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## THE IMPACT OF INDUSTRY 4.0 ON THE DIGITAL TRANSFORMATION OF MANUFACTURING ENTERPRISES IN UKRAINE

**Purpose.** To study the impact of Industry 4.0 on the current state of the digital transformation of the state’s industry and to substantiate promising directions of development.

**Methodology.** The study used a systematic and comparative analysis to provide a comprehensive understanding of the current state of digital transformation of industry in Ukraine. Research on the impact of Industry 4.0 on digital transformation was based on the results of a statistical analysis of the effect and the potential annual effect of the introduction of the Internet of Things on industrial and construction sites. Also, the method of deduction, logical research, and a graphical way of presenting information were used to demonstrate the significant results of the study.

**Findings.** In the process of research, the digital transformation of industry under the influence of Industry 4.0, which is accelerating, was considered. It has been proven that the digital transformation of Ukrainian enterprises must be carried out at several levels: in terms of industrial equipment, IT systems and internal business processes.

**Originality.** The influence of Industry 4.0 on the digital transformation of industry in Ukraine is substantiated. Eight main levers of value creation due to the implementation of “Industry 4.0” technologies in production are highlighted: optimization of equipment operation modes; optimization of equipment loading; increasing productivity and labor safety; logistic optimization; improvement of product quality; improvement in demand forecasting; shortening the terms of bringing products to the market; improvement of after sales service. Recommendations were given to enterprises regarding the formation of industry partnerships for joint financing of projects, risk reduction, interaction with state bodies, technological companies and research centers, within which expert consulting centers are to be created.

**Practical value.** The results of the research can be used by economists, scientists and practitioners for the development of further perspectives. Establishing strong horizontal ties with educational and research organizations, high-tech companies, as well as with public administration bodies will allow effective exchange of experience, development of joint innovative digital solutions, products and standards for a particular industry, adaptation of educational programs and development of skills in the application of digital technologies.

**Keywords:** *digital transformation, economic development, industrial enterprises, Industry 4.0*

**Introduction.** The digital revolution has a colossal impact on the transformation of industry, both in Ukraine and in other countries of the world.

The set of relevant tools that come together under the name “Industry 4.0” includes such innovative techniques as big data analysis, machine learning, machine vision, industrial Internet of Things, virtual reality, augmented reality, 3D modeling, 3D printing, unmanned aerial vehicles and robotics.

These technologies are already transforming industry around the world, and their full-scale adoption in the global economy in the future could have an impact on productivity and the labor market comparable to the industrial revolutions of the past.

The possibility of robotic production at Ukrainian enterprises is more than 20 times lower than the world average. Currently, Ukraine has every chance to close the gap with world leaders. At the moment, there are no countries that are unequivocal leaders in the implementation of Industry 4.0 technologies.

Enterprises that are the first to implement these technologies have the opportunity to gain an advantage over competitors due to the early start effect and even set standards for new generation industry solutions on a global scale.

This applies both to players in the industrial sector and to companies producing digital tools of Industry 4.0, as the demand for it from Ukrainian enterprises will stimulate the supply from the leaders of the domestic IT sector and innovative startups.

To realize this unique opportunity, it is important for the state and the private sector to act promptly and in a coordinated manner. Industry players can develop digital strategies involving technology partners, communicate the importance of new digital tools to managers at all levels, create a digital culture that promotes the development of new technologies, and create effective mechanisms for attracting competent personnel in this field.

From the part of the state authorities, a strategy for the modernization of industry should be formed to ensure readiness for the transition to “Industry 4.0”, the introduction of mechanisms to encourage enterprises to attract new technologies, as well as the provision of training programs for personnel who have the necessary knowledge, in close cooperation with research centers and industry associations.

**Literature review.** The wave of digitization creates opportunities for the community to engage in innovative action research and raise the apparition of the discipline. As scholars have been researching the trend of increasing use and integration of digital technologies for several decades, they also naturally respond when others argue that the transition to digital technologies is a new phenomenon [1].

