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SMART INDUSTRY: PROSPECTS AND CHALLENGES

The distinctive features of industrial smart factory (as a flexible cyber-physical production that provides fine tuning to customers and is based on the use of "big data"), as well as smart industry (as a complex of smart factories united through global computer networks with researchers, developers, suppliers, distributors, end users, etc.) have been established. New prospects, opportunities, and problems associated with the development of smart industry have been identified.

Keywords: smart industry, Industry 4.0, smart factory, industrial Internet of things, cyber-physical production systems, information and communication technologies, and "big data"

The key features of the world economy after the global financial crisis of 2008–2009 are knowledge- and innovation-based "smart growth" * and its driving link "smart industry".

The special role of industry in the modern world is explained, firstly, by the fact that it enhances efficiency of social labor and creates new jobs and opportunities for gaining income, which contributes to combatting poverty, achieving other goals of the human development, and addressing many social problems (including gender equality and fair employment for youth) ** and, secondly, by absolutely new opportunities that the industrial revolution known as "Industry 4.0" opens for the humanity.

In Ukraine, the role of the smart industry is determined by the fact that the conventional industry undergoes a deep crisis [1]. Therefore, **the aim of this research** is to understand the smart-industry and new prospects and problems associated with its development.

The term "Industry 4.0" was introduced into the scientific use in 2011, upon initiative of German businessmen, researchers, and politicians who strived to secure Germany's position as world industrial center. Therefore, it is widely used in the German-language environment (*Industrie* 4.0) [2]. The number "4" features the fourth stage of industrialization. Usually, the first industrial revolution (the first stage of industrialization) is related to mechanization of production, the second one is associated with electrification and mass production, and the third one is marked with automation and computerization of production. The forth industrial revolution implies the transition to the customer-oriented production based on cyber-physical systems. In addition, it should be noted that this stage is characterized by fusion of technologies and "blending" of physical, digital, and biological spheres [3].

The English-language environment uses the terms "Industrial Internet", "Industrial Internet of Things" (IIoT), and "Smart Industry". In this research, the authors prefer to use the last one, insofar as the primary element of cyber-physical system consists of smart machines united via Internet and smart products.

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* Communication from the Commission Europe 2020. A Strategy for Smart, Sustainable, and Inclusive Growth. COM (2010) 2020. – Brussels: European Commission, 2010.

** Lima Declaration. Towards Inclusive and Sustainable Industrial Development. – Lima – Peru: 15th UNIDO General Assembly, 2013.

Hereinafter, all these terms (“Industry 4.0”, “Industrial Internet”, “Industrial Internet of Things” and “Smart Industry”) are used as synonyms (however, each of them has a certain specific meaning contained in the name ***).

In terms of engineering and technology, the smart industry integrates the achievements in the sphere physical devices with those in the sphere of Information and Communications Technologies (ICT), which results in the formation of cyber-physical production systems – interacting intelligence networks of physical components (machines, equipment, sensors, and actuators) and computation algorithms.

The primary link of smart industry – smart factory – enables, with the use of IIoT, to monitor and to control the operation of machines and personnel and to use the collected data for raising labor efficiency and for improving technological processes and product quality (Fig. 1).

<table>
<tr><td colspan="6">PRODUCTION MONITORING
(real-time remote monitoring, analysis, simulation, optimization, and control of production)</td></tr>
<tr><td colspan="6">SAFE COMPUTER NETWORK</td></tr>
<tr>
<td>SMART ENGINEERING PREPARATION OF PRODUCTION
(optimization of asset flows, continuous remote control of warehouse equipment, condition of tools, and use of machinery)</td>
<td>SELF-DRIVEN VEHICLES
(justification of internal transport priorities and route optimization)</td>
<td>AUTOMATIC ADJUSTING EQUIPMENT
(automatic recognition and adjustment of machinery depending on manufactured products and external conditions)</td>
<td>SMART MAINTANANCE AND REPAIR
(continuous sensor monitoring of the state of machinery and equipment, forecasting of needs in maintenance, unscheduled downtime reduction)</td>
<td>PERSONNEL HEALTH AND LABOR SAFETY CONTROL
(continuous sensor monitoring, preventive notification and response on danger for personnel)</td>
<td>AUTOMATIC CONTROL OF PRODUCT QUALITY
(automatic verification of compliance of parameters of manufactured products with established requirements)</td>
</tr>
</table>

