# Using Industry 4.0 concept in Slovak chemical industry

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***Abstract:*** *Industry 4.0 has brought about the interconnection of the physical, cyber and socio-economic worlds. Bringing these three worlds together creates a revolutionary approach that is a new trend not only in industry but also in other areas of the economy, thus pushing the economy and business forward. The concept of Industry 4.0 represents the interconnection of digitalisation and automatisation with the use of smart technologies. The main benefit of Industry 4.0 is to produce tailor-made products where lower costs and shorter production efforts are the main values that will attract new customers and thus the profitability of industrial manufacturers will be significantly affected. Implementing Industry 4.0 in an enterprise will enable efficient use of human and natural resources and raw materials. It will also partially reduce the demands on the environment and create better living conditions for future generations. The intention of the paper was to explain how the Industry 4.0 concept is changing the direction of the Slovak chemical industry. The main objective of the paper was to explicate the Fourth Industrial Revolution in the form of the Industry 4.0 concept in 44 companies operating in the chemical industry in Slovakia on the basis of a knowledge base and a questionnaire survey.*
***Keywords****: DIGITALISATION, INDUSTRY 4.0, THE FOURTH INDUSTRIAL REVOLUTION, SLOVAK INDUSTRY*

## *1. Introduction*

The Fourth Industrial Revolution is a new way of organizing the means of production, the processes and all the organizational structures of the manufacturing and service industries. Through applications derived from scientific progress and technological development, a new way of doing is formulated in the business environment. The Fourth Industrial Revolution involves a transformation of processes, objects and consumer goods, as well as the way to acquire them, through a sudden break with the old methods of production that flourished during the Third Industrial Revolution [1]. The Fourth Industrial Revolution, also labelled Industry 4.0, was beget with emergent and disruptive intelligence and information technologies. These new technologies are enabling ever-higher levels of production efficiencies. They also have the potential to dramatically influence social and environmental sustainable development [2]. The Fourth Industrial Revolution is also referred to as Industry 4.0. It represents the interconnection of multiplied distributed artificial intelligence and making it available to human operators. In more detail, the multiplied and distributed artificial intelligence can be explained by cyber-physical systems (CPS), which are computers with networks of small sensors and actuators that are installed as embedded systems in materials, devices and machine parts and connected via the internet [3]. The Fourth Industrial Revolution and the underlying digital transformation, known as Industry 4.0, is progressing exponentially. The digital revolution is reshaping the way individuals live and work fundamentally, and the public remains optimistic regarding the opportunities Industry 4.0 may offer for sustainability [4].

Industry 4.0 was coined by German's group of mechanical engineers in the year 2011 to account for the widespread integration and adaptation of ICT in manufacturing industries [5]. The concept of Industry 4.0 originated in the 21st century in Germany. Its essence lies in the use of automation and digitalisation processes in industry, transforming existing factories into self-controlled and self-adaptive social and technical systems (smart factories) that enable the creation of intelligent value chains [6,7]. Digitalisation varies from country to country around the world. Companies in Japan and Germany are embracing digitalisation to improve their efficiency and product quality. In the United States, the trend is to develop new business models with the intention of leveraging digital offers and services and delivering these products and services digitally as quickly as possible [8]. The term Industry 4.0 stands for the Fourth Industrial Revolution which is defined as a new level of organization and control over the entire value chain of the life cycle of products; it is geared towards increasingly individualized customer requirements [9].

The basis of Industry 4.0 is the intelligent, horizontal and vertical interconnection of people, machines, objects and information and communication systems in real time with the intention of dynamically managing complex systems [10, 11]. Industry 4.0 is characterised by the use of intelligent products and processes, enabling autonomous data collection and analysis, and interaction between products, processes, suppliers and customers over the Internet [12]. Industry 4.0 is associated with cyber-physical systems (CPS) that are integrated into manufacturing operations and with Internet of Things (IoT) technologies into industrial processes, which can be represented by smart factories, smart products and extended value networks-vertical, horizontal and end-to-end integration [13, 14].

