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Sustainable Development of the Intelligent Industry from Industry 4.0 to Industry 5.0

Milan Majerník[1], Naqib Daneshjo[1*], Peter Malega[2], Peter Drábik[1], Barbara Barilová[1]

[1] Faculty of Commerce, University of Economics in Bratislava, Dolnozemská cesta 1, 852 35 Petržalka, Slovakia
[2] Faculty of Mechanical Engineering, Technical University of Kosice, Letná 9, 042 00 Sever, Slovakia
* Corresponding author's email: daneshjo47@gmail.com

ABSTRACT
The current stage of socio-economic development is focused on ensuring prosperity by meeting the goals and intensifying the practices of the 4th generation smart industry. The ways and methods of advancement are being scientifically researched and specified, while at the same time revealing errors and weaknesses in the development so far, which are the potential for continuous increase of prosperity and sustainable production and consumption. From this point of view, the paper analyses and more accurately formulates the effects of smart industry 4.0 on the economy and society in a global sense. In the context of the new industry 5.0 development concept identifies significant progress in automation, robotization and digitization of imaginary processes supporting economic growth with obvious reserves and risks in the social field, as well as in relation to sustainable development and climate strategies, especially in the environmental field. In the article, the authors present the concept of models for intensification and transition from the developed implementation model for Industry 4.0 to the environment and concepts of Industry 5.0. Priorities for the development and innovation of the fourth generation smart industry within the fifth generation concept and possible synergy effects from human-robot-machine-environment cooperation, especially in the social field and in ensuring the well-being of workers in industry, are formulated in more detail.

Keywords: industrial development, artificial intelligence, digitization, sustainability, environmental management, sociability, industry 5.0, worker well-being.

INTRODUCTION

The concept of a comprehensive 5th generation smart industry as a continuous continuation and intensification of the Industry 4.0 project is based on the knowledge and experience in implementing the 4th generation smart industry in the context of the potential needs of globalization caused by development socio-economic strategies. The basic goal of the 5th generation industry concept is the development and implementation of innovative models and procedures for more sustainable economic-socio-environmentally balanced industrial development: The purpose and goal is to further ensure the prosperity of socio-economic development through smarter production, respecting new environmental and social risks. The focus of further industrial development is therefore on the creation of inclusive workplaces, more flexible and socio-economically resilient supply chains and the implementation of more sustainable production and consumption patterns, including the intensification of innovation processes. These activities will gradually result in a synergistic effect of cooperation in the system man-machine-robot-environment (Industry 4.0 + 5.0).

MATERIAL AND METHODS

Analysis of the 4th generation industry understood as - economic and economic development strategy. Figure 1 shows that it is built on two main pillars [1, 3].

Digitization of products, processes, equipment, services

The world of Industry 4.0 is built on the fact that people, machines, equipment, logistics systems and products can communicate and cooperate directly with each other. Everything contributes to total networking. The reason is to use a huge amount of hitherto elusive information to make much faster and more correct decisions. Tight interconnection of products, equipment, and people increases the efficiency of production machines and equipment, reduces costs and saves resources [11]. Smart tracking and transparent processes provide organizations with a constant overview that allows them to respond flexibly and quickly to changes in markets.

Application of exponential technologies

Exponential technologies are characterized by the fact that the improvement in their performance usually doubles with each step of evolution. Today, we know many technologies that are evolving at a similar exponential pace: the performance of digital products, a computer program with artificial intelligence, 3D printing, etc. Digitization and exponential technologies redefine the management of production and logistics processes. Established process and strategic models are losing efficiency in the age of digital transformation and automation (Industry 4.0) [13]. Businesses therefore need to prepare for the further changes that exponential technologies and innovations bring.

Innovative business model

For the smart industry, it expects that one of the most significant changes will be brought about by the change of existing business models. The service orientation of companies will be significantly strengthened. Concentration on those business objects and processes that contribute the most to added value will be strengthened so that they are able to automatically interpret their tasks and understand each other, resulting in greater efficiency.

Connection and cooperation are the main imperatives of the smart industry. The smart organization works in the Smart Environment (Smart Grids, Smart Mobility, Smart Logistics, Smart Buildings) [2, 5].

The result of a Smart Enterprise is a smart product that is not overpriced and meets the individual needs of the customer. Industry 4.0 focuses on three key areas [6, 9]:

1. A product with the features of the Internet of Things.
2. Organization of the company in terms of Industry 4.0.
3. New business models of organizations - mostly focused on services

The results economy will be based on the ability of automated quantification of results.