According to Valenduc G. and Vendramin P., digitally codified information is becoming a strategic resource, while the network is becoming an all-encompassing principle of organizing the economy and society or the network society [2].

The early literature on the digital economy dates back to a time when the technical capabilities for encoding information were mainly computer programming and analog data transmission.

Brodny J. and Tutak M. in their works note that the process of digital transformation of the global economy is a natural stage of evolutionary changes, which is the result of the dynamic development of information and communication technologies [3].

Having assessed the importance and advantages of digital transformation, some countries began to strive for its implementation as soon as possible. According to scientists, in this context, it is important to study the level of digital maturity in Central and Eastern Europe, where the level of digitization is relatively low [3].

In our opinion, the factors caused by the spread of Industry 4.0 ideas also have a significant impact on the digital transformation of the country's industry.

These ideas are reflected in the research of Ukrainian and foreign scientists and lead to the conclusion that there is no universal approach to how to achieve progress in the digital world.

According to Rajnai Z. and Kocsis I., digital transformation of the global economy is a process closely related to the idea of Industry 4.0 [4]. Industry 4.0 is related to the digitalization of the economy and, in turn, significantly affects the activities of certain industries. In order to meet the growing competition and technological changes, these industrial enterprises must significantly change their strategies, including, in many cases, the way they work and their business profile [4]. It is also significantly influenced by the economic and social environment, which is changing very dynamically, including customer preferences and expectations [5].

All these factors lead to a growing transformation in the digitalization of manufacturing, service and commercial enterprises, which has been observed for several years all over the world. These changes are a consequence of technological progress, which forces a new approach to production itself and to the organization and management of enterprises (new business models), as well as to social and environmental problems [6].

It is difficult for manufacturing companies to keep up with the changes taking place due to digitalization. Siedler C., Dupont S., Zavareh M. T., Zeihsel F., Ehemann T., Sinnwell C. and Aurich J. C. note in their work that in order to successfully implement digitalization, manufacturing companies must consider their existing technical systems, organizational structures and processes, as well as social aspects [7]. By supporting a maturity model, a specific level of digitization can be assessed for a company to give manufacturing companies an initial idea of their specific status quo; it can be a starting point for future optimization and digitization projects [7].

Nadkarni S. and Prügl R. working on the topic of digital transformation and the influence of Industry 4.0, derive additional units of analysis that help to separate the peculiarities of digital transformation processes and thus highlight the most influential and unique prerequisites and consequences [8].

To help to bridge disciplinary gaps and strengthen a managerial perspective, scholars have added to the resulting state of the art of digital transformation by integrating interdisciplinary contributions from technology disruption and corporate entrepreneurship papers [9].

**Unsolved aspects of the problem.** A review of the researchers' literary sources indicates the identified needs for research on the impact of Industry 4.0 on the digital transformation of Ukrainian industry.

The available scientific publications do not fully reflect the modern views of scientists regarding the peculiarities of digital transformation management in Ukraine.

At the same time, a significant number of problems regarding the vision of the concept of digital transformation under the influence of Industry 4.0, effective ways of involving innovation in development and transformation, remain insufficiently researched and disclosed.

**The purpose of the article** is to investigate the impact of Industry 4.0 on the current state of the digital transformation of the state's industry and to substantiate promising directions of development.

**Methods.** Systematic and comparative analysis was used in the study to provide a comprehensive understanding of the current state of digital transformation of Ukrainian industry.

Also, such scientific methods as the method of deduction, logical research and the graphical way of presenting information were used to demonstrate the significant results of the study.

**Results.** The application of "Industry 4.0" tools will require enterprises to deploy the Industrial Internet of Things at their production facilities, which combines a set of necessary software tools, solutions, as well as the introduction of new types of equipment (for example, 3D printing machines, automated drones).

For the global economy, the annual effect of the implementation of the Internet of Things may be \$ 4–11 trillion by 2025 (Fig. 1).

The potential annual effect of the implementation of the Internet of Things on industrial and construction sites is estimated at 1.4 to 4.6 trillion US dollars and is presented in Fig. 2.