Fig. 1. Diagram of IIoT-Based Smart Factory

Prepared based on McKinsey Global Institute. The Internet of Things: Mapping the Value Beyond the Hype. – McKinsey & Company, 2015. – 131 p. – P. 66–73

The smart factory may be considered in terms of interaction of hardware, primary data, software, artificial and human intelligence. The data received using sensors, log-files, and search robots from physical devices and computer networks are gathered, transmitted, preprocessed, stored, visualized, analyzed, and used by highly qualified staff to simulate industrial products and production processes (Fig. 2).

*** The term “Industry 4.0” is focused on the stage of industrial development, whereas “Industrial Internet” and “Industrial Internet of Things” put emphasis on tools used for addressing problems of industrial development (the world system of united computer networks); the term “Smart Industry” points out at qualitative characteristics of new stage of industrial development (its smartness, intelligence).

	Network of physical devices	
Big data	Real industrial products	Real production processes
Receiving, preprocessing, storing, visualizing, and analyzing data	SAFE COMPUTER NETWORK	Optimization of production processes and industrial products
Product lifecycle models	Production process models	Data-driven decision making (DDD)
	Digital model network	

Fig. 2. Smart Factory as Integration of Real Things and Their Digital Analogs
Based on [4, 6; 5, 9–10]

The practical implementation of this interaction is associated with real-time processing of huge data volumes, the so called "big data" [6]. As noted in [7, 654], the big data technology describes a new generation of technologies and architectures designed to gain economic benefits from huge volumes of broad-range data using high-speed capture, detection, and/or analysis. This definition describes the four distinctive features of "big data" – volume, variety, velocity, and value. As a result, "4Vs'' are widely used as characteristics of big data. It should be noted that the volume of globally generated and collected data grows exponentially: in 1970–1980, from kilobytes (2^{10} bytes) and megabytes ($2^{10}\cdot2^{10}$ bytes) to gigabytes ($2^{10}\cdot2^{10}\cdot2^{10}$ bytes); in 1980–1990, from gigabytes to terabytes ($2^{10}\cdot2^{10}\cdot2^{10}\cdot2^{10}$ bytes); in 1990–2000, from terabytes to petabytes ($2^{10}\cdot2^{10}\cdot2^{10}\cdot2^{10}\cdot2^{10}$ bytes); nowadays, from petabytes to exabytes ($2^{10}\cdot2^{10}\cdot2^{10}\cdot2^{10}\cdot2^{10}\cdot2^{10}$ bytes). The highest data volume, about 2 exabytes (2010), has been reported for manufacturing industry [8].

To understand all these data, the advanced analysis tools (intelligence analysis, predictive analysis, object-based analysis, real-time scoring, predictive modelling, optimization, etc.) * are used [8, 675–677; 9]. Top managers of factories can use advanced analysis for deepening into historical data on production processes, which enables identifying and optimizing factors that have the largest effect on ultimate results. Many global commodity manufacturers in broad range of industries and geographical locations have already had a lot of primary manufacturing and marketing data obtained in real time. Integrating and analyzing the previously isolated arrays (including, semi-structured and non-structured ones [7, 654]), they get an opportunity to offer new important ideas [9]. All information obtained is used for data-driven decision making (DDD) [10] both in the field of current managerial effects and in strategic governance of various industrial systems [5, 9]. These decisions have helped *Toyota*, *Fiat*, and *Nissan* cut the time needed to develop new models by 30–50% [8].

To repay the costs of creation, operation, safety measures, and further development of IIoT the smart factories need high performance that can be obtained due to the following:

1) better regard to increasingly stringent customer requirements for product quality, active involvement of customers with design and development of goods **, transition from the mass to the customized production (upon individual requests) using smart systems for customer relations management ***;

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* IBM. Advanced Analytics / Ibm.com, 2017 [Electronic resource]. – Access: http://www.ibm.com/analytics/us/en/technology/advanced-analytics/ [Accessed 5 Jan. 2017].