1. THE INDUSTRIAL REVOLUTION	2. THE INDUSTRIAL REVOLUTION	3. THE INDUSTRIAL REVOLUTION	4. THE INDUSTRIAL REVOLUTION	5. THE INDUSTRIAL REVOLUTION
				
Transition from manual production to machine production using water propulsion and steam engines.	Beginning of division of labour and mass production using electricity, belt production.	Production automation through electronic systems and information technologies, computer-controlled production (digital production, digital machines, PLC, robotics)	The emergence of cyber-physical systems, intelligent cybernetic systems, intelligent production systems of the new generation connecting the Internet of Things, cooperating robots, elements of artificial intelligence.	„Robot and man „ 5.0 will bring a new model of cooperation between people and machines (environmentalizatio n and sociability, industry with a human shape)

Fig. 1. Stages of industry development in a global context - Industrial revolutions [2]

The basic goal of Industry 4.0 is to make production in related industries (e.g. trade, logistics) faster, more efficient and more customer-oriented, while going beyond automation, digitization and environmentalization and revealing new business opportunities and models [8].

The forthcoming 5th Industrial Revolution will focus on a more sustainable, economically, more flexible and socially resilient industry, focused on man and his industrial well-being through human-machine-robot cooperation and the creation of more inclusive workplaces.

The impact of Industry 4.0 on key areas of the economy and society

The concept of 4th generation smart industry is an expected response to the fourth industrial revolution, in which industrial production is entering a turning point - after the era of steam, electricity and computers comes the period of digitization [4]. Today, all developed countries in the world are intensively involved in the application of digitization in industry. The coming digitalization is fundamentally changing the nature of industry and has significant implications for other parts of the economy as well as society as a whole [12, 14]. The key areas of influence of the 4th generation industry are identified in Figure 2 and others specified in Table 1.

In Figure 3 and Table 2, the impacts and requirements of Industry 4.0 on trade and business are identified and specified.

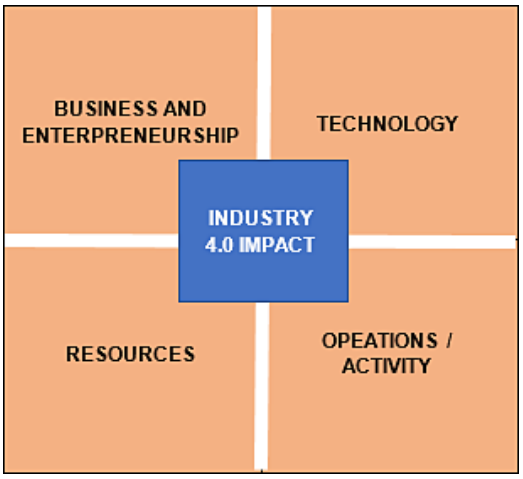

Fig. 2. Key areas Industry impact 4.0 [own research]

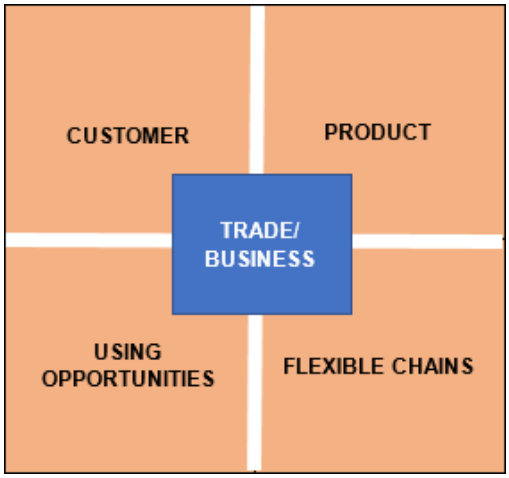

Fig. 3. Flooding and Industry 4.0 requirements for trade and business [own research]

Table 1. Industry 4.0 requirements for changes in the area [own research]

Key areas of influence of Industry 4.0 and requirements for their innovation activities			
Business and entepreneurship	Technologies	Operations/activity	Resources
Product	Hardware	Logistics	Machinery and equipment
Flexible chains	Software	Maintenance support	Material and energy
Using opportunities	Industrial internet	Quality	Working methods
Customer	Cyber-physical systems	Production	Person/employee

Table 2. Required innovations in trade induced by Industry 4.0 [own research]

Customer	Product
Expanding the circle of customers	Personalization - personification
Creating customers together	Rapid development
Digitized communication	Monitoring of LC, LCA
Use of Opportunities	**Flexible chains**
Platform and standardization	Demand prediction
Monetary data	Product design and value
Payments on use	Real time selection

The impact and requirements of the smart industry on technology innovation are specified in Figure 4 in Table 3.

