SILESIAN UNIVERSITY OF TECHNOLOGY PUBLISHING HOUSE

SCIENTIFIC PAPERS OF SILESIAN UNIVERSITY OF TECHNOLOGY 2023
ORGANIZATION AND MANAGEMENT SERIES NO. 169

INNOVATIONS IN INDUSTRY 4.0 CONDITIONS

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Purpose: The aim of the paper is to analyze the innovations in Industry 4.0 conditions.
Design/methodology/approach: Critical literature analysis. Analysis of international literature from main databases and polish literature and legal acts connecting with researched topic.
Findings: The publication concentrate on problems connected with various aspects of relations between Industry 4.0 and innovativeness. In the paper we presented the main presumptions of Industry 4.0 concept and it's nowadays usage. In the second part of the paper there is an analysis of main trends of today Industry 4.0 implementation approaches and innovativeness. Especially there is an description of main innovative trends of 2021 described from Industry 4.0 relations point of view. Also the paper deals with the social innovation aspect of Industry 4.0. There are very interesting and innovative concepts that can be used in today business environment and also governments. Some of them like universal basic income are a bit controversial but it needs to further more detailed analysis if it is possible and could benefit to the society. Other trends can be for example: new forms of employment or new types of organizational culture.
Originality/value: Detailed analysis of all subjects related to the problems connected with the innovations in Industry 4.0 conditions.

Keywords: Industry 4.0; innovation, industrial enterprise, research and development, innovative trends.

Category of the paper: literature review.

1. Introduction

Today, industrial production is driven by global competition and the need to quickly adapt to ever-changing market requirements (Zhong et al., 2017). Modern production was built on the experiences of the first industrial revolution, streamlining the operations of manufacturing plants; the second revolution, introducing electricity to industry; and the third revolution, automating uniform tasks for production workers (Zhong et al., 2017; Pilloni, 2018; Zunino et al., 2020; Wolniak, 2016; Czerwińska-Lubszczyk et al., 2022; Drozd, Wolniak, 2021; Gajdzik, Wolniak, 2021, 2022; Gębczyńska, Wolniak, 2018; Grabowska et al., 2019, 2020,

2021). The fourth industrial revolution—Industry 4.0—differs from its predecessors in that it applies to all areas of life (Herceg et al., 2020), including the dangerous phenomenon of an ageing population and the consequent decline in the workforce (Habek, Wolniak, 2013, 2016; Hys, Wolniak, 2018). This revolution is also connected with the fact that the opportunities for increasing the profit of industrial production are exhausted despite the use of the "lean" manufacturing concept and outsourcing (Lee et al., 2014; Longo et al., 2017). Industry 4.0 determines changes in production—from mass production to personalized production—which make the production processes more flexible and provide the means to meet the individual needs of different customers more effectively.

The aim of the paper is to analyze the innovations in Industry 4.0 conditions.

2. Basic aspects of Industry 4.0

The concept of Industry 4.0, although initialized in Germany (Nagaro et al., 2020; Zimmermann et al., 2020, is spreading around the world, and the countries implementing the idea define it differently. In the United States and English-speaking countries, it is called the industrial Internet. In others, it is called the Internet of Things or a smart factory (García-Muiña, et al., 2020; Jonek-Kowalska, Wolniak, 2021, 2022; Jonek-Kowalska et al., 2022; Kordel, Wolniak, 2021). Apart from the non-uniform term, the terminology used for Industry 4.0 is not consistent either. The variations depend on how individual business circles interpret this term. In the United States, it is seen as the integration of people with things and things among themselves, combining the analysis of large data sets with the Internet of Things (Ashton, 2009; Sitton-Candanedo et al., 2020.