** Smartindustry.nl. Smart Industry. Dutch Industry Fit for the Future. – 2014. – 63 p. – P. 26 [Electronic resource]. – Access: www.smartindustry.nl.

*** McKinsey Global Institute. The Internet of Things: Mapping the Value Beyond the Hype. – McKinsey & Company, 2015. – 131 p. – P. 60–61.

2) flexibility of highly specialized automated (with minimum human factor interference) manufacture based on decentralized module principle and rapidly re-adjustable for manufacture of products demanded by customer ****;

3) application of cutting-edge manufacturing technologies and materials that can assure state-of-the-art deliverables (for instance, advanced robots, 3D-printing, metals with given properties and memory effect, piezoelectric crystals, nanomaterials, and others) under given conditions (individualization and flexible manufacture) [11];

4) use of highly qualified personnel that is able, within the framework of cyber-physical systems, to effectively perform functions of maintenance and control of manufacturing process and, in addition to technical skills, has important non-technical competence (knowledge of English, project management skills, and teamwork skills, etc.) [12].

However, the smart industry is much more than individual factories and products manufactured by them. In the smart industry system, the factories are interconnected with researchers, developers, suppliers, distributors, customers and so on via ICT (mobile Internet, Internet of things, cloud technologies), due to which a global digital platform is formed. It is used for improving coordination and enhancing activity of all partners both in individual chains and in entire networks of value creation (Fig. 3).

The main idea behind all these network interactions is that processing and analysis of detailed real-time data received via ICT on the state of any process or product – from order placement to consumption of finished products, enable to assure flexibility of manufacture in response to changes and challenges of external environment *.

Hence, the information generated within the intelligent network-centric approach that comes as substitute for the linear interactions is an additional source of value creation, inasmuch as it enables **:

– to design and to manufacture what is really required: in terms of technical properties (specifications, quality, design), quantity (how many is required), time (when is required), and resource efficiency (at required costs);

– to intensify technology and product innovation due to obtaining new combinations of previously separated data on external environment and better understanding of manufacturing processes, capabilities of suppliers, and customer requests.

<table>
<tr><td colspan="2">Business management with the use of software applications (ERP*, CRM**etc.) for optimization of activities</td><td>Corporate business systems</td><td colspan="2">Real-time data flows between factories and distributors for optimization of commodity flows</td></tr>
<tr><td>Raw material producers</td><td>Suppliers</td><td>Smart factory</td><td>Distributors</td><td>End users</td></tr>
<tr><td colspan="2">Fast demand-driven supply chains with highly accessible products without necessity to form reserves</td><td>Equipment manufacturers</td><td colspan="2">Fast design and manufacture of high-quality equipment for working environments with zero downtimes</td></tr>
</table>

* ERP – Enterprise Resource Planning systems;
** CRM – Customer Relationship Management systems.

Fig. 3. Smart Industry as Network of Smart Factories United by ICT

**** Smartindustry.nl. Smart Industry. Dutch Industry Fit for the Future. – 2014. – 63 p. – P. 11 [Electronic resource]. – Access: www.smartindustry.nl.

* CFE Media. Digital Report: IIoT. – Consulting-Specifying Engineer Media, 2016. – 72 p. – P. 51–52.

** Smartindustry.nl. Smart Industry. Dutch Industry Fit for the Future. – 2014. – 63 p. – P. 17–18. [Electronic resource]. – Access: www.smartindustry.nl.

Based on: Smartindustry.nl. Smart Industry. Dutch Industry Fit for the Future. – 2014. – 63 p. – P. 18–22 [Electronic resource]. – Access: www.smartindustry.nl; SMLC. Implementing 21st Century Smart Manufacturing. Workshop Summary Report. – Washington, D.C.: Smart Manufacturing Leadership Coalition, 2011. – 27 p. – P. 5.

