Digitalizing Production and Industry through 4.0 Technologies Implementation

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Abstract

The authors presented the main aspects of digitization of production and industry using 4.0 technologies and based on the existing Industry 4.0 base. The opinion is expressed that the implementation of digital technologies is one of the main factors in the growth of the competitiveness of the enterprise and corporation in the conditions of global challenges and European integration processes in Ukraine. The world's most popular 4.0 technologies for the field of mechanical engineering are presented, namely: product life cycle management, predictive analytics (service) based on data processing; augmented and virtual reality, vertical and horizontal integration of machines using OPS UA, Production Management Systems (MES), smart devices and mobile applications, cloud platforms and services, etc. According to the research results, Industry 4.0 changes people's lives beyond recognition. Shortly, this will be the most global transformation in human history. And those countries that want to have high competitiveness and an efficient production system in the future should take part in it. This transformation will lead to a change in economic relations and customer needs, the way of production. Therefore, domestic production needs to take an active part in the global trend of development to occupy an important place in the world markets of high-tech products. The paper reveals the content of promising models of economic development and future markets according to UN expectations. As a result of the observation, the authors concluded that Ukrainian enterprises have underinvested in classic (3.0) technologies for years. The level of basic automation of ACSTP-IT does not exceed 50%, while Western countries, China, and Asia have mostly passed it. The authors expressed the opinion that there is no clarity on the priorities of digital technologies and the corresponding investments. There have been dozens of traditional 3.0 technologies for a long time, and newer ones belonging to the 4.0 generation are constantly being added to them today. As part of the topic of the article, it is stated that classic technologies (3.0+) should be considered robots, ERP, MES/APS/APC, SCADA/HMI, authorization, accounting/dispatching, data storage, mobile technologies, industrial networks, cloud computing. New 4.0 technologies are called IoT platforms, smart sensors, etc.

Keywords

Digitalization of production, technologies 4.0, Industry 4.0, digitalization of corporation, digitalization of industry, cooperation, smart production, digitalization of the region, European integration of Ukraine.

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1. Introduction

Thanks to the formation of the digital economy, small and medium-sized businesses have received an unattainable opportunity to be global and have an increasingly significant impact on the world economy. This trend opens up new prospects for the development of Ukrainian small and medium-sized businesses. After all, Ukrainian companies can integrate into international networks of added value, which some of them are already successfully implementing. This is the way to increase exports and production of products with greater added value [1–4].

Are enterprises ready to create such strategic development tools? When they come out, is it possible to launch them at the industry level? Who will be the first in this? Answers to these and other questions must be actively sought because it is speed, flexibility, and timeliness that will depend on the competitiveness of domestic products and services on the world market.

2. Formulation of the Problem

2.1. Analysis of Recent Research and Publications, Which Initiated the Solution of this Problem and on Which the Author Replies

Scientific works and practical research and development of such well-known scientists and inventors as V. Isaacson, S. Brand, J. Vales, B. Elbrecht, J. Licklider, J. Von Neumann, E. Peters, E. Reinert. Ukrainian scientists and economists are also actively involved in the creation of the conceptual apparatus of the institutional palette of "Industry 4.0" system research. Among them are the names of V. Geits, V. Halasiuk, I. Guzhva, O. Holoborodko, O. Zhmerenetskyi, O. Zerniuk, S. Ilyashenko, M. Kuzmuk, K. Kraus, N. Kraus, O. Kryvoruchko, A. Maksyuta, O. Marchenko, O. Manzhura, T. Ostrikova, V. Osetskyi, Yu. Pyvovarov, Yu. Radzikhovska, O. Shtepa, O. Yurchak.

But, at the same time, a significant number of problems regarding the vision of digitization of production and industry using 4.0 technologies at domestic enterprises, the analysis of positive and negative changes that this Industry 4.0 brings for companies, remain insufficiently disclosed. In particular, a significant number of questions such as: What is generally practiced already at Ukrainian enterprises? Can this be called a real way of digital transformation of production and industry? Why are old problems not solved, and new ones are added in terms of the digitalization of the economy using 4.0 technologies?

2.2. Formulation of Goals of the Article

The purpose of the article is to study the digitization of enterprises based on Industry 4.0 in the conditions of martial law and the rapprochement of Ukraine with the European Union. Development of practical recommendations and instructions in terms of speeding up the digitalization of production and industry in Ukraine. Presentation of the determinants of the qualitative step-by-step digitalization by business entities. Elucidation of the content and features of prospective models of economic development and future markets according to UN expectations. The justification of the main principles on which the positive quality of functioning of digitized productions and industrial facilities is based and the clarification of the most popular 4.0 technologies in the world for the field of mechanical engineering.