In France, the concept of "Industrie du futur" is based on the cooperation between industry and science. It is built on five pillars, namely: (i) state-of-the-art technologies, including additive manufacturing, virtual factories, the Internet of Things, and augmented reality; (ii) support to French companies to adapt to the implementation of new technologies; (iii) intensive training of workers; (iv) strengthening international cooperation on industrial standards; and (v) promoting the French industry of the future (Tran et al., 2019). In China, on the other hand, the concept consists of a comprehensive modernization of the Chinese industry, taking direct inspiration from the German concept of Industry 4.0 and adapting it to its own needs (Zhang, 2020; Kwiotkowska et al., 2021, 2022; Orzeł, Wolniak, 2021, 2022; Ponomarenko et al., 2016; Stawiarska et al., 2020, 2021; Stecuła, Wolniak, 2022; Olkiewicz et al., 2021).

In the digital age, an organization should adjust their production and logistics systems to meet new technologies. Business has evolved to improve in effectiveness and cost-efficiency.

Production systems should be customer-centric and should drive agility within the business. To meet these objectives, the implementation of Industry 4.0 is needed. We can distinguish the following reasons for why the conception of Industry 4.0 is so important (Zezulka et al., 2016, Veselovsky et al., 2018):

- Cost efficiency.
- Agility and flexibility of the production system.
- Customer-centric production systems, with customization of products.

In the Industry 4.0 environment, producers should better understand the patterns of consumption and based on that, be able to adjust the product to the specified requirements of the end-users (Brozzi et al., 2020; Wolniak, Sułkowski, 2015, 2016; Wolniak, Grebski, 2018; Wolniak et al., 2019, 2020; Wolniak, Habek, 2015, 2016; Wolniak, Skotnicka, 2011; Wolniak, Jonek-Kowalska, 2021; 2022). We can distinguish many technologies used in the Industry 4.0 concept. They may affect the methods of projecting, manufacturing, and delivering products to customers. The main technological conceptions supporting digitalization and servitization in Industry 4.0 are the following (Sułkowski, Wolniak, 2015, 2016, 2018; Wolniak, Skotnicka-Zasadzień, 2008, 2010, 2014, 2018, 2019, 2022; Wolniak, 2011, 2013, 2014, 2016, 2017, 2018, 2019, 2020, 2021, 2022; Gajdzik, Wolniak, 2023):

- adaptive robotics,
- cyber-physical infrastructure embedded systems,
- additive manufacturing,
- cloud technologies,
- visualization technologies, such as virtual reality and augmented reality,
- simulations,
- data analytics and artificial intelligence,
- industrial internet—communication and networking,
- RFID (Radio-frequency identification) and RTLS (Real-time locating system) technologies,
- cybersecurity,
- sensors and actuators,
- mobile technologies.

The main objective of Industry 4.0 is to increase automation so as to contribute to the operational efficiency and effectiveness of the company (Shabhazi et al., 2016). Industry 4.0 is based on the integration of new technical solutions. Particularly important, in this case, is the process of combining smart machines and systems, as well as changes in the production processes (Shanhazi et al., 2016).

Industry 4.0 is not only a technological revolution. It is also now connected with the problem of linking different devices together for achieving traceability and trackability. We can distinguish the following dimensions of the Industry 4.0 concept (Duflou et al., 2012; Müller, 2018):

- Internet of Things—the ability to conveniently access data from anywhere and exchange data between devices. All production systems become interconnected. There are real-time flows between all elements of the supply chain.
- Common digitalization—the process of ensuring digitalized, constant communication between all people and all devices and between people and devices themselves.
- Autonomous manufacturing systems—creating intelligent factories that organize production processes autonomously and can react flexibly to changes to the requirements of the manufacturing processes. Smart factories perform virtually the entire production processes themselves with minimal human input.
- Customization of the product—delivering a customized product to the customer, precisely according to their orders.
- Robotization—implementation of flexible production sockets, based on industrial robots, using robots adapted to cooperate with humans.
- Implementation of architecture based on cyberphysical systems.
- Widespread use of disruptive innovations—these can allow a rapid increase in the efficiency and effectiveness of the socioeconomic and operation system in an organization.