A high capacity of smart industry as network of smart factories united by ICT is confirmed by world leading corporations such as *Apple*, *Intel*, *Samsung* *, *ExxonMobil*, *Procter & Gamble*, *Tata Motors Ltd*, *Shougang Steel* etc. [13, 148–149]. According to expert estimates, the largest windows of opportunities open for reducing time of research and production cycle (from design of new products to their commercialization) (by 20–50%) and downtime of equipment (by 30–50%), for cutting costs of equipment service (by 10–40%) and costs of asset maintenance (by 20–50%), as well as for raising labor efficiency due to automatization of its intelligent component (by 45–55%) etc. **

Although, practically, it is not an easy thing to realize all these opportunities, especially, in the view of the fact that the background situation does not always correspond to high expectations. According to *Ubisense* (supplier of IIoT technologies and software for industrial corporations) data, up to 10% of clients still spend half working day searching required equipment and products, 40% do not have real-time data on manufacturing processes, and 50% are late to follow changes in these processes. In today's reality, even in such a breakthrough industry as automotive one, IIoT has not been completely implemented and exists as cyber-physical islands ***. In EU, less than 20% of manufacturing industry corporations have a high or a very high digital intensity index (DII) ****.

This situation is caused by numerous barriers on the path towards the development of smart industry, including technical, economic, and institutional ones.

The technical barriers are associated with problems of computer networks, their compatibility and safety. As experts noted *****, nowadays, the wireless networks are not widely used in critical applications, since they are not sufficiently safe, while the wired networks are quite expensive to install. Many factories have no infrastructure required for dissemination of data within corporation, much less between factories and suppliers on the global basis. The continuous data stream between machines and remote computer systems within the IIoT requires long-range communication with a high bandwidth. At the same time, in many cases, especially in the developing countries, factories are located as far as several hundred kilometers from large cities with developed telecommunication infrastructure ******.

In order to fully utilize the industrial Internet potential, it is critically important to ensure the compatibility of relevant devices and systems due to the development of open standards, as well as the implementation of computer platforms based on which different IIoT systems can interact, etc. However, this exacerbates the problem of confidentiality. The new opportunities for receiving and storing information from several billion interconnected devices create problems for the corporations in terms of preventing the disclosure of information and maintaining the data integrity, and for the individuals in terms of privacy, personal and family secrets.

The economic barriers on the path towards the smart industry development are associated with high costs of raising and renovating required physical and, especially, digital capital (digital tangible and intangible assets) ******* that complies with industrial Internet engineering and technological requirements. This necessitates

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* Ibid. – P. 12, 32.

** McKinsey & Company. Industry 4.0 at McKinsey's Model Factories. – McKinsey & Company, Inc., 2016. – 11 p. – P. 7.

*** CFE Media. Digital Report: IIoT. – Consulting-Specifying Engineer Media, 2016. – 72 p. – P. 50–53.

**** Digital intensity index is a micro-level indicator that characterizes access of corporation to 12 various digital technologies, including: Internet, at least, for 50% of employees; use of ICT specialists; broadband access to Internet (30 Mbit/s and higher); mobile Internet devices for, at least, 20% of employees; website; website with advanced functions; social media; ERP; CRM; electronic exchange of information on supply chain management; the share of e-commerce circulation over 1% of the total turnover; the share of web sales based on business-to-consumer – B2C model higher than 10% of the total web sales. The index varies from 0 to 12 (Integration of Digital Technology in the EU 2016 /European Commissions, 2016 [Electronic resource]. – Access: ec.europa.eu/newsroom/dae/document.cfm?action=display&doc_id=15811 [Accessed 18 Jan. 2017]).

***** CFE Media. Digital Report: IIoT. – Consulting-Specifying Engineer Media, 2016. – 72 p. – P. 52.

****** McKinsey Global Institute. The Internet of Things: Mapping the Value Beyond the Hype. – McKinsey & Company, 2015. – 131 p. – P. 72.

******* Digital capital is resources required for the operation and development of the economy based on digital computer technology. It has the two forms: 1) digital tangible assets (servers, routers, printers, and other physical devices, together with relevant further accelerated reduction in the costs of basic hardware (sensors, micro-electromechanical systems, RF identification means, power sources for sensors, etc. *) and in the costs of storage and processing of "big data" **.