3. Presentation of the Main Material of the Study with a Full Justification of the Obtained Scientific Results

3.1. The Role of Industry 4.0 in the Digitalization of the Country's Economy and Increasing its Competitiveness on the World Stage

The term "digital transformation" (TC) appeared in the world back in the 2000's. In 2011, from the submission of GapGemini Consulting and other consulting companies, the term received a powerful conceptual base,

which explains how digitalization can radically change business performance. In 2014, the term Industry 4.0—the next stage of digital transformation in the industry—was widely heard at the Hannover Exhibition, and in 2015 Klaus Schwab's bestseller "The 4th Industrial Revolution" was published. In 2016, the IT and industrial automation associations joined forces in Ukraine to create the "Industry 4.0 in Ukraine" movement.

Since then, attempts to understand the state of digitalization in various sectors of industry, in cities and their urbanism, and the possibility of accelerating this development have been traced in Ukraine. The mechanical engineering sector is the driver for the development of the entire industry in the era of 4.0. After all, smart machines are the basis of intelligent production. But this is not the only reason why nowadays the focus is on mechanical engineering. The dramatic drop in the volume of this industry after 2014 in Ukraine called into question the very existence of the industry—on the scale and boundaries that have more or less been maintained since 1991.

In addition to the traditional explanation about the loss of the CIS markets, the development of exports to other markets, as well as domestic competition, raised the question of the competitiveness of Ukrainian manufacturers. And among the factors of competitiveness, there is a special interest in those that are directly affected by digitalization. The results of a survey of the mechanical engineering industry conducted by the APPU [5] are somewhat controversial.

On the one hand, respondents show a good awareness of Industry 4.0 trends, and recognize Ukraine's lagging but also believe in the significant impact of digital transformation on the competitiveness of their enterprises in the future. On the other hand, the interviewed experts from the market speak of excessive optimism and the "advancedness" of these results. For example, one can only be happy that 78% have digital transformation goals and 55% are implementing digital programs. However, it was not possible to get more specific information on these goals and programs. Certain contradictions in the results can be explained by the fact that those who are already approaching the implementation of 4.0 but may not yet be sufficiently confident in the integrity and integration of these strategies in their enterprises, took part in the survey. The role of digital technologies is one of the main factors in the growth of competitiveness.

The fact that 4.0 technologies are among the priority factors of competitiveness has long been recognized in developed countries, and in general, still very little in Ukraine. According to McKinsey data in 2016, more than 80% of the heads of industrial enterprises believe that technologies 4.0 will fundamentally change the landscape of industries in the next 5–10 years. In particular, 30% of them are already investing in these technologies. According to the early data of APPAU in 2016–2017 (before the 2018 survey), >90% of Ukrainian managers simply do not understand "what it is." Accordingly, it was never about "faith", and even more so about "investment" [5]. The general effect of technologies 4.0 for industry, the big four of the world's largest consulting companies talk about revolutionary changes in the world's economies thanks to digitalization.

The Ukrainian Digital Agenda Ukraine program gives average indicators of contribution to growth at the level of 20–25%. The European association Orgalime especially emphasizes and emphasizes the role of Industrial Engineering in mechanical engineering—"The primary focus of digitalization should be on those who start it (enablers)—these are the engineering industries". Industrial engineering is machine-device and other construction, complex engineering and system integration, technology design, industry-oriented R&D centers, etc. The position of the Ukrainian movement 4.0 about mechanical engineering. The national movement "Industry 4.0 in Ukraine" puts engineering and mechanical engineering sectors as a priority—the focus of national and state economic development programs should be on these sectors:

1. The processing industry (3rd level) consumes ready-made technologies—lines, machines, technological complexes, devices, etc. These products are manufactured in the Engineering & OEM category. If there are no local ones, imports will increase.

2. The main technological innovators in digitization come from another category—developers, system integrators, and IT vendors. The speed and power with which they affect categories (food and processing, metallurgy, energy, oil and gas,

pharmaceuticals, building materials, urban infrastructure) is decisive for digital transformation. Industries such as mechanics, electronics, and electrical engineering are rapidly degrading in Ukraine because the conditions for development have not been created for them [6, p. 1888; 6, p. 144, 189, 255]. Accordingly, the main challenges in Ukraine are:

- For industrial end-users and engineering industries—to change the focus and understanding of key business drivers: from only cost—to those that are important in the global world (business drivers)—quality, time to market, productivity, and customer experience.
- For technological innovators: change the attitude of the categories of mechanical engineering and 4.0 innovators to digital technologies—instead of being an "appendage" to machines, they should become the main ones in creating added value.

There are many studies on the influence of digital technologies on the state of mechanical engineering today:

1. The McKinsey report "How to Success: Strategic Options for European Machinery" refers to a survey of more than 240 machine-building companies and focuses on strategic changes in 3 areas:

- Change in growth patterns—both in the geography of presence (including areas of profit growth) and also in the management of value creation chains. Regarding the latter, the shift from products to services is a definite trend. Next, we see the growth of digital services.
- Increasing rates of digitization—and calls into question the durability of existing business models [7, p. 722].
- Acceleration of organizational changes—which are necessary for the implementation of the above two directions of growth.

