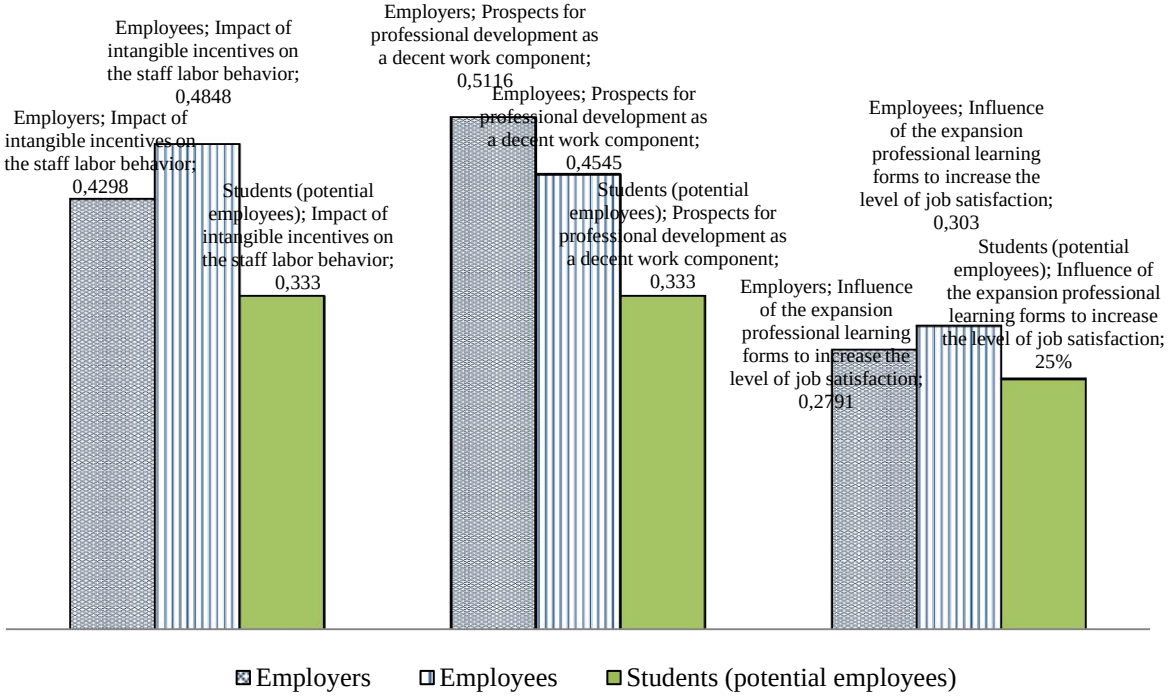
However, in transition to the 21th century it is clear, that to satisfy only the economic achievements is not enough. They aren't the destination point, but constitute only a means to reach the goal. The incomes of the society are significant factor, but they should be directed on achieving the decent employed social security payments of and creation of a safe, comfortable environment in the workplace. However, the quality of working life does not always coincide with the level of material incentives. If people were only interested in the money earned in the workplace, it is unlikely, that there would have been so many successful and rich people. A worker is driven not only by the financial conditions, but also by passion, interest, ability of self-fulfillment and individual professional growth.

Studies confirm the abovementioned statements. They were carried out at the beginning of 2017 among different categories of respondents: students of universities without working experience (they express their view, wishes about the future place of employment), working students (they act as wage earners, able to evaluate subjectively the current situation of their workplace due to the inner feeling about all positive and negative aspects of the working process) and entrepreneurs, who act as employers. Respondents had a chance to answer a number of questions, which defined their attitude to different subjects of social and labor relations to the problem of professional training of the staff within the companies, industrial enterprises.