Also, there are serious problems with human resources. As mentioned above, the smart industry needs highly-qualified personnel. However, according to McKinsey Global Institute data, in 2020, a global undersupply of highly-educated staff will reach 38–40 million employees or 18% of the employers needs ***. This situation is caused mainly by rapid aging of the workforce, especially in Europe, Japan, and China. In the USA, some 8% of the members of the National Association of Manufacturers have reported having trouble filling positions vacated by retirees [8]. However, it's not enough just to fill them. The smart industry requires new competencies and a new system of training (ongoing training, certification) for the market of digital vacancies (robot designers, computer network upgrade specialists, network security system engineers, specialists in "big data", advanced analytics, etc.) ****.

The institutional barriers for the smart industry development are steady organizational routines (historical behavioral patterns of individual groups) that form a collective memory of corporation and reduce costs of decision-making in ordinary conditions [16, 138–188]. The problem is that in the manufacturing processes involving intelligence and DDD, ICT specialists shall play a leading role in all directions of management related to information from physical devices located "on the floor". This principle causes a manifest cognitive dissonance in many managers at different levels and requires revising the steady behavioral patterns in accordance with new understanding of ICT-infrastructure both as incremental ancillary to the existing management systems and as strategic investment *****.

More broadly, the smart industry can face an unfavorable institutional environment as a whole. New business models will require ongoing innovations in the sphere of goods and services. Since the network-oriented productions create broader opportunities with information flows increasing up to an unprecedented level, new opportunities will appear in the future as well. The competition in the world market requires ongoing innovations and prediction of these opportunities ******. Therefore, these problems concern, first of all, the countries and regions with low national investments in R&D, serious problems with property right protection and fulfillment of contractual undertakings, corruption, etc., where business entities are governed by "short rules" and choose profit-oriented policy instead of innovation one.

The IIoT success is based on freedom of global collection and transmission of "big data". To ensure DDD efficiency it is necessary to go beyond the country borders. However, this explicitly contradicts the interests of economic policy of growing national champions [17], when priority is given to decisions based on national interests (Politically Driven Decision – PDD) instead of technical and economic data. The problem is that

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computer programs); 2) digital intangible assets (websites, unique designs that engage large numbers of users and improve their digital experiences, digital capture of user behavior, intense big-data and analytics capabilities, etc.; patents and software products that can be licensed for royalty income, brand equity that companies create through digital engagement, etc.). According to experts from McKinsey & Company, digital capital becomes one of the main factors of global economic growth. Investments in digital capital have exceeded 8% of world nominal GDP. Globally, levels of digital intangible investment are more than half those of digital tangible investment. In more highly digitized economies, such as Israel, Japan, Sweden, the United Kingdom, and the United States, spending on intangibles represents two-thirds of digital capital's total value. [14].

* The potential and pace of possible progress in the manufacture of electronic components can be estimated using the so called "Moore's Law" based on observations that the number of transistors in dense integrated circuit doubles every two years, with their cost remaining the same [15]. Later, similar exponential dependence was established for memory capacity of devices, for number of pixels in digital cameras, etc.

Immediately after appearance of this hypothesis, in 1965, and later Moore's law has been many times prophesied to die inevitably, since in the real world nothing can grow infinitely (for instance: The Economist (2015). The End of Moore's Law [Electronic resource]. – Access: http://www.economist.com/blogs/economist-explains/2015/04/economist-explains-17 [Accessed 21 Jan. 2017]). However, so far, engineers have managed to find technical solutions that keep this empirical dependence in force.

** McKinsey Global Institute. The Internet of Things: Mapping the Value Beyond the Hype. –McKinsey & Company, 2015. – 131 p. – P. 11.

*** McKinsey Global Institute. The World at Work: Jobs, Pay, and Skills for 3.5 Billion People. Executive Summary. – McKinsey & Company, Inc., 2012. – 12 p. – P. 2.

**** World Economic Forum. Industrial Internet of Things: Unleashing the Potential of Connected Products and Services. – Cologne/Geneva, Switzerland: World Economic Forum, 2015. – 39 p. – P. 21–22.