2. Back in 2016, Quest Trend Magazine determined in a survey of more than 150 machine builders that 66% of them are already on the way to Industry 4.0, and another 28% are planning these changes. Only 6% of respondents said that they do not plan any movement in this direction.

3. Another report of the same agency was specified for tasks of network interaction of machines, both vertically and horizontally of the enterprise. As you know, easy network interaction of people, machines, and systems is the cornerstone of Industry 4.0. The results show a great awareness of machine builders with both network interaction technologies and a purposeful movement in the direction of horizontal and vertical integration.

4. Hampleton analysts provide a rather extensive report showing the interest of large companies in acquisitions and purchases of technological representatives in the field of mechanical engineering. The most revealing here is the acquisition of the robotics leader Kuka by the Chinese Midea. There are dozens of similar reports and testimonies of digitization strategies of European and global machine builders in the world today [5].

Recognizing the primacy of large companies in digitalization processes, commitment to the course of digital transformation and Industry 4.0 is expressed, in particular by market participants—global vendors, integrators, business associations, consulting companies, and even the government. There are many reasons for highlighting the trend "large companies are the driver of digital transformation". DTEK, Ukrzaliznytsia, Metinvest, Interpipe, KB "Pivdenny", FED, subsidiaries of JSC "Naftogaz", Kernel, MHP, and many others have openly declared their commitment to the course of digitization of enterprises. All the aforementioned companies are seriously investing in new technologies, and some of them have launched their corporate accelerators. The trend of corporate innovation is also fueled by several IT incubators that seek to involve the IT industry and the startup community in the transformation processes of our enterprises.

3.2. Types of Innovative Solutions in the Economy

Despite all the positives of this trend, it is not difficult to see some distortions or "punctures" typical for this early stage of evolution. It makes sense to consider them in the 3 most typical categories of approaches to innovation:

1. Traditional, rigid selection through tendering. This is the classic and most common

method of selecting contractors for certain works. For state-owned enterprises, e-tendering through the Prozorro system, where the bid price is the main criterion, is also a mandatory selection condition.

The most telling here is the tender of Ukrzagvydobuvannya (UZD) for the monitoring of wells for gas production, where the American Honeywell won with the sum of more than 10 million dollars. This is a rather complex and large-scale project, in which USD managers managed to correctly conduct pre-qualifications, as a result of which the most qualified contractors made it to the tender finals. Moreover, the bidding price in the final fell by half. The challenges of digital transformation are generally a positive moment for the oil and gas industry, which is rapidly catching up with the modernization opportunities lost in previous years in terms of investments. However, in terms of digital transformation, this project does not address many other challenges facing such state-owned companies:

- Ukrainian contractors or manufacturers are not visible at all—in this way, state companies increase the import component.
- According to the available information, the technologies that will be used by Honeywell belong to classic 3.0 rather than innovative ones. In particular, the project does not yet solve typical 4.0 tasks of this scale, such as the creation of IoT platforms. Although it was probably a chance—we are talking about a huge distributed system of remote monitoring and control.

If the investment costs (IC_t) associated with the implementation of the investment project are carried out in several stages, the calculation of the current net reduced income is calculated according to the formula:

$$NRI_b = \sum_{t=1}^{n} \frac{NCF_t}{(1+i)^t} - \sum_{t=1}^{n} \frac{IC_t}{(1+i)^t}, \quad (1)$$

where NRI_b is the amount of net reduced income for an investment project with multiple implementations of investment costs (IC_t), NCF_t is the amount of net cash flow for separate intervals of the general period of operation of the investment project, i is the discount rate used, n is the number of intervals in the total calculation period t.

For simultaneously implemented investment costs (IC_o), this index (ID_o) is determined by the formula:

$$ID_o = \frac{\sum_{t=1}^{n} \frac{NCF_t}{(1+i)^t}}{IC_o}, \quad (2)$$

where ID_o is an index (coefficient) of profitability for simultaneous investment costs, NCF_t is the amount of net cash flow for separate intervals of the general period of operation of the investment project, and IC_o is the amount of simultaneous investment costs for the implementation of the investment project.

If the investment costs associated with the future implementation of the investment project are carried out in several stages (IC_t), the calculation of the index (coefficient) of profitability (ID_i) is calculated according to the formula:

$$ID_b = \frac{\sum_{t=1}^{n} \frac{NCF_t}{(1+i)^t}}{\sum_{t=1}^{n} \frac{IC_t}{(1+i)^t}}, \quad (3)$$

The index (coefficient) of profitability (IP_i) of the investment project can be used as an auxiliary evaluation parameter because it does not allow to evaluation of the entire return flow for the project. This index is calculated according to the formula:

$$IP_i = \frac{NIP_i}{IC}, \quad (4)$$

where NIP_i is the average annual amount of net investment profit during the period of operation of the project, and IC is the amount of investment costs for the implementation of the investment project.