The results of the study revealed that not long ago common Human Resources (HR) strategy – to fire an employee in case one is not satisfied with his or her qualifications and to find the right person in a labor market – slowly, but go back to the past. On the way to increase productivity and efficiency, companies prefer to spend resources on professional training of their employees. They want to form a qualified and competent staff, able to create products and services that could compete with foreign goods and services. It is confirmed by the survey data. It turns out, that 83,3% of enterprises are carried out vocational training, and only at 16,7% of them this aspect of working life is not defined. This situation shows the positive shifts that occur in the Ukrainian society. They are reflected in the real actions and understanding that learning is a key for training staff to come to a correct decision, to analyze a wider range of tasks and to provide the highest level of efficiency. It will not only increase the level of workers' knowledge and develop the required professional skills, but will form their system of values and attitudes, which corresponds to modern realities and the market organizational strategy of a company.

Comparing the views of three categories of participants in social-labour relations (employers, employees and students as potential applicants), we found that

more than half (51,16%) of respondents-entrepreneurs to an extent consider providing professional development aspect, which will give a workplace with decent working conditions (Fig. 1). At the same time, the rest of respondents to the survey assessed the value of this indicator as less important.



Source: calculated by the authors

Fig. 1. Priorities of various social groups in professional development

Such a paradoxical situation can be explained by the existence of practical experience of employers and rational way of thinking that helps to achieve positive results in business. They realize the value of the human development concept, according to which there has to be a person at the center of a society development, but not just economic indicators. An ultimate goal and a criterion of progress success is expansion of opportunities for people, a better satisfaction of their needs and realization of human potential. The same idea is also put in the concept of decent work: it is not enough for a person to have a workplace and to earn a financial reward carrying out his or her working duties. In such conditions an employer also cannot expect productivity growth and accumulation of social wealth. The formation of effective and sustainable economic growth consistently bring it to a logical result achieved by the expanding capabilities of people, the fulfillment of their economic, political rights and freedoms, satisfaction of spiritual and material needs of present and future generations of population. Expanding capabilities means improving the human potential, knowledge, skills, physical and mental abilities [8].

Fig.1 shows that the distribution of priorities for the other two indicators, namely, the impact of intangible incentives, including professional development on the labour behaviour of the employee and expansion of professional learning forms of vocational training to increase the level of job satisfaction, differs from that described above. The results of the survey show that

all subjects of industrial relations are below the average level. However, employees have motivation to receive in the workplace intangible acknowledgement of work results (48,48%) and diversification of professional education forms (30,3%). With these measures, an employee feels a greater loyalty to a company that gives him or her work, his or her own affiliation with it. If HR policy shows and marks the value, appreciates the results of each staff member, it is automatically doomed to create a favorable image of such an employer in the community and beyond.

It turns out that employers show less interest in diversity in vocational training of their employees (27,91%). This effect could arise from a number of factors such as unstable economic and political situation in the country, which led to straightened circumstances and inability to implement new modern technologies, staff development programs. The students' proportion, who gave positive answers, helped to define the weight of these indicators. In the overwhelming majority youth shows the desire to receive material incentives for the results of work. Young people want to get financial independence. So at this stage of their personal formation, they do not allocate additional opportunities as too important and do not pay them due value.

Companies, which have a regular professional training, allow the workforce feel satisfaction with working conditions. This is evidenced by the data, obtained in the result of the survey. As it is become evident, 36,4% of staff appreciated the degree of received satisfaction from employment and 39,4% of employers annually provide the improvement of staff qualification at the company's cost (table. 1).

Table 1.

The respondents' answers on the frequency of employees' professional training at the company's cost

The period of study	The proportion of respondents, %	
	Employees	Students (potential employees)
Every year	39,4	54,17
Every two years	3,03	20,83
Every three years	–	12,5
Less than once in three years	3,03	8,33
Vocational training was not conducted	54,55	4,17

Source: compiled by the authors

While the average job satisfaction is expressed by 57,6 % of respondents, the low one is expressed by 6,1% of them. The values of the indicators correlate with the staff proportion that underwent training once in two years, less than once in three years or had no such a possibility in the company.