In Figure 5 identifies the effects of Industry 4.0 on production operations and in Table 4, the areas of influence are specified in more detail.

The effects of Industry 4.0 on resources and resources are listed and specified in more detail in Figure 6 and in Table 5 in relation to the necessary innovations.

This decomposition of Industry 4.0 development will not only fundamentally change individual organizations, but will also transform market dynamics across a range of industries. And this is true in countries around the world - both in developed and emerging markets [7, 10]. At the end of this transformation process, successful industrial organizations will become true digital enterprises, with core products enhanced by digital interfaces and innovative active data-based services at the core. These digital businesses will work with their customers as well as suppliers in industrial digital ecosystems.

Although industry 4.0 is currently being addressed in research and development and implementation, scientists and innovators are already working intensively on the concept of the 5th Industrial Revolution based on intensive cooperation and interaction between humans and intelligent machines and robots, in which production environment and solutions issues of social sociability Figure 7.

The coming 5th Industrial Revolution as an Innovated Model of Smart Industry 4.0 can be characterized as: a more sustainable, economically

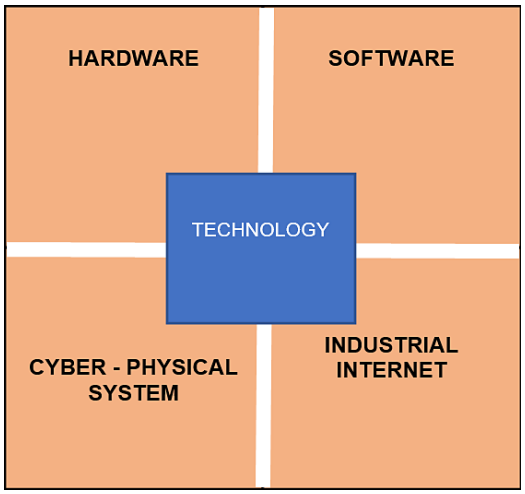

Fig. 4. Flooding and Industry 4.0 technology requirements [own research]

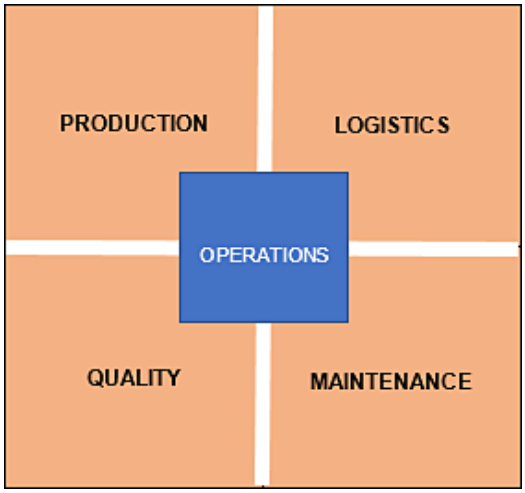

Fig. 5. Flood Industry 4.0 on operations [own research]

Table 3. Impact of Industry 4.0 impacts on technologies and their innovation [own research]

Hardware	Software	Cyber – physical system	Industrial internet
• Autonomous and cooperating robots • Augmented reality • Comprehensive sensor security everywhere	• Big data • Computer networks • Service orientation • Systems integration	• Virtualization • Simulation • Decentralization • Self-regulation	• Internet of things • Interoperability (touch operability) • Cyber security

Table 4. Impact and requirements of Industry 4.0 on operations and their innovation [own research]

Production	Logistics	Quality	Maintenance
• Digital and physical transmission • 3D Printing positioning • Equipment flexibility • Predictive production	• Increased intelligence • Real-time benefit optimization • Real-time supply chain optimization	• Digital quality management • Advanced process controls • Statistical process controls	• Predictive maintenance • Remote maintenance • Self-service through virtual instructions