The payback period is one of the most widespread and understandable indicators of the assessment of an investment project. Calculation of this indicator can be performed by two methods:

- Statistical (accounting)
- Discount.

The undiscounted (statistical) payback period (PP_n), determined by the statistical method, is calculated by the formula:

$$PP_n = \frac{IC}{NCF_p}, \quad (5)$$

where IC is the amount of investment costs for project implementation, and NCF_p is the average annual amount of net cash flow during the period of project operation (for short-term real investments (up to 1 year) this indicator is calculated as a monthly average).

The discounted payback period (PP_d) is determined by the formula:

$$PP_d = \frac{IC_o}{\frac{\sum_{t=1}^{n} \frac{NCF_t}{(1+i)^t}}{t}}, \quad (6)$$

where PP_d is the discounted payback period of simultaneous investment costs for the project, IC_o is the number of simultaneous investment costs for project implementation, NCF_t is the amount of net cash flow at separate intervals of the total period of operation of the investment project, i is the discount rate used, n is several intervals (years, months) in the total calculation period t, t is the total estimated period of operation of the project (years, months).

The Internal Rate of Return (*IRR*) is the most difficult (to calculate) indicator of the effectiveness of real investment projects. It characterizes the level of profitability of a specific investment project, which is expressed by the discount rate of cash flow, and is reduced to the current value of monetary investment costs.

The internal rate of return (*IRR*) = the discount rate (i), at which the *NRI* = 0.

That is, *IRR* calculations are carried out according to the formula:

$$\sum_{i=1}^{n} \frac{NCF_t}{(1+VSD)} = 0, \quad (7)$$

where NCF_t is the amount of net cash flow in separate intervals of the general period of operation of the investment project, and n is the number of intervals in the total calculated period t.

When determining the internal rate of return, a full capitalization of the entire amount is assumed, a net cash flow with a future rate of return equal to the internal rate of return.

2. Partner—through cooperation. This approach involves traditional, long-established cooperation with recognized contractors, system integrators, and developers of ACSTP-IT. Private companies are following this path. A vivid illustration of such approaches is the first 4.0 cases in Ukraine from Interpipe and PJSC "FED." There are many more of them in IT-Enterprise. Thanks to the stability of the relationship, the company was able to develop its vision of digital transformation according to the stages of maturity of the customer.

Challenges to digital transformation are, first of all, dependence on one large contractor, whose range of competencies is a priori limited. Without synergy and integration, it is impossible to talk about real and deep integration processes of the enterprise—especially vertically, from sensors to ERP. Therefore, in 2018, IT-Enterprise made attempts to create its technological ecosystem and invited other ACS integrators to its ranks.

3. Focus on innovators through corporate accelerators. The leaders of investments in this approach in 2018 were DTEK and Ukrzaliznytsia. The essence of accelerators is to collect the best offers from the market according to predefined needs (cases), with the signing of contracts with finalist companies. The most qualitatively such technique was developed at DTEK. Together with RadarTech (the organizer of the accelerator), DTEK "filtered" more than 400 companies, including not only startups but also mature companies.

3.3. Prospective Models of Economic Development and Future Markets

In general, if we talk about promising models of economic development and future markets, it is worth noting that, according to the expectations of the UN, promising trends should be expected from the development of the bioresource economy, the closed cycle economy, the exabyte economy, the welfare economy, the impression economy, and the carbon-neutral economy. We tried to present the content and general characteristics of each of the above-mentioned economies, their potential, opportunities, expectations, and prospects in Table 1. It is also worth noting one undeniable fact that each of these economies, in addition to its formation, is already undergoing a deep digital transformation, which the same will be strengthened every year and will form Industry 5.0 in the cross-section of various sectors of the economy [8, p. 1010–1015].

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Table 1

Prospective models of economic development and future markets according to UN expectations (grouped by the author based on sources 22; 14; and own observations)