***** CFE Media. Digital Report: IIoT. – Consulting-Specifying Engineer Media, 2016. – 72 p. – P. 52–53.

****** Smartindustry.nl. Smart Industry. Dutch Industry Fit for the Future. – 2014. – 63 p. – P. 32 [Electronic resource]. – Access: www.smartindustry.nl.

implementation of DDD in the global context may conflict with PDD. Even USA that possess a powerful economy have faced problems in the world of globalized industry, and now they shall adjust their economic policy in the context of industrial reshoring and stiffer protection of national interests *. One of possible ways to solve this problem is to transit from the IIoT openness in the system of unreliable global relations strongly influenced by politics to the mutually beneficial cooperation and openness in the system of regional, multilateral, and bilateral economic relations where the political factor can be controlled.

If the mentioned barriers are overcome, the world smart industry has very promising prospects. According to data of *McKinsey &Company*, the disruptive technologies for digitalization of physical world have the largest potential in the sphere of manufacturing industry. Based on the analysis of various options for pace of IIoT growth, economic and demographical tendencies, and technology evolution forecast for ten-year period, experts have estimated a global effect from the use of IoT in manufacturing industry as varying within USD 0.9 trillion to USD 2.3 trillion, in 2025. Till that time, from 80 to 100% of the world manufacturing industry will be covered with IIoT technologies, with operating expenses reducing by 2.5–5%, as a result [11, 55].

According to estimates of *General Electric Co.* experts, till 2030, the world industrial Internet network expansion will add about USD 15 trillion to the world GDP (in fixed prices of 2005). In other words, the world diffusion of smart industry attributed to a higher growth pace of labor productivity can generate an additional GDP equivalent to that of today's U.S. economy. Consequently, average income per capita will increase. Till 2030, it will grow by 1/5 as compared with the basic scenario without industrial Internet taken into account [5, 29–30].

The mentioned considerations are on the one hand. On the other hand, an extensive global diffusion of the smart industry can lead, among others, to such an undesirable effect as aggravating global problems of inequality, as a result of growing importance of highly-paid skilled labor [18] and replacement of the routine labor (that bear the main weight of change attacks) by machines. Dropping relative prices for investment goods caused by a progress in information technologies and computerization have already stimulated corporations to switch from labor to capital, given that over the past 35 years (as compared with the beginning of the 1980s), in the vast majority of countries and industries, there was a decline in the share of labor in the corporate value added and, accordingly, an increase in the share of capital [19, 61].

The recent achievements in the sphere of robotics, artificial intelligence, and machine learning are signs of new era of automation, insofar as many machines have the same or exceed the human capabilities in various types of works (including those required cognitive abilities). The *McKinsey Global Institute* analysis of more than 2000 specializations within 800 various occupations has shown that about a half of jobs can be replaced by machines using already known technologies **. However, this does not inevitably lead to growing global unemployment. Vice versa, the world economy will need every erg of human labor, in addition to robots, in order to overcome trends towards demographic aging both in advanced economies and in emerging markets ***. However, the nature of labor will essentially change, with creative STEM (Science, Technology, Engineering, Math) personnel able to design, to master, and to maintain new technologies gaining an advantage.

Unfortunately, what is fundamentally a labor-versus-capital problem has often been portrayed as a labor-versus-labor problem, with some in advanced economies claiming that developing countries are taking their jobs. This has contributed to the rejection of trade openness and calls for protectionism [20]. As mentioned above, indeed, such trends in the world economic policy have been reported. Although it is not necessarily true that all these things contribute to the success of industrial reshoring processes to advanced economies. Firstly, the current industrial leader among the emerging markets – China – is actively developing its own R&D field, which allows it not only to replicate western technologies, but also to promote its own ones (including digital

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* U.S. President Donald Trump in his inaugural address stated, "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 [Electronic resource]. – Access: http://edition.cnn.com/2017/01/20/politics/trump-inaugural-address/ [Accessed 24 Jan. 2017]).

** McKinsey Global Institute. A future that works: automation, employment, and productivity. – McKinsey & Company, 2017. – 135 p. – P. vii.