An interesting difference is observed in the responses of workers and students who do not work. Training was not conducted at all in the workplace for 54.55% of employees, at that time 54.17% of students believe that it should be implemented annually. This tendency proves that people are focused on professional growth, and the employer seeks to economize on this.

This reason is often crucial for employment. The choice falls on the company that is able to provide the candidate the need for self-improvement. The staff development program contributes to the formation of personal integrity, raises the intellectual level of its participants and expands the range of person's communication skills. Therefore, the employee begins to have more knowledge and a strong motivation to

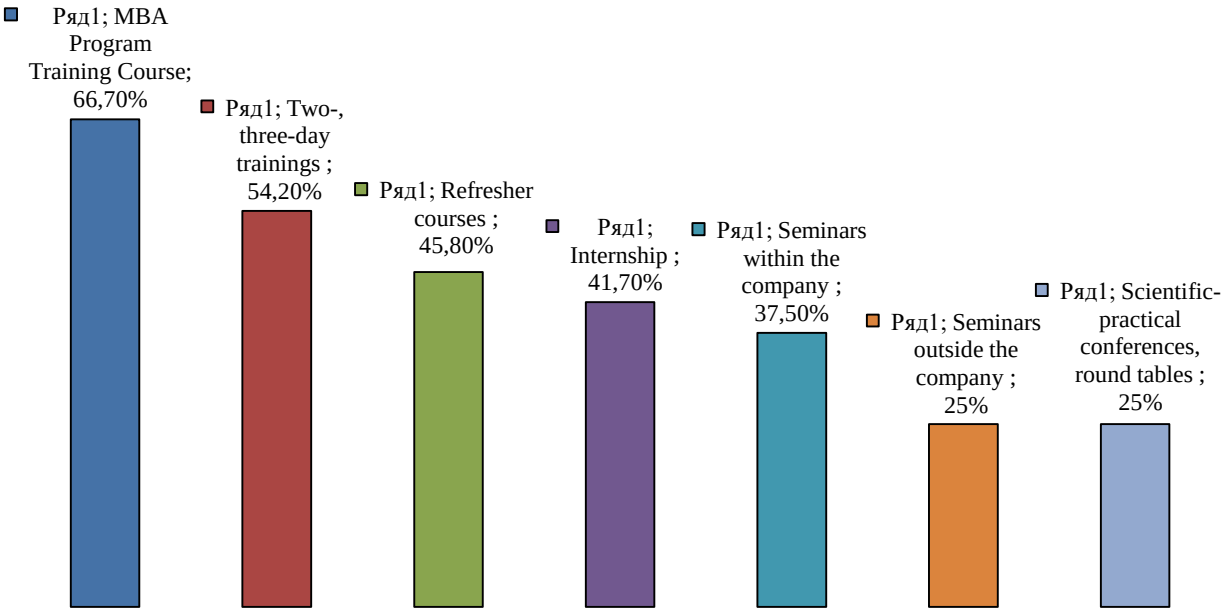
do tasks standing before him. Also an improvement of the moral and psychological climate in structural divisions of the organization is happening due to this that reduces staff turnover. The employee perceives the company's business as his or her own and believes that it is his or her own duty to contribute to its prosperity. Thus, for the sake of securing their economic interests, the employers should strive to cut the gap that has emerged between the perceptions and desires of potential employees with the realities that came in force in the domestic labor market (table. 1). The company could improve the situation by organizing regular events for professional training at least once a year.