Economic development model	General characteristics and content	Potential and opportunities	Expectations and perspectives
BioGrowth Economy—economy of biogrowth, S1 trillion	It is about new agriculture and biomaterials. Creating biodegradable biomaterials can be very useful. It will become easier to process agricultural waste into fuel on an industrial scale. New crops with high nutritional qualities and greater resistance to disease and drought may appear. This will reduce the risks associated with dependence on monoculture and accelerate the development of the seed industry. Innovative types of agricultural production—hydroponics and vertical farming—are becoming more and more widespread. Building on the experience during the COVID pandemic, countries are rethinking food security policies by strengthening local and regional production. Such a reorientation will accelerate the introduction of new technologies.	• By 2021, the global biorefining market has already reached 550 billion pounds. • The market for animal protein substitutes grew from $4.63 billion to $6.43 billion by 2023. • The global market for agricultural biotechnology has already increased from 22 billion pounds in 2016 to 40 billion pounds by 2022. • By 2022, the global bioplastics market has already exceeded 33 billion pounds, compared to 13 billion pounds in 2017.	The industrial biotechnology sector will hold the largest share of the thermochemical bioremediation market. So, by 2020, it reached 447.3 billion dollars compared to 224.8 billion dollars in 2014.
Exabyte Economy—exabyte economy, $8 trillion	It's about devices, digital technologies, and people. Two-thirds of the world's population use mobile phones, and more than half have access to the Internet. After the pandemic, more and more people (+7% per year) will work on the Internet. The Internet of Things (IoT) will evolve: by 2023 there will be around 3.5 billion connections compared to 1 billion in 2018. 5G technology will speed up data flow. They will gradually move to online education, personalized health care, finance, and energy efficiency. After the pandemic, digitization and automation will only increase.	• The estimated economic impact of the Internet of Things is estimated at $11.1 trillion per year in 2025. This is equivalent to 11% of world GDP, almost 40% of which can be obtained in developing countries. • 5G is not only "foil hats", but also up to $12.3 trillion to the global economic output in ten years.	• According to forecasts, the size of the cognitive computing market by 2025 will amount to $49.3 billion. • Health improvements for people with chronic diseases due to connected devices for remote monitoring can be estimated at $1.1 trillion per year by 2025.
Circular Economy—the economy of a closed cycle, $4.5 trillion	This is about conscious consumption and extending the service life of goods. It is the response of governments and corporations to population growth, resource costs, and increased public awareness of the needs of future generations. Cities will implement new systems to reduce environmental impact by reducing waste, recycling resources, and generating energy.	• 40% of steel is produced from scrap. The metal recycling market is projected to grow from $277 billion in 2015 to $406 billion by 2025; • In Europe alone, the net benefit of applying circular economy principles could reach €1.8 trillion annually by 2030, reducing the cost of goods, leaving more income for consumers, and creating jobs in the fields of product design and waste management engineering. • The European Commission plans to invest 1 trillion euros by 2030 in projects related to supporting sustainable development within the framework of the European "green course."	The global fashion industry could release $150 billion in net income by fighting waste and encouraging large-scale resale of used products.
Wellbeing Economy, $7 trillion	It is about rethinking approaches to one's health—physical and mental. Consumer behavior will change and this will expand the global wellness market: fitness, diet, beauty industry, travel and real estate, educational and organizational practices, and mental health balance. Health tourism and online training using special programs are important here.	• In the USA alone, the self-improvement market in 2016 was valued at $9.9 billion, and by 2022 it will reach $13.2 billion. • The market of preventive and personalized medicines in 2017 amounted to $574.8 billion, the average annual growth rate was 3.7%.	Health tourism is growing at the intersection of the tourism industry, $2.6 trillion, and the health market, $4.2 trillion.

		• The market for health trackers and remote monitoring devices in 2023 amounted to $60 billion.	
Experience Economy—the economy of impressions, $6.5 trillion	A paying customer does not buy a product, but an emotion. The thesis is not new, but now it will be filled with technological highlights. This applies to everything from healthcare to banking. It is also about complex software algorithms and high technologies: from 3D reality for trying on clothes to virtual trips to remote places.	• The global digital content market will reach $237.3 billion by 2024 compared to $143 billion in 2019. • The global market of banking and financial chatbot services was estimated at $357 million in 2017 and may reach $2.1 billion by 2024. • The 3D printing sector will grow to $28 billion in two years.	• According to forecasts, the world market of sports tourism will amount to $2.9 billion by 2028 compared to $1.4 billion in 2018. • The experience economy is not a new concept, but it is evolving. Although humanity is moving towards conscious consumption and care for the environment, it still wants impressions and travels.
NetZero Economy—carbon-neutral economy, $2.3 trillion	Innovation, technology, and investment models in markets will accelerate the world's transition to CO_2 reductions. About one-sixth of the world's investment in energy resources went to renewable energy sources in 2017.	The potential depends on public pressure on the government and consumer behavior.	• It is expected that the world renewable energy market will exceed $1.5 trillion by 2025. • By 2025, the global electric car market will grow by 22.3% to $567 billion. • By 2025, the market of lithium-ion batteries will amount to $93 billion, the market of hydrogen production by 2023—$199 billion. • Going Net Zero could create 42 million renewable energy jobs by 2050 and lead to cumulative savings of $62 trillion.

