

## РОЗДІЛ 2

### Інноваційні процеси в економіці

#### Economic and Social Challenges of Disruptive Technologies in Conditions of Industries 4.0 and 5.0: the EU Experience

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The paper analyses the economic and social challenges of disruptive technologies in conditions of Industry 4.0 and Industry 5.0. The paper overviews research progress on Industry 4.0 and 5.0 and their influence on sustainable development. The research explains disruptive technologies trends for sustainable development. The paper examines the development process of “disruptive technologies”, which are numerous: telephone (replaced the telegraph), steamboats (replaced the sailing vessels), semiconductors (replaced the vacuum equipment), e-mail (instead of traditional mail), etc. The paper analyzes basic disruptive technologies for creating the Internet of Things. The paper shows potential economic characteristics of disruptive technologies for the nearest five-year perspective. It investigates the EU experience on the realization of Industries 4.0 and 5.0. The paper highlights the trends that positively impact business growth up to 2022 according to the EU Future of Jobs Report: increasing adoption of new technology and big data; advances in mobile internet; advances in artificial intelligence and cloud technology; shifts in national economic growth; expansion of education; advances in new energy supplies and technologies. The research demonstrates how disruptive technologies will accelerate by 2025 and how both positive and negative impacts on business will grow up. The article tackles the issues of the potential economic and social impact of disruptive technologies in the nearest future. It distinguishes possible consequences of the implementation of key disruptive technologies of our time: for example excessive psychological impact; the risk of creative potential reduction; increasing information dependence; reduced the privacy of personal life; risks of uncontrolled reduction of

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information security (for example, due to hackers); increased information vulnerability of civilization; risk of loss of human control over cyber systems, etc.

*Key words:* economic challenges, social challenges, Industry 4.0, Industry 5.0, disruptive technology.

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**Introduction.** Disruptive innovations and technologies open a new technological cycle, a new cycle of innovative business, since their purpose is not to develop an existing and established basic technology, but to completely change this technology and radically change the market. Nowadays, the world is living in conditions of Industry 4.0 and 5.0. We have already studied that “Industry 4.0” logically continues the trajectory of the Third Industrial Revolution, in which the synergetic base is the driving force behind the development of socio-economic systems [11]. The basic principles of Industry 4.0 are the integration of all stages of the life cycle into a single information space and the interaction of machines without human intervention. The main role of man in Industry 4.0 is to develop algorithms and teach machines the programming method. Industry 5.0 will be based on self-learning principle, copying the actions of humans or other robots and automatic optimization of production algorithms [15].

**Problem.** Except positive influence and effects of disruptive technologies there are debates concerning the negative effects disruptive technologies may bring. Negative effects are much more difficult to predict taking into consideration the fast development of disruptive technologies and changes that are brought into economic and social systems.

**Recent research.** Schwab C. [16], Davis N. [17] study the basis of the Fourth Industrial Revolution, Rada’s M. [13] and Vollmer’s M. research [20] tackle the technical issues Fifth Industrial Revolution. Manyika et al. [9], Christensen [3] study the changes that disruptive technologies bring. Voytko S. [1] studies educational and industrial potential of Industry 4.0, Nahavandi S. investigates Industry 5.0 and collaboration of robots and human brain.

**Goal of the article.** The research distinguishes economic and social challenges of disruptive technology in conditions of Industry 4.0 and Industry 5.0 incorporating the EU experience for achieving sustainable development goals.

Clayton Christensen’s theory on “disruptive innovation” was first introduced in 1997, in his book “The Innovator’s Dilemma: When New Technologies Cause Great Firms to Fail) [3]. This model can be used to describe the impact of new technologies on the company’s functioning. Clayton Christensen studied the reasons why the largest companies, industry leaders are rapidly losing their dominant position, losing their primacy when new technologies appear on the market. Everything changes when consumers feel the need for new properties of goods and services. In the broadest sense, disruptive technology is understood as technological innovation, which opens up a new technological cycle for the development of production systems. Examples of “disruptive technologies” are numerous: telephone (replaced the telegraph), steamboats (replaced the sailing vessels), semiconductors (replaced the vacuum equipment), e-mail (instead of traditional mail), etc. Basic disruptive technologies for creating the Internet of Things are shown in Figure 1.