A reliable assessment of the effect of the deployment of other elements of Industry 4.0 has not yet been carried out, but it is clear that these elements increase the positive impact on industry.

Companies that will be able to use all the key levers of value creation with the help of Industry 4.0 technologies will have a sustainable competitive advantage and will be able to strengthen their positions both at domestic markets and internationally.

We highlight eight main levers of value creation thanks to the implementation of "Industry 4.0" technologies in production:

- optimization of equipment operation modes;
- optimization of equipment loading;
- increasing productivity and labor safety;
- logistic optimization;
- improvement of product quality;

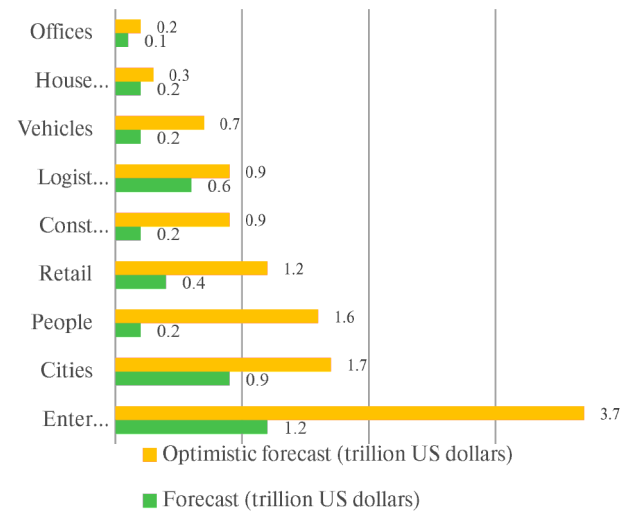


Fig. 1. The effect of the introduction of the Internet of Things (trillion \$)

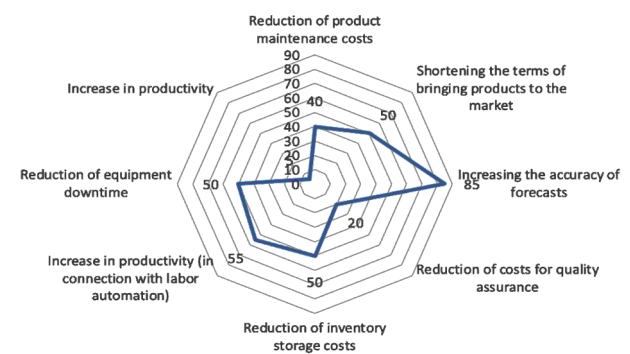


Fig. 2. Potential annual effect of the introduction of the Internet of Things on industrial and construction sites (US\$ trillion)

- improvement of demand forecasting;
- shortening the terms of bringing products to the market;
- improvement of after sales service.

1. Optimization of equipment operation modes. With the help of Industry 4.0 tools, enterprises can flexibly optimize the operating modes of equipment to increase the output of final products.

The optimization is based on the analysis of data collected from the sensors of the automated enterprise management system and the automated technological process management system, which is carried out in real time.

Such an analysis using machine learning methods makes it possible to identify patterns that increase production efficiency, which could not be detected using standard analytical methods.

Enterprises, in their activities, can also consider the possibility of optimizing the use of resources, such as:

- raw materials;
- electricity.

This goal can be achieved by implementing “smart” systems of the new generation that control their consumption in automatic mode using data received from sensors [10, 11].

For enterprises, it is relevant and possible to introduce decentralized power supply systems based on renewable energy sources into the general structure. At the same time, with the aim of sufficiently energy-efficient use of such mini-power plants in the structures of power supply systems, it is necessary to thoroughly analyze the issues related to the modes of operation of the energy equipment of these enterprises.

2. Optimization of equipment loading. A planned and preventive approach to maintenance and repair allows increasing the equipment’s technical readiness ratio by reducing downtimes.

On the basis of the analysis of data from sensors on the wellsites, the history of maintenance and repairs of all types of equipment, as well as information about the modes of operation of the wells and using a self-learning model, oil production companies will be able to optimize the composition of geological and technical measures and increase the volume of production by about 10 %. With an efficiency improvement program based on the application of these technologies, the coal and chemical industry will be able to achieve a 50 % increase in profits.