Digital transformation challenges are the right approach widely used around the world to find and encourage innovators. Nevertheless, many questions were raised by the general strategy and selection criteria of DTEK—companies that offer "light" solutions and mainly related to control and accounting in non-production processes made it to the finals:

- Unified infrastructure solutions as IoT platforms.
- New solutions regarding cyber security (we are talking, by the way, about the largest operators of critical infrastructure).
- Asset management systems and predictive equipment diagnostics.
- Solutions that allow for a "digital leap"—i.e., how to solve the backlog of the same mines or power plants in the mass digitalization of physical assets.
- Without solving such tasks, it is difficult to make serious changes in approaches to the digital transformation of such enterprises. Without this, and against the background of a constant increase in tariffs, the question that market participants ask themselves is becoming increasingly acute—"What is the essence of these innovations?" [9].

3.4. Strategic Challenges of the Digital Transformation of the Economy

The above-mentioned approaches can be complementary. What is generally already practiced at such enterprises as DTEK? Can this be called the true path of digital transformation? Do these approaches solve the main issues of acceleration in the field of ACS-IT in the 21st century? Rather "no". Mainly because old strategic challenges are not solved, and new ones are increasing.

First, there is no clarity on the priorities of digital technologies and the corresponding investments. There have been dozens of traditional 3.0 technologies for a long time, and newer ones that belong to the 4.0 generation are constantly being added to them today [10–12].

Classic technologies (3.0+): robots, ERP, MES/APS/APC, SCADA/HMI, authorization, accounting/dispatching, data warehouses, mobile technologies, industrial networks, and cloud computing. New technologies 4.0: IoT platforms, smart sensors, cobots, 3D printing, artificial intelligence, cyber security, VR/AR, Real-time Location Services, Wearable, drones.

Which of them are priorities today and why? For example, with a limited budget, should you invest in AR/VR technologies, IoT, cloud platforms, etc.? Or maybe take up cyber security first? What do priorities depend on—or only ROI? And how can you calculate the ROI for completely new technologies? And what about financial indicators in cyber security issues?

Similar questions have been around for a long time, but there are usually no unequivocal answers to them.

Secondly, there are no "digital leap" strategies. Ukrainian enterprises have underinvested in classic (3.0) technologies for years. The level of basic automation of ACSTP-IT does not exceed 50%, while Western countries, China, and Asia have mostly passed it.

In conversations about 4.0, a clear answer should also be given to the question of "digital leap"—how to raise the necessary base for data processing technologies. This is the main principle of digitization and it is about the automatic acquisition of data from physical assets. Without it, talking about artificial intelligence and other smart technologies in most cases sounds like fiction.

And again, there are no clear answers to this question yet. It is not clear why many esteemed customers need new 4.0 technologies if many of their control-accounting-automation tasks have not been solved. And they are solved by classic, long-available methods and contractors. Without clear answers to these questions, companies will catch up with the developed world in another 10–20 years. But then there will be new technologies.

Thirdly, endless tenders and the practice of "squeezing"—even in the case of quality contractors, have had a bad effect on the confidence of industrialists. The implementation of complex projects is always associated with risk management, and teamwork between the contractor and the customer—and on a long-term basis. But if you squeeze and tender all the time, lowering the price—what kind of parity of interests are we talking about? This is also one of the reasons why many leading developers prefer to work abroad. To this, it is worth adding that even in tenders there are clear criteria for the selection of the contractors in question.

As for innovation competitions, the questions are the same. Why did certain companies win in them in past years—the criteria are extremely blurred and unclear. In addition, the organizers of such competitions—even if hundreds of companies pass through them—do not make any final analysis of the results. Meanwhile, such analytics are extremely important for the orientation of other customers in understanding "who is who", and for market participants to understand "where to move or where the growth zones are". As a result, many customers go around in circles—it seems that there are also many developers, and they have already worked with many—and for some reason, it is necessary to "launch everything from the beginning."

Fourth, the a lack of focus on the ecosystem. The "fashion for startups", which captures the mind of some CEOs, is harmful because it distracts from a much more important strategic question—how to revive and strengthen the innovation ecosystem in your industry? That is, customers from the easy supply of IT incubators, and today already state structures and international funds, are trying to build an increasingly "sophisticated" system of filters to filter out the best proposals from developers. Not analyzing at the same time—"Where do these proposals come from and are there conditions for creating a flow of innovative products?". The innovation ecosystem in most sectors of Ukraine, which includes modern research institutes, project institutes, laboratories, technology parks, funds, etc., has been destroyed. Most often, it is so obvious that it does not even require special evidence. And instead, of restoring it together, the largest market operators continue to "milk" it. All this is similar to the notorious phenomenon—of the desire to get "milk without a cow".

Fifth, ignoring the standards on which the world industry 4.0 is based. Talks about interoperability, integration, and cyber-physical interaction are completely groundless without consideration of the standards underlying these phenomena. And here is the surprise—it turns out that many directors do not need these things at all. They don't even realize how similar innovative approaches are to the same invention of the bicycle. After all, you will have to redo everything. What then is the meaning of these innovations?