Technical structures are flexible and open, they permit autonomy to the employees and can help organize a structure with fuzzy boundaries. The likelihood that innovations will emerge in such an open and flexible organizing structure is high. We are dealing with this kind of situation in the Industry 4.0 conditions.

For example the widespread of Industry of Things can have positive effect on innovativeness. Using this method organizations can gain access to new sources of data and new information which can be used for decision-making process in a more comprehensive way. Such data systems may contribute to detection of new patterns of behaviour or machine interactions. The access to those data can enable managers at the strategic level of researchers to create new innovations. The development of new Industry 4.0 applications and novel business models change from pure production to customer-oriented and personalized services for special solution possible (Wilkesmann, 2018).

3. Innnovations in Industry 4.0

Innovation ecosystems are collaborative networks focused on the cocreation of value (Russell, Smorodinskaya, 2018). The structure of innovation ecosystem can be self-organized or managerially designed with multilayer networks of actors with different attributes to provide a system of innovative product and services (Tsujimoto, 2018). As in other innovation ecosystem, Industry 4.0 innovation ecosystem will also need to deal with lifecycle stages. The regional consolidation process while many technologies emerge and different economic aspects of the ecosystem ten to consolidate in the condition of industry 4.0. The capability dimension of innovative ecosystem in industry 4.0 conditions reflects the organization's capability to organize itself to provide value and foster growth in the ecosystem (Benitez, 2020).

According to international research it can be distinguished the list of Top 10 Industry 4.0 Trends and innovations in the year 2021. The authors of this research analysed sample of 770 global start-ups and scaleups. The result of the research was data-driven innovation intelligence that improves strategic decision-making by giving an overview of emerging technologies in the Industry 4.0 (Top 10, 2021). The Top 10 Industry 4.0 innovative trends in 2021 are described in the table 1.

Table 1.
Top 10 Industry 4.0 innovative trends in 2021

Trend	Explanation
Cyber Security, Transparency & Privacy	The flow of information due to the connectedness in Industry 4.0 is raising concerns about security, transparency, and privacy. As the manufacturing practices are increasingly becoming personal and customizable, the data management practices done outside and within the shop floor will hugely influence the appeal of the company. The transmission and processing of sensitive industrial data need to be done securely to avoid cyberattacks on critical industrial facilities. Digital ethics and privacy, privacy-enhancing technologies, self adaptive security, zero-trust security, end-to-end communication security, blockchain are some of the new developments in this front. The focus on cybersecurity needs to be balanced with transparency and privacy.
Edge, Fog & Cloud Computing	The immense amount of data being generated by the industrial internet of things (IIoT) is propelling the adoption of edge, fog, and cloud computing capabilities in Industry 4.0. Custom hardware and software solutions like connected clouds, distributed clouds, distributed compute and storage, hybrid computing, low code development platforms, microservices, mobile computing, and multi-access edge computing are shaping up this industry 4.0 trend.
Artificial Intelligence	AI and machine learning are driving innovations across industries and functional areas. AI-specific hardware and new algorithms are being developed to optimize the existing systems and tackle new challenges facing manufacturing. Factories are beginning to integrate AI across their production systems and processes. Advanced AI makes it possible to conduct predictive maintenance, cognitive computing, swarm intelligence, context-aware computing, smart machines, hardware accelerators, and generative design. All of these technologies propel manufacturing facilities to move towards complete lights-out manufacturing.

Cont. table 1.