According to Digitising European Industry initiative the EU’s IoT vision is based on three pillars:

- a thriving IoT ecosystem;
- a human-centred IoT approach;
- a single market for IoT [6].

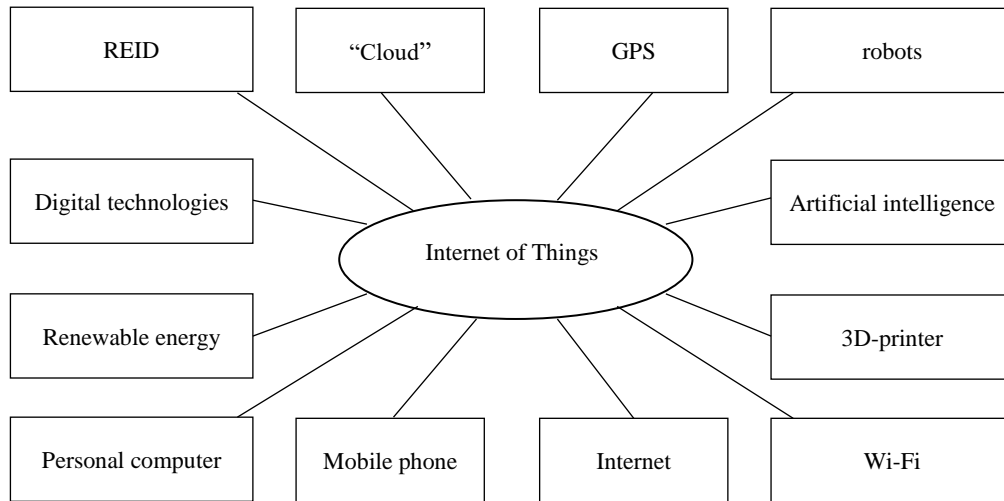


Figure 1. Basic disruptive technologies for creating the Internet of Things

As shown in [18] IoT market value will reach 1.6 trillion by 2025. According to the World Economic Forum, most technologies of the Fourth Revolution will become commonplace in 2027 [2]. The main developments of Industry 4.0 to businesses around the world and trends for sustainable development are presented in Table 1[4]:

Table 1

Disruptive technologies trends for sustainable development

<i>Development</i>	<i>Characteristics</i>
Web 3.0	the next iteration of the internet
Simulation and digital twins	a useful way to digitally represent physical assets
The Market of One	the phenomenon of mass personalization
Edge computing	a shakeup to the traditional topology of a computer network
The voice economy	to improve interaction with machines
Strategic automation	intelligent automation, which includes automation and AI to automate business processes and drive efficiency
Ubiquitous	artificial intelligence incorporation of AI to majority of machines, applications, and processes.
Spatial computing	calculus based on augmented, mixed, and virtual reality
Quantum computing	provides unprecedented scope for the way to process information

**Economic challenges of disruptive technologies.** Citi GPS: Global Perspectives & Solutions released a report indicating ten disruptive technologies that are extremely valuable. The capital input of these technologies is not very high, but in the future, they will bring billions to investors. A Citi GPS: Global Perspectives & Solutions study says that these technologies will change the value of the existing world and humanity’s vision of the future. Positive effects of disruptive technologies are the following: dematerialization of economy, decrease of environmental pressure, improving efficiency, solidarity economy formation,

circular economy formation, personalization of consumption, socialization of development, reduction the risk of accidents and disasters, improving health and the quality of life.

Tables 2 and 3 resent potential economic characteristics and acceleration of disruptive technologies for 2025.