3. Increasing productivity and labor safety. Many tasks performed by high-skilled and low-skilled workers can be performed more efficiently through digitization. For example, the use of four-dimensional seismic modeling in oil production, which involves the collection and processing of a large amount of data, allows better prediction of oil migration, increasing the oil recovery rate by 2–4 %.

Modern technologies help to increase the level of safety in production, which is especially important for industrial enterprises. The mining industry can use unmanned and remote-controlled equipment that can improve both labor productivity and workplace safety.

The use by workers of portable devices connected to the network and sensors that automatically track the movement of employees and signal the risk of dangerous situations is another means of increasing the safety and controllability of production processes. Such means are used, for example, in metallurgical and mining industries.

4. Logistics optimization. Automating the exchange of information between various elements of the supply chain accelerates logistics and reduces the inventory of goods, raw materials and spare parts stored in warehouses to the necessary minimum. The synchronization of the logistics chain from the mining site to loading at the port, which would allow a copper mine to increase its overall productivity by 20 %, would be an example.

5. Product quality improvement. Digitization of existing equipment, as well as the introduction of new-generation technology, such as 3D printers, gives enterprises the opportunity to manufacture products that cannot be produced on an industrial scale in a traditional way.

Due to the accumulation of “digital” skills and data on the operation of their own products, manufacturers who have implemented modern IT tools have the opportunity to earn not only from their sales and after-sales service, but also to provide their customers with additional services.

6. Improvement of demand forecasting. Advanced analytics powered by automated digital systems enable businesses to achieve more accurate demand forecasting based on historical production and sales statistics as well as real-time current sales data.

Such information can be used for both sales planning and production planning.

7. Shortening the terms of bringing products to the market. Advanced digital technologies make it possible to significantly shorten the development and market launch of new and modernized existing products.

8. Improvement of after sales service. Industry 4.0 technologies help manufacturers to improve the quality of after-sales service: information about the use of products by customers is collected through a sensor system and analyzed automatically.

For capital-intensive industries, such as oil and gas production, electric power, Industry 4.0 technologies open up opportunities for significant efficiency gains, but do not involve a radical transformation of the business model. For more labor-intensive industries, the optimization potential lies in increasing the efficiency of the production process due to automation, the use of sensors connected to the Industrial Internet of Things, and advanced analytics [12].

A significant effect from the introduction of digital technologies can be obtained in the manufacturing industry due to its high labor intensity and technological lag behind advanced countries [13, 14].

Here, an increase in efficiency is possible in all sections of the added value chain – from accelerating the development and introduction of new products to the market, synchronizing the production chain and supply of components to a significant increase in the efficiency of planning, production, quality control and the level of service of final products [15, 16].

Thanks to the modernization of mechanical engineering based on the principles of Industry 4.0, it is possible to significantly increase labor productivity in this field, reducing the lag behind the most industrialized countries.

In the oil and gas industry, 3D field modeling tools are used, and in the mining industry, sensors and portable devices are actively used to help to track the condition and location of equipment, the location of workers, the level of gassing of mines, and also optimize the work of repair crews.

Multidimensional design and construction planning tools are gradually being introduced in the construction of nuclear power plants.

Ukraine still lags far behind European countries in the level of digitization of basic industries, which negatively affects labor productivity [17].

At many factories, even the technologies of previous generations, such as systems of automated design and production management, electronic document flow, automation of management and accounting, planning and management of supply chains, are poorly mastered, and therefore there is a significant potential for increasing efficiency [18,19].

As the experience of other countries shows, technologies of previous generations can be mastered simultaneously with the introduction of Industry 4.0 technologies.

Managers need to change the approach to decision-making, in which the implementation of modern “Industry 4.0” technologies is delayed due to a low level of automation.

This applies to those cases when the introduction of previous generation technologies is a necessary condition for the operation of “Industry 4.0”: for example, the presence of sensors for operational monitoring of production process parameters, without which it is impossible to apply the methods of in-depth analysis of large data sets.