The aim of Industry 4.0 is to apply innovative solutions not only in the form of technological change, but also to introduce new ways of working and a new role for employers in industry [15]. The main idea Industry 4.0 is to exploit the potentials of new technologies and concepts such as: availability and use of the internet and IoT, integration of technical processes and business processes in the companies, digital mapping and virtualization of the real world, smart factory including smart means of industrial production and smart products [16]. Industry 4.0 has become part of the integrated and interconnected world that has evolved as a result of the information and communication revolution. This technological revolution has come about through the Internet of Things (IoT) and the Internet of Services (IOS), which connect industry through a supply chain network in an internal and external electronic way. This makes the industry intelligent and all this is supported by cyber-physical systems (CPS) [17]. Industry 4.0 comprises five key elements - digitalisation, optimisation and customisation of production, automation and adaptation, human-machine interaction, value-added services and commerce, and automated data exchange and communication [18]. Industry 4.0 includes additive manufacturing, advance robotics and cobots, artificial intelligence, augmented reality, human-machine interfaces, machine-to-machine communication, blockchain, internet of things, cloud stored data, internet of services, digital transformation, autonomous vehicles, drones [19]. The core technologies of Industry 4.0 include: big data analytics, autonomous robots, cloud technologies, simulation, industrial IoT, additive manufacturing, augmented reality, business intelligence, cybersecurity [20]. Opinions on Industry 4.0 technologies are diverse. We are confronted with the definition of 35 key disruptive Industry 4.0 technologies. These key technologies include: internet of things, big data, additive manufacturing, cloud computing, autonomous robots, virtual reality, cyber-physical systems, artificial intelligence, smart sensors, advanced simulation, nanotechnology, drones, biotechnology, block chain, industrial internet of things, cybersecurity, smart factory and intelligent factory, internet of services, vertical and horizontal (V&H) system integrations, renewable energy and advanced energy storage, machine-to-machine communication, 5G network, information and communication technology, quantum computing, mobile devices, manufacturing execution system, neurotechnology, predictive maintenance, advanced human to machine interface, material

science, internet of data, internet of energy, flexible production system, location detection and digital twin [21].

## 2. Aim, Methodology and Data

The main objective of the paper was to create an analytical view of the concept of Industry 4.0 through a bibliographic-information analysis and the implementation of a questionnaire survey. The questionnaire survey was implemented in companies of selected industry in Slovakia. The survey was realised in 44 chemical companies.

In order to provide a comprehensive view, it was necessary to define the terms and concepts related to the Fourth Industrial Revolution and the characteristics of Industry 4. Subsequently, in the next part of the paper we focused on the identification of selected questions from a questionnaire survey conducted in the Slovak chemical industry. To process the information and knowledge in the paper on the use of Industry 4.0 in Slovakia, we used classical methods: literature search, analysis, synthesis, induction, deduction and comparison. The visualization method was also used to make the data on Industry 4.0 more transparent through group bar charts and pie charts.

The object of research in the present paper were 44 companies operating in the chemical industry in the Slovak Republic. For the categorization of companies we used the EU Commission Regulation No. 651/2014, which distinguishes between micro, small, medium-sized and large companies. 4.6% of small companies, 29.5% of medium-sized companies and 65.9% of large companies participated in the questionnaire survey.

By legal form of business, limited liability companies were the most represented in the survey with the largest percentage share of 77.3%. Businesses that indicated the legal form of a joint stock company had a share of 22.7%. Other forms of business did not participate in the survey.

According to the geographical location of Slovakia, the most represented companies in the survey were from the Trnava Region with a share of 22.7%. A high percentage of participation also had enterprises from the Trenčín Region with a share of 20.5%. The least number of respondents participating was from the Košice Region. This region was represented in the survey with a share of 2.3%.

## 3. Results and Discussion

In the following part of the paper, selected findings related to Industry 4.0 in the Slovak chemical industry were analysed.