Vocational training assigns to workplace the rank of worthy. It is confirmed by 57% of staff respondents. The development within the enterprise provides more employment security and a sense of stability due to reducing risks of frequent staff transferring from one company to another. Conversely, frequent transfers of personnel in search of better salary lead to horizontal shifts along the corporate ladder for them with the loss of opportunities for growth. On average, the adaptation of an employee in a company takes about a year. It means that only in a year an employee is fully mastered in the new team, gets acquainted with the orders and rules, the technical specifics of tasks [6]. In a year the employee begins his or her to professional development. Therefore, if a specialist transfers from one company to another each year, then he or she will constantly be in the process of adaptation, rather than development. This will lead to a situation, when he or she will be lagging behind requirements of employers and will go down the corporate ladder. If a person changes jobs every two years, the adaptation will take about half the time, which remains from the current tasks on development. The same applies to an employer. In case when an employer is in constant search for and hiring of the best employees, he or she spends more time and money to acquaint new staff member with the team, requirements, tasks, that is, with the process of adaptation. Therefore, it is more rational to develop skills of a company's already working employees. The company must give them a range of opportunities to advance their knowledge, abilities, set new goals for them, which in turn will strengthen social protection and improve working conditions in Ukraine. Besides, a fair system of vocational training and better quality of such training, of course, could greatly contribute to the reduction of inequality in incomes of the society, thus implementing aspects of the concept of decent work.

Special attention should be noted on most attractive to employees forms of vocational training. Respondents identified the top three forms that they would preferred. These forms are: Master of business administration – MBA (66,7%), two- or three-days training course (54,2%) and extension courses (45,8%). The intermediate results goes for internships (41,7%) and seminars within enterprises (37,5%). Round tables (25%), scientific conferences and seminars outside of enterprises are uninteresting (Fig. 2).

However, the current financial situation with costs on training in Ukrainian companies differs from budgets of leading companies of the world. According to a survey, conducted by the International consulting company Hay group in 2015, the budget for staff training amounted to 9,7% of the total HR budget in the average market in 2015 [13]. The majority of Ukrainian companies planned to keep spending on staff training and development unchanged in 2016. Increase of the budget for training and development was provided only by 16,4% of analyzed companies, 7,3% of them were going to enhance the filling of the training package while saving the budget. So, the most common methods of staff training in Ukrainian companies are the following:

mentoring and training during work; courses, seminars, workshops, carried out outside the enterprise with the calling of external experts; audio and video courses; specialists rotation; exchange of knowledge within the company.



Source: compiled by the authors

Fig. 2. The respondents opinion about forms of vocational training

Employers, representing Ukrainian companies, believe that the achievement of high results is possible only by an implycation of an integrated approach, combining different methods that take into account peculiarities of the audience. For example, the best combination of master classes, conducted with the assistance of competent professionals, and video courses that will help to combine the knowledge for the applied skills development of staff of industrial enterprises. Professional conferences, creative competitions are best suited for improving the professional qualities of employees of advertising, sales and development departments, etc. Non-standard teaching methods are best suited to improve the professional level of top managers. Unconventional training, theater performances, metaphorical games and other unusual methods of teaching career and personal growth could be given even to the most experienced and competent managers.