Sixth, uncertainty in "non-technological" factors. The simplest principle of PPT (People,

Process, Technologies) was invented in IT, in particular, to introduce the principle of any technological implementations as complex changes in the organization. That is, "you can't automate chaos"—you can't implement new modern technology without changes in business processes, organization structure, methods and culture of interaction, personnel skills, knowledge, etc. This high-tech axiom is already 25 years old, if not more [9].

3.5. The World's Most Popular Technologies 4.0 for the Field of Mechanical Engineering

Industry 4.0 is about the rapid and massive introduction of new digital technologies. Evidence of this is presented in Table 2.

Table 2

The world's most popular technology 4.0 for the field of mechanical engineering

Technology	Characteristics of the technology	Fields of application in Ukraine
1	2	3
Predictive analytics (service) based on data processing	Predictive maintenance is a new type of machine and equipment maintenance that replaces traditional methods such as planned preventive maintenance (PR). Stoppage of production can cost an enterprise from several thousand dollars per day (FMCG) to 2.5 million per day (automotive industry). Today, smart machines can provide data on why and when a particular part or assembly might fail. Applying predictive analytics with new data processing methods and models can save up to 40% on maintenance and reduce unplanned downtime by up to 50%.	The most active in Ukraine is the Ukrainian company IT-Enterprise, whose product SmartEAM is the winner of the 2017 4.0 competition. SmartEAM uses the RCM method, which is the next step in the maintenance of PPR.
Product Lifecycle Management (PLM)	Product Lifecycle Management (PLM) is especially relevant for machine builders when it comes to innovation and constant change. The main trends in this area concern the transfer of PLM to the cloud environment, the emergence of Product-Data-asa-Service (PDA AS), which turns product data into valuable assets, collaboration platforms, micro-services, as well as blockchain integration.	The greatest effect from the application of "Engineering Data Management PDM" is achieved when integrated with the typical configuration of "Management of a manufacturing enterprise for Ukraine": this is how PLM technology is implemented—product life cycle management technology.
Augmented and virtual reality	To master new machines, put them into operation, and then in service, operators and operating personnel used to use instructions in PDF or printed format. But when it comes to quickly finding the information you need, as a rule, such things do not work—it takes too long! It is another matter when the image of the necessary unit or part is presented in a visual form in 3D and also with all the accompanying information in real-time about the state of the mechanism. This is how Virtual and Augmented Reality (VR & AR) technologies work. The use of AR significantly reduces the cost of personnel training and equipment maintenance, as well as reduces unplanned downtime.	Companies active with these technologies in industrial segments are currently unknown. Although their number is growing rapidly—the first classification and landscape were made in Unit.city. The Sensorama company is included in the 4.0 movement from this list.
Vertical and horizontal integration of machines using OPS UA	The "chips" of 4.0 are implemented by interoperability—both vertically and horizontally (the value creation chain) of the enterprise—this is the OPC UA standard (MEC 62541). This is the de facto standard for 4.0 projects (included in the RAMI model) and supports several other protocols and mechanisms—TCP, HTTPS, UPD, AMQP, and MQTT. Available implementations are today in Java, .Net, and ANSIC/C++. OPC Foundation has more than 500 companies that support and implement their developments.	OPS UA has long been widely used by many market players at the SCADA/HMI level. New controllers (such as the Schneider Electric M241/M251) allow the use of an OPC UA server "on board"—this provides more opportunities for integration into the cloud environment and work in distributed architectures.
Production Management Systems (MES)	Production management systems are not a new thing in the industry. We are already talking about the 4th generation of MES (Manufacturing Execution System)—software for managing production processes in real-time. From autonomous, local solutions, through integrated and modular solutions based on platforms that allow easy integration of third-party solutions and applications (apps).	It seems that Ukraine missed the 3rd generation of MES—it is extremely difficult to find them at our (any) factories. This is additional evidence of gaps between the levels of IT and OT (ASUTP)—after all, there are already many ERP systems on the one hand, and ASUTP on the other in enterprises.
Smart devices and mobile applications	The transfer of intelligence to any device is a characteristic of IoT and 4.0. Decreasing the price of sensors and many other field devices makes it possible to significantly increase the intelligence of physical objects into which they are integrated. Typical use cases are better monitoring of equipment, including predictive analytics, tracking of wagons or machines, mobile personnel, optimization and better management of production, etc. One of the best cases	"Smart" (more intelligent) devices that are easily integrated into the network have long been offered by a lot of manufacturers in Ukraine, primarily Western ones. Yes—sometimes they are more expensive, but even in such cases, the benefits of using them compensate for the initial cost. One of the best examples of the use of the new Real-Time Location Services technology with new type sensors and the use of mobile