Based on the answers from the respondents, it was reported that 63.7% of chemical companies are interested in the ongoing digitalisation. 31.9% of the responding companies expressed partial interest in digitalisation. 4.4% of enterprises are not interested in the topic of digitalisation in the company.

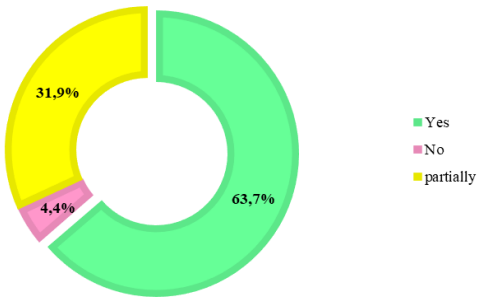


**Fig. 1.** *Interest in digitalisation in the company*
*Source: own processing*

At the core of Industry 4.0 is the Internet of Things and Services, intelligent devices that communicate with each other through cyber-physical systems to achieve a smart factory. Therefore, we wanted to know from the respondents whether they are interested in these concepts that are inherently related to Industry 4.0. From the responses, it was found that 52.3% of chemical companies are aware of and interested in these concepts. A high percentage of 40.9% of companies are partially aware of and interested in these concepts. Only 6.8% of the surveyed companies are not interested in these concepts that are related to Industry 4.0.

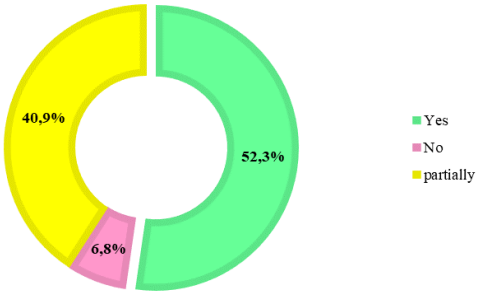


**Fig. 2.** *Interest in concepts - Smart Factory, Internet of Things, Cyber-physical system*
*Source: own processing*

The Industry 4.0 concept is used by 56.8% of chemical companies in Slovakia. It is partially used by 38.6% of the surveyed enterprises. Based on the answers of chemical companies Industry 4.0 is not used by 18.2% of respondents.

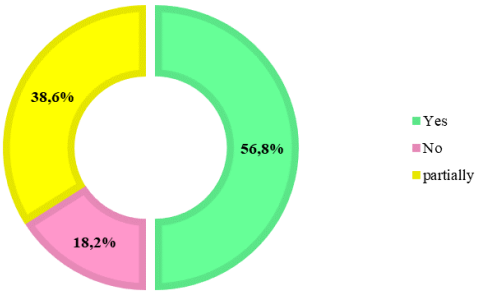


**Fig. 3.** *Applying Industry 4.0 concept in the company*
*Source: own processing*

Applying Industry 4.0 also requires the digitisation of individual business areas. From the responses of the surveyed companies, we were informed that 68% of the respondents apply the Industry 4.0 concept in IT. Production represented a high percentage, with 67% of chemical companies applying the concept. The least number of companies from the chemical industry apply Industry 4.0 in service. This business area reached 43%.

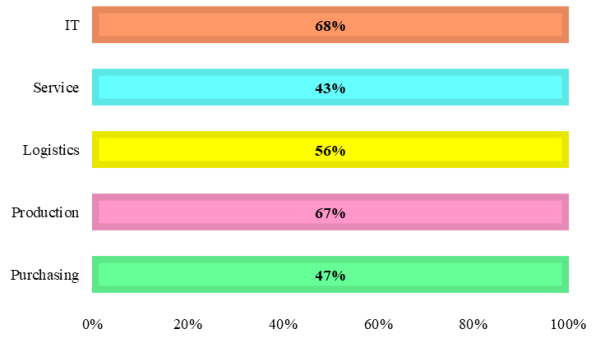


**Fig. 4.** *Applying the Industry 4.0 concept in business areas*
*Source: own processing*

The application of Industry 4.0 was also examined from the perspective of the business size. Of the chemical industry companies, Industry 4.0 is most widely used in large companies with a share of 54.5%. Medium-sized companies apply Industry 4.0 with a share of 25%. The smallest percentage share (4.5%) of the application of the Fourth Industrial Revolution was recorded in small companies.