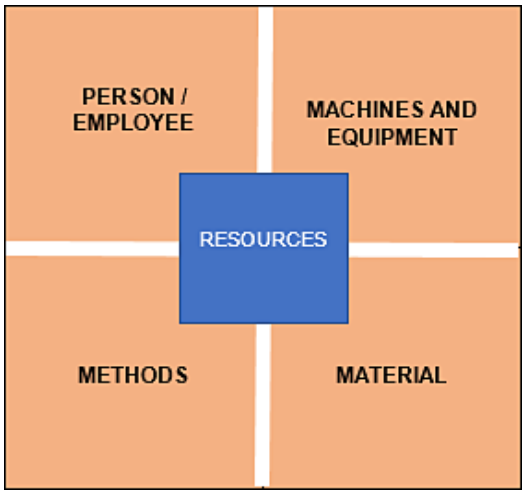

Fig. 6. Impact of Industry 4.0 on resources [own research]

flexible and socially resilient industry focused on people, people and their well-being in industry; a new innovative model of cooperation between humans - machines - robots - environment and synergies from such cooperation; addition resp. significant expansion of Industry 4.0 by the environmental and social dimension and human rights bases (Figure 8).

The following benefits are expected from the implementation of the technical and economic development strategy formulated in this way: workplaces that are more inclusive and the well-being of the industrial worker; more flexible and smarter supply chains; more sustainable production and consumption patterns; accelerating digital and green growth, green socio-economic

Table 5. Impacts and requirements of Industry 4.0 on resources and their innovation [own research]

Person/ employee	Working methods	Machines and equipment	Materials
• Man-machine cooperation • Knowledge for working in automation • Delegation of work and decision-making	• Virtual work instructions • Fast experimentation and simulation • Self-learning systems	• Flexibility of machines and equipment • System operability • Remote monitoring and control • Self-regulation	• Memory materials • Intelligent quantities • Precise localization in the processing process • Waste-free processing processes

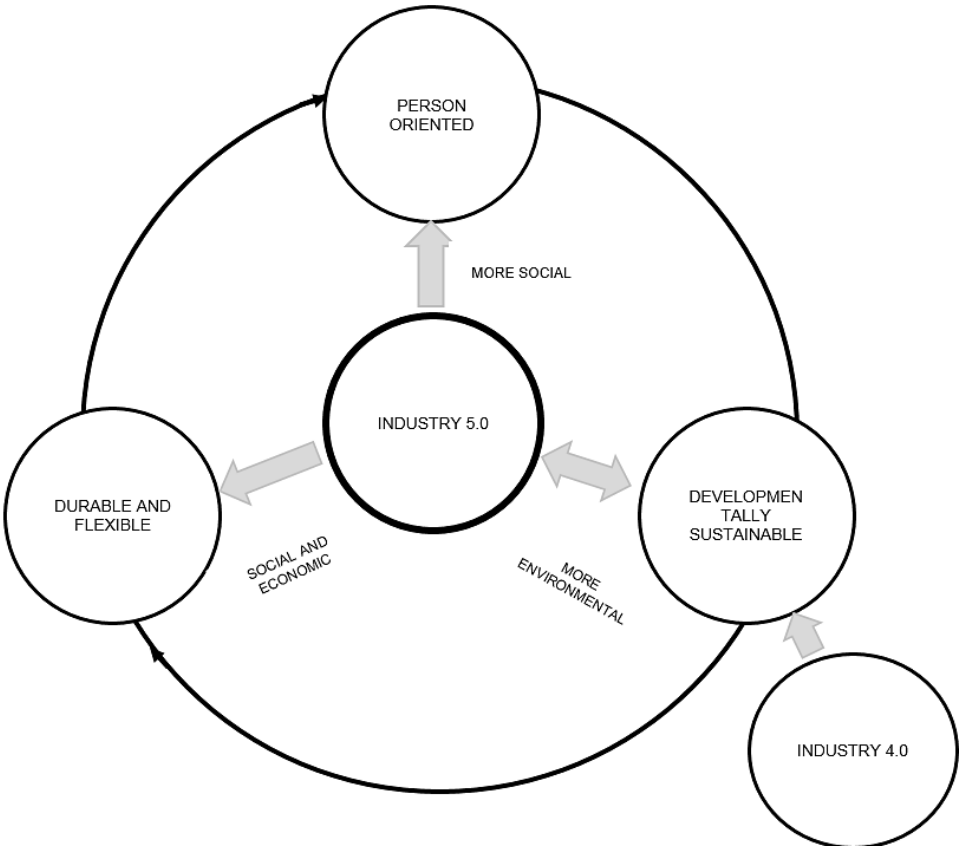

Fig. 7. Development routing within Industry 5.0 [own research]