*Table 2*

Potential economic characteristics of disruptive technologies for 2025 [8]

<i>Technology</i>	<i>Potential effect assessment</i>
Mobile Internet	10–20% reduction in the cost of treating chronic diseases through remote health monitoring
Automation of knowledge work	Increased labor productivity equivalent to the additional use of 110–140 million full-time workers
Internet of Things	It will reduce operating costs to 36 trillion US dollars, due to increased efficiency in processing, healthcare, and mining
«Cloud»	15-20 % increase in productivity due to the creation of IT infrastructure, development of necessary applications and programs
Advanced Robotics	Potential to improve the lives of 50 million amputees and those with impaired mobility
Autonomous and near-autonomous vehicles	30 to 150 thousand of saved lives are expected due to the prevention of fatal traffic accidents
Energy saving	40 to 100 % of vehicles expected to be electric or hybrid
3D printing	It can save from 35 to 60 % of operating costs per unit of manufactured products and achieve a very high level of customization (i.e. manufacturing according to individual customer requirements)
Advanced materials	The use of new nanomedical drugs can successfully cure up to 20 million newly diagnosed cases of cancer
Renewable energy sources	It is possible to prevent emissions from 1 to 2 million tons of CO2 until 2025.
Genetics for future generations to come	Increased life quality for 75 % of potential recipients

*Table 3*

Disruptive technologies acceleration [8]

<i>Country</i>	<i>Type of technology</i>	<i>Effect by 2025</i>	
		Value	
United States	IoT car safety technology	Significant reduction of crashes	Save insurance companies \$45 billion over the next five years
Emerging economies	mobile banking	New jobs creation	95 million new jobs and increase GDP by \$3.7 trillion

New research state that both positive and negative impacts on business will growth up till 2022. The Future of Jobs Report [19, p.6] shows the Trends set to positively impact business growth up to 2022:

- increasing adoption of new technology;
- increasing availability of big data;
- advances in mobile internet;
- advances in artificial intelligence;
- advances in cloud technology;

- shifts in national economic growth;
- expansion of affluence in developing economies;
- expansion of education;
- advances in new energy supplies and technologies;
- expansion of the middle classes;

The same Report presents the trends set to negatively impact business growth up to 2022 [19]:

- increasing protectionism;
- increase of cyber threats;
- shifts in government policy;
- effects of climate change;
- increasingly ageing societies;
- shifts in legislation on talent migration;
- shifts in national economic growth;
- shifts of mindset among the new generation;
- shifts in global macroeconomic growth;
- advances in artificial intelligence.

We can see how potential economic impact of disruptive technologies in 2025 may change national economies and world economy in general (Table 4).

Europe is one of the leaders in implementation of disruptive technologies. The Horizon 2020 scientific cooperation program initiated by the EU shows how much attention is paid to the implementation of disruptive technologies. The EU launches different projects and initiatives the study the impacts of disruptive technologies. The majority of the research is dedicated to artificial intelligence, blockchain, large databases of analytical data (analytics), the Internet of Things, materials for the future, virtual and augmented reality, modeling (simulations) and playing (gamification) of reality, algorithmic methods (algorithmic techniques). B. Rossi explains the essence of the Fifth Industrial Revolution in such a way: “It is aimed at achieving the interaction between man and machine, the harmony of man’s mental work and cognitive computer. A person must return to industrial production in collaboration with robots ... This should ensure, among other things, mass customization and personalization for consumers” [14].

Overall, the EU plans to mobilise up to EUR 50 billion of public and private investments in support of the digitisation of European industry: “EUR 37 billion investment to boost digital innovation; EUR 5.5 billion national and regional investments in digital innovation hubs; EUR 6.3 billion for the first production lines of next-generation electronic components; EUR 6.7 billion for the European Cloud Initiative” [5].

**Social challenges of disruptive technologies** Disruptive technologies may bring serious social challenges. Possible consequences of the implementation of key disruptive technologies of our time are: excessive psychological impact; the risk of creative potential reduction; increasing information dependence; reduced the privacy of personal life; risks of uncontrolled reduction of information security (for example, due to hackers); increased information vulnerability of civilization; risk of loss of human control over cyber systems, etc. As for example, table 5 demonstrates social impact of AI.