*** Ibid. – P. 2.

technologies) *. Secondly, the smart industry tends to the consumer. The number of basic consumers (from the middle class) in the emerging markets is constantly growing [21]. This means, in the upcoming decades, the share of such countries will prevail in this respect. Thirdly, in the places of location of smart factories there must be necessary conditions, including appropriate infrastructure, accessible and affordable capital, and labor resources, and the advanced economies do not always have an advantage in this respect **.

It should be noted that the smart factories essentially differ from the ordinary ones in terms of production factors, which will affect the choice of their location. "What shall be the production factors (production (transformational) capital – K_T; digital (informational) capital – K_I; labor related to physical capital – L_T; labor related to digital capital – L_I) ratio?" and "What are their relative dynamics?" are open questions.

Each industrial corporation can be presented as interaction of transformation flows (T) (processing of raw "input" into product "output") and information flows (I) required for organization and management of transformation processes. The smart factory (s) differs from the usual one (u) with the use of DDD based on big data:

$$\partial I_s / \partial T_s >> \partial I_u / \partial T_u, \qquad (1)$$

where

$$I_s = f_s^I (K_{I_s}, L_{I_s}); T_s = f_s^T (K_{T_s}, L_{T_s}); I_u = f_u^I (K_{I_u}, L_{I_u}); T_u = f_u^T (K_{T_u}, L_{T_u}).$$

However, increasing information flows make sense only if they lead to outstripping growth in efficiency of production, i.e. under the following conditions

$$\partial C_s / \partial T_s << \partial C_u / \partial T_u, \qquad (2)$$

where $\tilde{N}_s = \varphi_s (K_{I_s}, L_{I_s}, K_{T_s}, L_{T_s})$ – information and transformation expenses of the smart factory; $\tilde{N}_u = \varphi_u (K_{I_u}, L_{I_u}, K_{T_u}, L_{T_u})$ – information and transformation expenses of the usual corporation.

Insofar as relations between I and T are nonlinear (probably, of logistic type), the determination of parameters at which the inequality (2) is satisfied, is a nontrivial problem in each specific case (with place and time taken into consideration).

Generally, the simulation of cyber-physical systems, which enables to essentially reduce costs of their embodiment in metal and to enhance safety and integrity of each is a very complicated problem that requires uniting efforts of researchers and manufacturers in order to create more perfect tools for support of various (agent-oriented, probabilistic, factor, etc.) applicable simulation methods (including model management and traceability support) and to keep different levels of granularity and abstraction in appropriate relationships to each other [22, 18]. Multispherical, multidimensional, and multi-objective models are promising directions in the development of cyber-physical system simulation [22, 46].

Conclusions

Global manufacturing is rebounding [8]. The smart industry becomes even more relevant and highly-demanded. It can be defined in different ways, but it's success is based a harmonious combination of the physical and the informational worlds, which "blurs" the usual dichotomy between the transformation of matter and energy (production), on the one hand, and the production of information that is an attribute of matter and energy (services), on the other hand. However, information without disruptive material production is not efficient, although the digital technologies of production systems (3D-printing, bio-, nano- and other disruptive methods and tools), to a greater extent, define the specifics of "smart industry".

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[*] The Economist (2016). China's Tech Trailblazers. The Western Caricature of Chinese Internet Firms Needs a Reboot [Electronic resource]. – Access: http://www.economist.com/news/leaders/21703371-western-caricature-chinese-internet-firms-needs-reboot-chinau2019s-tech-trailblazers [Accessed 24 Jan. 2017].

[**] Typical example from USA. In 2012, at the meeting with CEOs of leading technological corporations Mr. Obama asked, "Why can't that [*Apple*] work come home?" Mr. Jobs unambiguously replied, "Those jobs aren't coming back". The main reason was the fact that the infrastructure development, accessibility, and system of staff training (for instance, qualified engineers) in the United States did not meet *Apple* needs [23].

The key benefits of the smart industry, as a whole, and the smart factories, in particular, are derived from the digital technologies that enable the integration of new information flows from the world of things into the industrial value chains.