Therefore, the digital transformation of Ukrainian enterprises must be carried out at several levels: in terms of industrial equipment, IT systems and internal business processes.

The introduction of modern technologies can significantly improve the activities of enterprises in a number of industries. For example, in the sphere of production operations management, Industry 4.0 technologies can contribute to:

- optimization and automation of the main production and management business processes;
- increasing the efficiency of the use of the company's equipment due to the processing of data arrays received in real time and the detection of hidden interdependencies;
- improvement of the planning of raw material costs and the schedule of finished-product output.

In the field of equipment maintenance, modern technologies make it possible to build a system of preventive maintenance that functions on the basis of predictive models using the data obtained in real time that help to assess the real need for maintenance and repair of equipment and to optimize these processes.

Such systems contribute to increasing the technical readiness ratio of the equipment (therefore, reducing unproductive downtimes) and extending the life cycle of the equipment with the help of more efficient maintenance.

Digitization opens interesting prospects for companies to increase efficiency in the field of management of warehouse stocks and logistics processes of the enterprise [20]. The implementation of automated supply chain management systems allows for significant optimization of stocks of finished products, raw materials, and spare parts stored in the company's warehouses.

Digital tools also reduce logistics costs, help to plan routes more efficiently, control vehicle loading, and more accurately prioritize logistics operations of all the enterprise [21].

"Industry 4.0" technologies make a significant contribution to increasing production safety and improving occupational health and safety at enterprises. First of all, this concerns the possibility of placing sensors on equipment and personnel for automated monitoring of their movements on the production site, analysis of potentially dangerous actions, prevention of injuries and accidents at work.

The process of developing new types of products can also be improved with the help of Industry 4.0 tools. On the basis of the analysis of data on the actual use of products by customers, the development of new types can be carried out, as well as the improvement of the efficiency of the pre-sales analytics process when introducing new products to the market.

The implementation of certain elements of modern IT systems can also allow one to achieve improvements in the field of personnel productivity.

Modern systems with access to data coming from production lines make it possible to reduce the number of errors made by employees due to the optimal supply of raw materials, ensure more complete loading of production equipment and reduce the amount of waste.

In addition to the areas of improvement listed above, the implementation of the elements of "Industry 4.0" will also lead to a general increase in the quality and competitiveness of Ukrainian products both at the domestic and global markets.

In most cases, it is not easy for companies to make decisions regarding the implementation of Industry 4.0 technologies. Often, such a step does not seem reasonable to managers, since these technologies do not always affect the production process and can revolutionize the industry, but at the same time require significant capital investments and attention.

Often, companies do not see the need to increase labor productivity due to the low cost of labor and the presence of social obligations to the staff, which makes it difficult to reduce their number. Another important obstacle to the implementation of Industry 4.0 technologies is the current low level of automation and digitalization, as well as the lack of data that can be analyzed.

An important role is also played by the factor of outdated technical regulation, which complicates the introduction of

new technologies. It is also worth noting the lack of qualified specialists in digital technologies in the industry, who at the same time would be well versed in both industry technological processes and the latest digital tools.

In the end, it is worth noting the low digital culture of management and insufficient understanding of the mechanism of application of digital methods and their effect, a conservative attitude to innovations, especially in industries and processes where high reliability is required, and in those departments where the concept of "breakthrough technologies" arouses rather anxiety than enthusiasm among managers.

The primary task of industrial companies is to identify promising areas of implementation of Industry 4.0 technologies, as well as to develop and implement a strategy for their development. For the successful implementation of such a strategy, it is necessary to clearly explain the advantages of using digital technologies at all levels of management, to create a digital culture within the company that will encourage experimentation and the rapid development of new technologies.

The most important factor in the success of the digital strategy is the presence of experts on digital technologies in the company, therefore it is necessary to create a system for the selection and retention of such personnel and training of existing and potential employees in digital disciplines.

To do this, it is necessary to develop educational programs together with technological companies, universities and professional education organizations, including those that provide for obtaining double majors and internships at enterprises.