Currently the European Union and its institutions initiate a variety of initiatives to engage in social dialogue on digitisation in every Member State. These EU-level initiatives, developed within European Platform of National Initiatives “needs to take into account the

social aspects of digitisation, coordinating and stimulating discussion in all Member States through the relevant National Initiatives”. They are aimed at ensuring “a decent living from his/her work – i.e. prevent unemployment and in-work poverty and have a reasonable confidence in his/her future” [7]. This is the necessary condition for our If European and world society want to be “inclusive, innovative and able to adapt to the massive societal challenges of the 21st century” national governments should support such initiatives, include and implement in the national sustainable development strategies.

*Table 4*

Potential economic impact of disruptive technologies in 2025 [9]

Technology	Impact	
		Productivity
Mobile internet	\$3.7 trillion – 10.8 trillion	10-20 % potential cost reduction in treatment of chronic diseases through remote health monitoring
Automation of knowledge work	\$5.2 trillion – 6.7 trillion	Additional labour productivity could equal the output of 110 million – 140 million full-time workers
IoT	\$2.7 trillion – 6.2 trillion	Potential to drive productivity across \$36 trillion in operating costs of key affected industries: manufacturing, healthcare, and mining
Cloud	\$1.7 trillion – 6.2 trillion	15-20 % potential productivity gains across IT infrastructure, application development, and package software
Advanced Robotics	\$1.7 trillion – 4.5 trillion	Potential to improve the lives of 50 million amputees and those with impaired mobility
Autonomous and near-autonomous vehicles	\$0.2 trillion – 1.9 trillion	Could save 30,000-150,000 lives from potentially fatal traffic accidents
Next generation genomics	\$0.7 trillion – 1.6 trillion	Extending and enhancing lives accounts for 75 % of potential impact
Energy storage	≈\$0.1 trillion – 0.6 trillion	40-100 % of vehicles could be electric or hybrid
3D printing	\$0.2 trillion – 0.6 trillion	Consumer’s use could save 35-60 % in costs per printed product, while enabling a high level of customization
Advanced materials	\$0.2 trillion – 0.5 trillion	Nanomedicine could be used to deliver targeted drugs to 20 million new cancer cases worldwide
Advanced oil and gas exploration and recovery	\$0.1 trillion – 0.5 trillion	Offers potential to supply an additional 3.6 billion – 6.2 billion oil-equivalent barrels of oil and gas annually by 2025
Renewable electricity – solar and wind	\$0.2 trillion – 0.3 trillion	Potential to avoid emissions of 1.000 million – 1.200 million tons of CO <sub>2</sub> annually by 2025

**Conclusions.** Disruptive technologies and technological innovations open a new technological cycle of development of production systems and drive transformation processes in modern socio-economic systems. Disruptive technologies form the basis for application new methods of production and consumption especially in conditions of industry 4.0 and 5.0. They drastically change design and manufacturing technologies, communications, knowledge and skills of contemporary producers and consumers.

Table 5

Social Impact of AI [10]

<i>Types of impact</i>	<i>Negative consequences</i>
AI Bias	Built-in bias can lead to biased results
Loss of Certain Jobs	Machines will take over the jobs done today
A shift in Human Experience	New activities will appear as a result of extra freedom
Global Regulations	New laws and regulations requirements
Accelerated Hacking	Increased speed of hacking
AI Terrorism	Autonomous drones and robotic swarms
Autonomous weapons	Danger from global autonomous weapons
Social manipulation	Targeting individuals with fact or fiction information format
Lack of privacy and deep social grading	Constant tracking of individual's every daily life
Misalignment between our goals and the machine's	Different goals as a result of unclear intentions set by humans for AI machines
Discrimination	Use of personal information for dangerous purposes.

Such disruptive technologies as artificial intelligence, the Internet of things, methods for producing renewable energy, additive technologies of material production using 3D printers, “cloud” technologies, block chain, virtual and augmented reality bring not only positive changes, but provoke social and economic challenges that should be carefully studied within the framework of sustainable development.