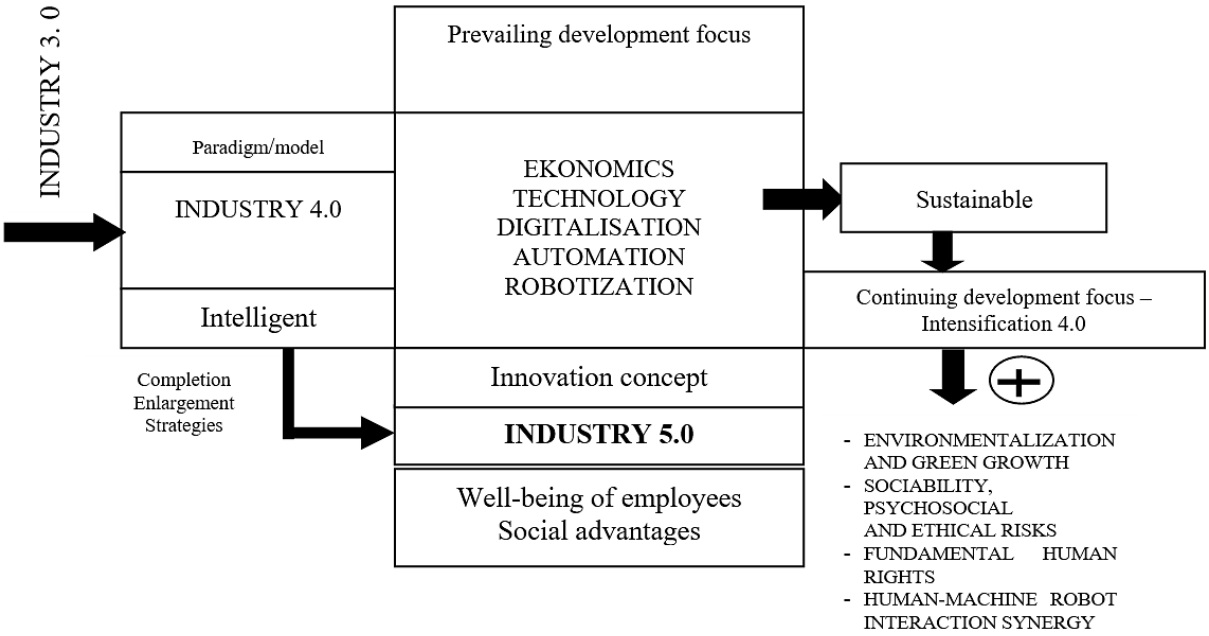

Fig. 8. Sustainable development concept of the human-centred 5.0 industry [own research]

transformation; radical innovations based on digitization, artificial intelligence and robotics; Optimization of human-machine-robot-synergy interactions; a "human-shaped" industry, a more sustainable and resilient society and a resilient economy; environmentalization of the economy, circular economy, green economy.

CONCLUSION

Industry 5.0 brings innovation and acceleration of the development of industrial technologies in the attractiveness of employment processes in fully automated production, especially for young latent in search of their purposeful and sustainable life. It brings also building more sustainable technological workplaces through digitization, artificial intelligence and robotics, optimizing human-machine-robot interactions and supporting empowerment rather than replacing them with industrial robots. The key element of Industry 5.0 is the environmentalization of the economy through the implementation of environmentally friendly technologies, environmentally friendly products and the use of best practices of environmental management, especially recognized systems according to ISO 14001 and EMASIII according to European Regulation no. 1221/2009. It is also necessary to know, that Industry 5.0 addresses the transformation of industries and its effects on changing the skills and competencies of workers and addressing their status and sociability. Finally, yet importantly, Industry 5.0 treats with the solution and management of psychosocial risks of influencing machines-industrial robots and manipulators-man and his well-being in the workplace, including ethical and human-legal aspects of cooperation.

The smart industry also brings new challenges in the field of labor law, aimed primarily at protecting the mental health of workers. It will be necessary to address the potential stresses of human cooperation with machines and robots and to develop methodologies for measuring and evaluating mental workload and the emergence of mental illness. The new code of ethics will also need to more precisely specify and dimension "employee well-being" in the environment of 4th and 5th generation smart industries.

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