Human Augmentation & Extended Reality	The physical and cognitive augmentation of humans forms another major industry 4.0 trend. The limitations in humans are being augmented with the help of technologies such as wearables and exoskeletons. Further, industrial mobile devices, natural and intuitive UI, and portable machine control screens enhance the ease of using such technology. XR technologies like mixed reality (MR), augmented reality (AR), and virtual reality (VR) are already in use in Industry 4.0 from the research and development (R&D) to full-scale production and post-production processes. This multi-experience paradigm is changing the way industrial manufacturing systems function. The nature of human-machine interaction is aligning more toward machine-enabled workers.
Network & Connectivity	Network and connectivity are among the main driving forces in enabling Industry 4.0. A number of technology developments such as edge-to-cloud, gigabit ethernet time-sensitive networks, low-power wide-area network (LPWAN), 5G, machine-to-machine communication (M2M), real-time deterministic ethernet, time-sensitive networking (TSN), ubiquitous radio access, unified IoT framework, and zero-touch networks nudge factories to implement IIoT to transform into Industry 4.0 facilities.
Advanced Robotics	Advancements in robotics make the processes in industry 4.0 faster, efficient, and safer. The most prominent robotic technologies impacting manufacturing include autonomous robots, collaborative robots (cobots), collaborative autonomous mobile robots, humanoid, mobile robots, cloud robotics, APIs, pick and place robots, and robot swarms. The use of robots offers higher precision and agility while improving the capability of rapidly developing customizable robots. Robots also free up time for the human workforce to focus on other non-repetitive or high-value tasks.
Internet of Everything	The machine-machine, human-machine, and human-human real-time connectedness together comprise the internet of everything in manufacturing. It includes IIoT, internet of skills, internet of services, internet of systems, and shop floor IoT. The internet of everything combines together real-time data, machine intelligence, and human skills, resulting in faster, efficient, and cost-effective manufacturing processes. Interoperability and a unified internet of things framework are crucial for the smooth implementation of industry 4.0 facilities.
Digital Twin	Digital twin technology creates virtual models of industrial assets by combining dynamic real-time sensing and visualization data. Some of the promising use cases of digital twins include model-driven design, virtual prototyping, virtual system validation, throughput optimization, and evolutionary design. The use of digital twins is propelling industry 4.0 manufacturing towards hyper-automation. Digital twins provide valuable insights into all steps of the manufacturing process.
Additive Manufacturing	Manufacturers constantly search for new technologies to cater to all aspects of the growing market demand. Additive manufacturing, which started out as a prototyping technique, is revolutionizing and decentralizing production. Hybrid manufacturing aims to integrate both additive manufacturing and subtractive manufacturing. The advancement in material science and techniques such as stereolithography and metal 3D printing enables simpler fabrication of intricate structures and complex components. Additive manufacturing is making highly-customizable and sustainable cloud-based production a reality.
Big Data & Analytics	The scale of industrial data collection eventually enables factories to make the transition into industry 4.0 facilities. Big data is complex and is valuable only when it is captured, stored, and analyzed in a quick and cost-effective manner. Advancements to utilize data for gaining valuable insights into the manufacturing systems, along with the availability of immediate and real-time data, open up opportunities for prescriptive, predictive, and augmented analytics at different levels of a company's manufacturing facilities.

Source: On basis. (Top 10, 2021).

Disruptive Industry 4.0 innovative startups in the world include (Industry 4.0 Innovation Map, 2023):

- Israeli startup Augury allows "machines to talk". By "listening" to machines the startup anticipates malfunction or failure and currently further develops the machine diagnostics backend of the Internet of Things (IoT).
- Waylay masterminds an intelligent SaaS decision-making platform. The Belgian startup generates a compact logic for easy maintenance – dynamic processes in the cloud, for the cloud.
- German Additive Works makes additive manufacturing less costly. The startup's solution entails a four-step system called the ASAP Principle (Assessment, Simulation, Adaption, Process), on which their software solution "Amphyon" is built.
- UK-based SQR Systems bridge the secure communications gap between mobile & IoT by enabling companies to protect their data and build secure products by taking away the pain of regulatory compliance and security assurance.
- Netherland-based Semiotic Labs works with Artificial Intelligence (AI), specifically machine learning algorithms and sensors, to optimize the process of predictive maintenance in smart factories.