For the smart factories that can have different size (small, large, medium) and types of industrial activities, this key benefit is a more flexible high-tech cyber-physical production that ensures precise customization (delivery time, quantity, quality, manufacturing costs), and is based on the use of "big data" and DDD-management.

For the smart industry, it is a qualitative leap in cooperation and coordination of the activities of smart factories united through global computer networks with researchers, developers, suppliers, distributors, end users, and others.

The smart industry as a whole has huge prospects and associated challenges and problems (including in the area of information security, employment, and income). The question is who will capitalize these prospects and who will face challenges and problems.

For the time being, in Ukraine, the situation has not been developing in the best way. The reason for this is banal problems with innovations associated with a generally unfavorable institutional environment, short rules of behavior of economic actors, and low investments in R&D *, which result in Ukraine's weak position according to the ICT development index (76th place, in 2016) **.

Although it should be noted that a certain progress in the development of smart industry, upon grassroots initiative has been reported ***. As regards central government bodies, the government of Ukraine has planned priority actions in the economy till 2020 ****, which could cover the smart industry, among others. However, there are some problems with this plan. Firstly, unlike the action plans of USA, China, EU core countries, and other industrial leaders, the developed plan does not mention the smart industry (Industry 4.0, IIoT, disruptive digitalized production, etc.) at all, even more so as national strategic investment. Secondly, there are problems related to ensuring real independence of the bodies responsible for the development of innovation, as a whole, and industry, in particular, from political influence. Thirdly, there are shortcomings in the system of training and retraining of STEM-personnel. And fourthly, the financial resources of government and business entities are scarce since they have been exhausted recently, for various reasons, (which has become usual for Ukraine).

Obviously, all these barriers shall be removed one by one, while addressing the strategic tasks of industrial growth quality improvement and orientation of the national production (that shall be upgraded based on ICT, IIoT, and DDD-management) towards the needs of domestic and foreign customers (primarily, European ones) instead of its mere restoration on the existing engineering and technological basis.

To this end, it is necessary to do as follows:

– Firstly, to proceed from a holistic and fully dimensional vision of the national industry development problems and the necessity of observing the regularities of co-evolution of socio-economic, engineering-technological, socio-cultural, and ecological spatial systems, since these regularities are not universal, but depend on specific conditions of country's development in space and time and determine the specifics of goals setting and ways to achieve them at this stage;

– Secondly, while choosing the basic directions and mechanisms of the formation of national smart industry, to actively use advantages of free trade within the framework of multilateral (primarily, with EU) and bilateral agreements, as well as the possibilities of escalating the European institutional pressure in order to speed up progressive organizational, managerial, engineering, technological, structural, and industrial transformations, as well as to integrate into European Digital Single Market and European Digitizing European Industry [22, 9];

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* European Commission. Peer Review of the Ukrainian Research and Innovation System. Horizon 2020 Policy Support Facility / Directorate-General for Research and Innovation. – Luxembourg: Publications Office of the European Union, 2016. – p.76.

** ITU data. ICT Development Index 2016 [Electronic resource]. – Access: http://www.itu.int/net4/ITU-D/idi/2016/ [Accessed 24 Jan. 2017].

*** Conference Connecting IT & OT – report / Association of Corporations of Industrial Automation of Ukraine, 2016 [Electronic resource]. – Access: http://appau.org.ua/ru/Conferencya_Connecting_IT_&_OT-zvit [Accessed 24 Jan. 2017].

**** The Prime Minister has presented a draft medium-term plan for priority actions of the government till 2020 / Government portal, 2016 [Electronic resource]. – Access: http://www.kmu.gov.ua/control/uk/publish/article?art_id=249628227 [Accessed 24 Jan. 2017].

– Thirdly, to take into consideration the competitive advantages of both newly created cyber-physical systems and already existing productions and resources, assuming that in the modern economy not one industry can be *a priori* referred to advanced or backward one, with each having both corporations with advanced digitalized technologies and management systems and those with backward ones; therefore, the government industrial policy shall shift the focus from the industry level to the level of corporations and their spatial agglomerations.

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