	described by us in Industry 4.0 where mass use is mentioned of smart sensors in production is Intel's case.	applications is demonstrated by Kyiv-based Leantegra. The company is widely implementing this technology in Turkey for tracking rolling stock and personnel in underground mines.
Cloud platforms and services	Digitalization is impossible without IT infrastructure. Its central elements are the network and data centers (data centers). Maintaining your own, modern data center is an expensive "entertainment" for most enterprises, which is why most manufacturers today switch to using cloud services and platforms. Industrialists need to know that the trend in Industry 4.0 is the use of ready-made platforms-as-a-service (PaaS). Almost every manufacturer of CAE/CAD/PLC/SCADA and even field devices offers integration into them today. Platforms such as Mindsphere (Siemens), Predix (GE), Ability (ABB), Ecostruxure (Schneider Electric), and many others are increasingly used, including machine builders.	Ukrainian industrialists are very cautious about new opportunities. Bias about cyber threats, ignoring global trends, reluctance to pay for subscription services, etc., collectively throw us back into the last century. Still, there is movement. In the field of industrial platforms, good examples are shown by the winners of the 4.0 competition in 2017—IT Enterprise, Indusoft, and Novatek-Electro (Overvis).
Cyber security	The Internet of Things is sometimes called the Internet of Threats. Cyber-attacks on Oblenergo, "Petya" and other (including many non-public) attacks are eloquent evidence of the vulnerability of Ukrainian customers. Centrifuges at the Iranian nuclear power plant went "down" due to the Stuxnet virus, which "broke" control algorithms in Siemens controllers. Does this mean that we should then ban the Internet and close ourselves off in our environment, "on proprietary protocols"? Not! The whole world is moving to cloud technologies and the Industrial Internet of Things (IIoT), where cyber security issues are one of the main ones. The IEC 62443 standard is mandatory for industrialists to follow this path and build their systems and products to be safe. For machine builders, the MEK 62451 (OPC UA) standard is also important, which allows you to "build" an OPS server into a machine in a safe manner.	Technical Committee 185 and its group on cyber security are actively working on the harmonization of Ukrainian DSTU to international standards. It is worth knowing and following the best practices of brand leaders present in APPAU and the 4.0 movement—from Siemens, Schneider Electric, Phoenix Contact, and others. But you should not ban the Internet, as the heads of some Ukrainian enterprises still do—this path is a dead end.
Simulation, virtualization, and digital twins	Machine builders increasingly use virtualization and simulation technologies in the process of developing new products. This makes it possible to reduce the cost of production many times over and speed up the pace of development. Therefore, digital simulation—in all its varieties—becomes a mandatory part of the PDP (Product Development Process). Simulation and digitalization capture the entire life cycle—for example, from the design of a mechanical product to the programming of the machine on which it is produced, and to its introduction into production. Here is a classic example from Dassault Systemes from the Hannover Exhibition 2017. In 2018, Hannover demonstrated even more similar cases. An even more advanced level is digital twin models that virtualize the behavior of a real object at all phases of its life cycle.	Such things are completely new for Ukrainian machine builders. We do not have any information about development or implementation.
New business models	The transition to service models is a typical characteristic of Industry 4.0. Paradigms and "xxx-as-a-Service" approaches are beginning to be applied to everything around—SaaS (Software-as-a-Service) models, products, and platforms (PaaS) have been in use for a long time. Now it's the turn of the Machines. Similar approaches are available thanks to the digitization of machines. After all, the main problem of operation is machine maintenance. Thanks to predictive maintenance, including a whole set of 4.0 technologies (digital twins, cyber security, cloud computing—analytics...) all these become realities.	Ukrainian OEMs have known about service models for a long time. At least, giants like Corum Group had their attempts to switch to them 3–4 years ago. We still have a long way to go to the level of Kaeser Kompressoren, which already sells a service (compressed air), not compressors, in Germany. If only because none of the machine builders has yet fully implemented the technologies that provide the Product-as-a-service or Machine-as-a-service model. And they are all based on 4.0 technologies.

4. Conclusion

Returning to the main intrigue of the last three years—the trend of "big—as drivers," today's success is decided precisely by the ability to create and implement effective strategic development plans. So far there are none. Perhaps they are not there because large enterprises act in the old way—they try to create important things of a strategic nature (sometimes—at the level of the entire country) in their closed environment—without involving the best market experts, without analyzing world trends, without a strategic focus on the wider ecosystem.

Industry 4.0 is changing people's lives beyond recognition. Shortly, this will be the most global transformation in human history. And those countries that want to have high

competitiveness and an efficient production system in the future should take part in it. This transformation will lead to a change in economic relations and customer needs, the way of production. Therefore, domestic production needs to take an active part in the global trend of development to occupy an important place in the world markets of high-tech products.

We hope that ahead of us is the wide implementation of innovative technologies in production, increasing the efficiency of business operations and, accordingly, increasing its competitiveness. Of course, for this, it is necessary to overcome several challenges that the modern world poses to Ukraine, but the main thing is that the country is on the right path, which will not only significantly increase the level of business, but also help accelerate the economic development of the entire country.

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