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**Экономические и социальные вызовы прорывных технологий  
в условиях Индустрии 4.0 и 5.0: опыт ЕС**

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В статті проаналізовані економічні та соціальні виклики проривних технологій в умовах Індустрії 4.0 та Індустрії 5.0. В статті розглянуті напрями досліджень в області Індустрій 4.0 та 5.0 та їх вплив на стійке розвиток. В дослідженні пояснюються напрями розвитку проривних технологій в контексті стійкого розвитку. Розглядається процес розвитку проривних технологій, таких як телефон, який змінив телеграф, паропходи, змінивши парусні судна, напівпровідники, які прийшли на зміну вакуумному обладданню, електронна пошта, змінивши традиційну та багато інше. В статті аналізуються основні проривні технології створення Інтернету речей. В статті показані потенціальні економічні характеристики проривних технологій в найближчі п'ять років. Досліджується досвід ЄС по реалізації потенціалу проривних технологій в умовах Індустрії 4.0 та 5.0. В статті освітлюються тенденції, які позитивно впливають на зростання та розвиток бізнесу до 2022 року згідно з звітом про майбутнє ЄС. Це, зокрема, активне використання найновіших технологій та використання великих даних; поширення мобільного Інтернету; прогрес в області штучного інтелекту та хмарних технологій; зростання національних економік; поширення освіти; досягнення в сфері енергозабезпечення та технологій альтернативної енергетики. Дослідження демонструє, як змінюються проривні технології до 2025 року та які позитивні, та негативні зміни можуть статися в бізнес-спільноті. В статті розглянуті питання потенціального економічного та соціального впливу проривних технологій в найближчому майбутньому. Дана характеристика можливих наслідків впровадження ключових проривних технологій сучасності: наприклад, надмірне психологічне вплив; ризик зменшення творчого потенціалу; посилення інформаційної залежності; зниження конфіденційності приватного життя; ризик неконтрольованого зниження інформаційної безпеки (наприклад, через хакерів) підвищення інформаційної вразливості цивілізації; ризик втрати людиною контролю над кіберсистемою, тощо.

*Ключові слова:* економічні виклики, соціальні виклики, Індустрія 4.0, Індустрія 5.0, проривні технології.

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**Економічні та соціальні виклики проривних технологій  
в умовах Індустрії 4.0 та 5.0: досвід ЄС**

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У статті проаналізовано економічні та соціальні виклики проривних технологій в умовах Індустрії 4.0 та Індустрії 5.0. У статті розглянуто напрямки досліджень у галузі Індустрії 4.0 та 5.0 та їх вплив на сталий розвиток. У дослідженні пояснюються напрямки розвитку проривних технологій в контексті сталого розвитку. Розглядається процес розвитку проривних технологій, таких як телефон, який змінив телеграф, пароплави, які прийшли на зміну вітрильним суднам, напівпровідники, що прийшли на зміну вакуумному устаткуванню, електронна пошта, яка змінила традиційну і багато іншого. У статті аналізуються основні проривні технології створення Інтернету речей. У статті показані потенційні економічні характеристики проривних технологій у найближчі п'ять років. Досліджується досвід ЄС щодо реалізації потенціалу проривних технологій в умовах Індустрії 4.0 та 5.0. У статті висвітлюються тенденції, які позитивно впливають на зростання та розвиток бізнесу до 2022 року відповідно до звіту про майбутнє ЄС. Це, зокрема, активне застосування новітніх технологій та використання великих даних; поширення мобільного Інтернету; прогрес у галузі штучного інтелекту та хмарних технологій; зростання національних економік; поширення освіти; досягнення у сфері енергозабезпечення та технологій альтернативної енергетики. Дослідження демонструє, як зміняться проривні технології до 2025 року та які позитивні та негативні зміни можуть відбутися у бізнес спільноті. У статті розглянуто питання потенційного економічного та соціального впливу проривних технологій у найближчому майбутньому. Подано характеристику можливих наслідків впровадження ключових проривних технологій сучасності: наприклад, надмірний психологічний вплив; ризик зменшення творчого потенціалу; посилення інформаційної залежності; зниження конфіденційності особистого життя; ризики неконтрольованого зниження інформаційної безпеки (наприклад, через хакерів); підвищення інформаційної вразливості цивілізації; ризик втрати людського контролю над кіберсистемами, тощо.

*Ключові слова:* економічні виклики, соціальні виклики, Індустрія 4.0, Індустрія 5.0, проривні технології

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