We can find definition of Industry 4.0 where an attention on innovativeness is taken place. For example the Working Goup prepared following definition of Industry 40: Industry 4.0 regards it as a series of disruptive innovations in production and leaps in industrial processes resulting in significantly higher productivity. It is viewed as the fourth time such a disruption took place (Oluyisola et al., 2020; Industry 4.0 and fourth, 2023).

In the time of Industry 4.0 we can invent not only technical innovation but also invent and use social innovations. In the table 2 we put some example of emerging social innovations which are strictly connected with fourth industrial revolution.

Table 2.
Main social innovations connected with Industry 4.0

Innovation	Characteristic
Universal basic income	To a varying degree, this proposal seems to be supported by both liberals and conservatives. As early as in 1979, Friedrich Hayek referred to this concept in his work Law, Legislation and Liberty. In general, it is assumed that the value of such income should correspond to an existential minimum. This idea is very controversial however, nowadays it seems to be a robust, even though not perfect, social solution which can combat the negative effects of technological unemployment and make "life financing" possible.
Education	It is significant encouragement to create forms of supported structurally lifelong learning, which do not concentrate on professional qualifications, but rather on the development of skills as "something that whatever job you're in there's something that you can do about. And if you invest the right skills, you can leave yourself in a better place to benefit from the opportunities of the future". Modernisation of education systems should also be accompanied by innovative support programmes for grassroots forms of learning. An example can be the Fab Labs/ FabLearn Labs, the essence of which is knowledge and skills sharing on the basis of coaching or Internet mentoring. Voluntary organisations or education crowdfunding can also be considered the grassroots forms of learning in both cases, digital communication technologies (DCT) are used to share knowledge.

Cont. table 2.

New forms of employment	It is mostly about sharing economy solutions that need to be identified both with the concept of sharing various resources with other members of the community to use them better and of sharing new models of business practice that use Internet platforms. We can also consider crowdfunding to be a new form of work – it is about putting own project into action, which is financed by the community that believes in its meaning and chance of success based on donation culture that fully implements existential dimensions of work; similarly as "community entrepreneurship" based on benefit corporations, the profit from such ventures is the result of implementation of e.g. social and environmental goals, that is goals that improve the quality of life.
Development of socially useful activities	Currently, the traditional forms of voluntary service, such as participation in social life, were extended with all open source forms, the flagship example of which can be Wikipedia. It is crucial to notice that communication platforms and IoT created completely new possibilities in this scope, starting from sharing computing power of one's devices through search for new drugs to predicting climate change in searching for new planets, etc.
Establishing a culture of "new" values	Creating social initiatives, the goal of which is to boost creativity and develop community cooperation, as the sources of high quality of life. In the economy paradigm, work was a source of wealth that not only conditioned survival, but also expressed one's social position and defined one's identity, etc. Nowadays, this simple correlation is not so obvious anymore. This is due to several factors, including the sense of wealth in developed countries as well as research on the sense of life satisfaction, proving that material values are not able to ensure our well-being, therefore, work or other activities we undertake should also refer to other values.

Source: On basis. (Osika, 2019).

4. Conclusion

The publication concentrate on problems connected with various aspects of relations between Industry 4.0 and innovativeness. In the paper we presented the main presumptions of Industry 4.0 concept and it's nowadays usage. In the second part of the paper there is an analysis of main trends of today Industry 4.0 implementation approaches and innovativeness. Especially there is an description of main innovative trends of 2021 described from Industry 4.0 relations point of view. Also the paper deals with the social innovation aspect of Industry 4.0. There are very interesting and innovative concepts that can be used in today business environment and also governments. Some of them like universal basic income are a bit controversial but it needs to further more detailed analysis if it is possible and could benefit to the society. Other trends can be for example: new forms of employment or new types of organizational culture.

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