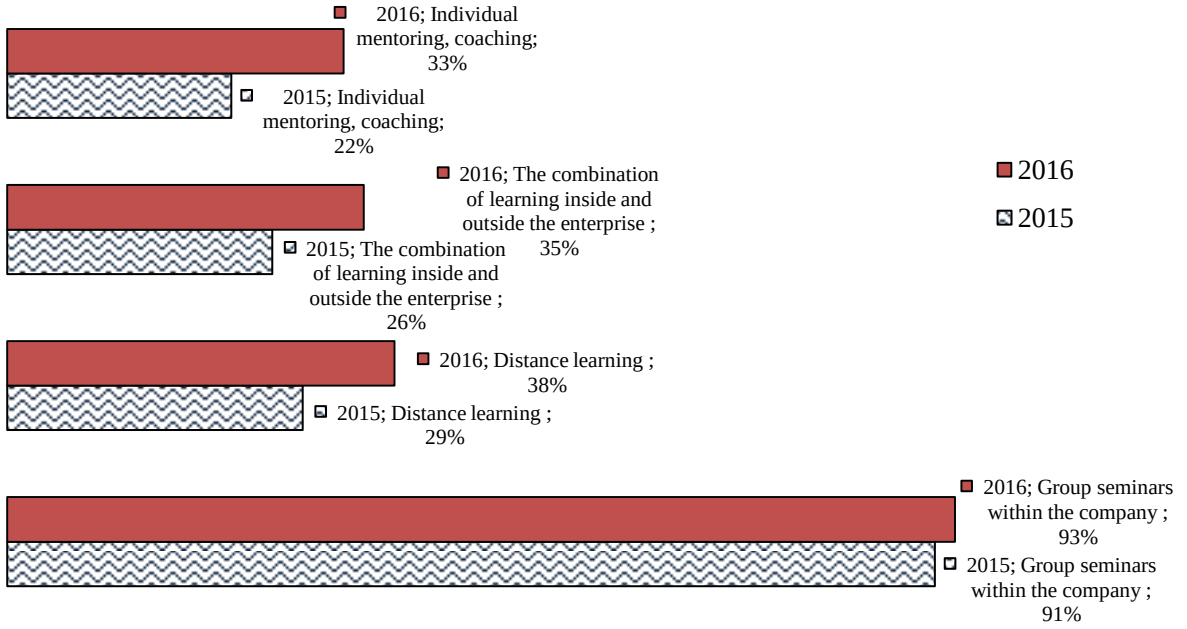
To improve Ukrainian system of staff development it is necessary to adapt the EU experience. The transfer of skills in the structure of continuing professional education in European companies traditionally is associated with workspace, supplemented in modern conditions by a range of different training forms: conference, seminars, job fairs, lectures (51%), self-study (for example, e-learning) (30%); participation in training cycles and quality (18%); work rotation, exchange or study visits (18%), etc. The problem of staff development in Europe is considered by such scholars as K. Cohen, V. Bartz, H. Shibl, A. Sorge and etc. [9]

It is important to note that in the framework of the strategy of education throughout life the formal professional education is an alternative to independent self learning. About one-third of European or-

ganizations practice various forms of stuff self-study. The distribution of different forms of employees' self-training depends on the size of organizations. Various forms of self-education in the system of continuous vocational education reduce costs for enterprises of different sizes. Self-education also means greater autonomy in time scheduling and content of training for employees. New opportunities are opened up by multimedia technologies, including open and distance learning. [9]

The company CegosGroup is a world leader in the field of vocational training during the last century. It conducted the study among 2640 employees in 6 European countries (France, Germany, UK, Spain, Portugal and Italy) in 2016 [12]. It was determined that compared to 2015 the company increased the training provision in enterprises. The largest breakthrough is observed in spreading such method of human potential development as coaching (Fig. 3). Personal trainer can achieve good results because a lot of attention is paid to the present and future goals, ways to succeed them by trainees. The coach helps to learn how to find independently a way out of difficult situations through a prism of stimulus, positive emotions and the desire to form, change and improve oneself.

Individual mentoring is effectively used in industrial plants, because it ensures continuity of management and the best disclosure of human potential decreases the employees' turnover and increases the interest of new employees in the production. Communicational skills are forming and corporate culture increases, developing each of staff's abilities and skills with the smallest expenses from the firm's side.



Source: calculated by the authors based on [12]

Fig. 3. Methods of vocational training of European workers in 2015-2016

According to the abovementioned results, foreign companies have long come to realize that human capital and knowledge economy are becoming an increasing source of economic growth. Investments in human capital are the most cost-effective. Therefore, in the Millennium Declaration, adopted at the special summit in September 2000,

the Heads of all United Nations' (UN) states members identified issues directly related to the expansion of human capabilities as one of the main tasks of the international community.

In the resulting document of the new program "Transforming Our World: The 2030 Agenda for Sustainable Development" sustainable development goals were defined as a result of the negotiation process with 193 UN member states as well as involvement of an unprecedentedly wide range of civil society groups and other interested parties.

Among the 17 comprehensive goals particular attention was paid to fair high-quality education, including vocational one. The challenge is in providing an adequate level of education and training, productivity, employment and economic growth that will bring huge social and economic benefits. It is planned to develop strategies to promote youth employment, integrated balancing growth and job creation targeted intervenetions, such as help in job search, or support of young entrepreneurs [14].