**Conclusions.** The development of "Industry 4.0" technologies requires the concentration of resources, so companies need to form industry partnerships for joint financing of projects, risk reduction, interaction with government bodies, technology companies and research centers, within which they are to create expert consulting centers, model enterprises, develop industry platforms, solutions and standards.

Large companies can establish interaction with technological entrepreneurs and specialists in digital technologies by forming their own venture funds and business incubators specializing in "Industry 4.0" technologies, as well as in the framework of technological competitions aimed at solving specific problems and business tasks.

Ukraine has the necessary technological capacity in order to offer quality solutions in the field of "Industry 4.0" technologies to the domestic market.

The development at the state level of a long-term strategy for the modernization of the country's industry based on the principles of Industry 4.0 and the use of financial and non-financial mechanisms to stimulate demand from companies for such technologies could significantly support the digitalization of the Ukrainian economy.

At the same time, it is important to motivate industrial enterprises to attract Ukrainian suppliers, engineering companies and research centers for the development and implementation of these technologies. Thanks to this approach, domestic demand will become a locomotive for the development of local technological enterprises.

As part of the implementation of this strategy, the government could develop programs for the localization of advanced foreign developments, increase the amount of state funding for R&D in the field of digital industrial technologies, and subsidize the creation of experimental sites for testing domestic technologies.

The training of personnel in the field of new industrial technologies, as well as support for corporate and regional programs of retraining and advanced training, digital literacy and mastering of new technologies by the personnel of Ukrainian industrial enterprises will be an important element of state policy.

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## Вплив Індустрії 4.0 на цифрову трансформацію виробничих підприємств в Україні

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**Мета.** Оцінити вплив Індустрії 4.0 на сучасний стан цифрової трансформації виробничих підприємств в Україні та обґрунтувати перспективні напрями розвитку.

**Методика.** У дослідженні було застосовано системний і порівняльний аналіз для забезпечення всебічного розуміння існуючого стану цифрової трансформації виробничих підприємств в Україні. Дослідження впливу Індустрії 4.0 на цифрову трансформацію ґрунтувалося на результатах статистичного аналізу ефекту й потенційного щорічного ефекту від упровадження інтернету речей на виробничих і будівельних майданчиках. Також використовувався метод дедукції, логічних досліджень і графічний спосіб подачі інформації для демонстрації значущих результатів дослідження.

**Результати.** У процесі дослідження розглянута цифрова трансформація виробничих підприємств під впливом Індустрії 4.0, що прискорюється. Доведено, що цифрову трансформацію українських підприємств необхідно проводити відразу на кількох рівнях: у частині промислового обладнання, IT-систем і внутрішніх бізнес-процесів.

**Наукова новизна.** Обґрунтовано вплив Індустрії 4.0 на цифрову трансформацію виробничих підприємств в Україні. Виділені вісім основних важелів створення вартості завдяки впровадженню технологій «Індустрії 4.0» на виробничих підприємствах: оптимізація режимів роботи обладнання; оптимізація завантаження обладнання; підвищення продуктивності й безпеки праці; логістична оптимізація; підвищення якості продукції; покращення прогнозування попиту; скорочення термінів виведення продукції на ринок; покращення післяпродажного обслуговування. Надані рекомендації підприємствам у частині формування галузевих партнерств задля спільного фінансування проектів, зниження ризиків, взаємодії з державними органами, технологічними компаніями й дослідницькими центрами, у межах яких створювати експертно-консультаційні центри.

**Практична значимість.** Результати дослідження можуть використовуватися економістами-науковцями та практиками для розвитку подальших перспектив. Встановлення міцних горизонтальних зв'язків з освітніми та дослідницькими організаціями, високотехнологічними компаніями, а також з органами державного управління дозволить ефективно обмінюватися досвідом, розробляти спільні для тієї чи іншої галузі інноваційні цифрові рішення, продукти та стандарти, адаптувати освітні програми й розвивати навички застосування цифрових технологій.

**Ключові слова:** цифрова трансформація, розвиток економіки, промислові підприємства, Індустрія 4.0

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