Such measures are necessary to form good conditions in the national labour market. Additionally, the elimination of mismatches between key skills and job requirements is of incredible importance that can be done by ensuring that the training programs meet the needs of the labour market and the components of providing work experience in the field of technical vocational education and training.

Conclusions. The reorientation of the Ukrainian economy in an innovative direction has caused significant shifts in social and economic relations, changes in their essence and the needs of their rethinking. The value of human life increases significantly due to the high pace of technology. The development strategy aims to define the priorities and directions of economic and social programs realization aiming at optimal allocation of resources and efforts.

Modern approaches to the organization management are based on the staff, because it is a key factor, determining the efficiency of all other resources. As experience shows, the most successful domestic and foreign companies invest in staff, create conditions for the employees' professional growth and enhancing their professional skills, that give 2-3 times higher returns than expenses, directed on solving production tasks only. The dynamics of changes that occur in business, the rapid deterioration of acquired knowledge encourages organizations to continuously keep up a process of their staff intellectual potential development.

However, it was defined that in Ukraine, employers do not want to spend money on professional development of their staff due to financial reasons, while employees need this. The research shows, that society call workplace as a decent one in cases, where there is a practice of professional training of personnel. Therefore, training activities not only bring positive results, worth the resources invested, but also a chance to raise the company's competitiveness in the labour market. Besides, it is necessary to view the successful experience of international companies and adapt it to national conditions. The authors of the paper suggest adapting such European forms of vocational training as individual mentoring, coaching, job rotations, distance learning, group workshops, etc. Their implementation in practice is capable to bring a positive effect of training to Ukrainian enterprises, including industrial ones. Thus, the formation of a good system that ensures continuous learning and staff development organization, becomes one of the most pressing issues that need further consideration.

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ЗАБЕЗПЕЧЕННЯ ПРОФЕСІЙНОГО РОЗВИТКУ ПЕРСОНАЛУ ЯК КОМПОНЕНТА КОНЦЕПТУ ГІДНОЇ ПРАЦІ

Досліджено тенденції професійного розвитку в Україні, враховано думки різних категорій учасників соціально-трудових відносин. Визначено головні аспекти, які дозволяють пов’язувати підвищення кваліфікаційного рівня персоналу та забезпечення гідних умов праці. Проаналізовано актуальні методи професійного навчання на ринку праці України та країн ЄС.

Ключові слова: професійний розвиток, гідна праця, наймані працівники, роботодавці, ринок праці.

JEL codes: J2, I25.

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ОБЕСПЕЧЕНИЕ ПРОФЕССИОНАЛЬНОГО РАЗВИТИЯ ПЕРСОНАЛА КАК КОМПОНЕНТА КОНЦЕПТА ДОСТОЙНОГО ТРУДА

Исследованы тенденции профессионального развития в Украине, учтены мнения различных категорий участников социально-трудовых отношений. Определены основные критерии, которые позволяют связывать повышение квалификационного уровня персонала и обеспечение достойных условий труда. Проанализированы актуальные методы профессионального обучения на рынке труда Украины и стран ЕС.

Ключевые слова: развитие, достойный труд, наемные работники, работодатели, рынок труда.

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ПРОБЛЕМИ СТРАТЕГІЇ РОЗВИТКУ ТА ФІНАНСОВО-ЕКОНОМІЧНОГО РЕГУЛЮВАННЯ ПРОМИСЛОВОСТІ

ПРОБЛЕМИ ЕКОНОМІКИ ПРОМИСЛОВИХ ПІДПРИЄМСТВ І ВИРОБНИЧИХ КОМПЛЕКСІВ

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СОЦІАЛЬНО-ЕКОНОМІЧНІ ПРОБЛЕМИ РОЗВИТКУ ПРОМИСЛОВОСТІ

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