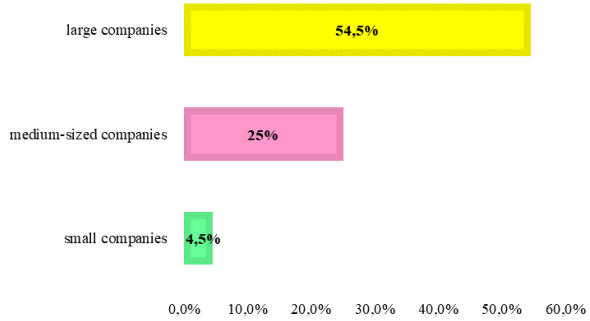


**Fig. 5.** *Applying Industry 4.0 concept in companies by business size*
*Source: own processing*

The concept of Industry 4.0 was also analysed in chemical industry companies in Slovakia according to the legal form of business. According to the answers of the respondents, Industry 4.0 is mostly used in limited liability companies. This legal form reached 65.9%. Chemical companies that operate as a joint stock company use the concept of Industry 4.0 with a share of 15.9%. This uneven percentage distribution is due to the fact that limited liability companies were represented in the survey with a higher proportion.

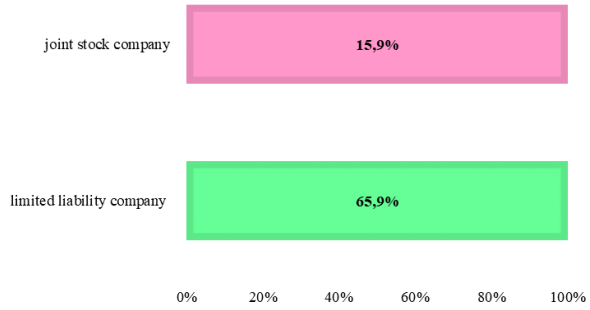


**Fig. 6.** *Applying the Industry 4.0 concept in enterprises by legal form*
*Source: own processing*

## 4. Conclusions

The concept of Industry 4.0 is dominant worldwide. This new concept not only brings revolutionary changes in manufacturing, but will fundamentally change society and the country's economy itself. Its main essence is digitalisation and automatisation linked to intelligent technologies. A significant factor is the Internet of Things and Services, which communicates through cyber-physical systems independently of humans.

The main objective of the paper was to create an analytical view of the concept of Industry 4.0 through a bibliographic-information analysis and the implementation of a questionnaire survey. The questionnaire survey was implemented in companies of selected industry in Slovakia. The survey was realised in 44 chemical companies.

Within the selected aggregated responses, we were informed by companies from the chemical industry in Slovakia that 63.7% of the respondents are interested in the ongoing digitalisation. 4.4% of companies are not interested in the topic of digitalisation in the company. From the answers of the respondents, it was found that 52.3% of chemical companies in Slovakia know and are interested in the concepts related to Industry 4.0 - Internet of Things and Services, smart devices, cyber-physical systems. Only 6.8% of the surveyed companies are not interested in these concepts. The concept of Industry 4.0 is applied by 56.8% of chemical companies in Slovakia. From the answers of the surveyed respondents we were informed that 68% of the respondents apply the concept of Industry 4.0 in the business IT area. The least chemical companies of apply Industry 4.0 in the business area - service. In the Slovak chemical industry, Industry 4.0 is mostly used in large companies, where the share reached 54.5%. At the same time, the Fourth Industrial Revolution has affected chemical companies with limited liability the most, where the percentage share reached 65.9%.

## 5. Acknowledgment

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## 6. References

1. A. M. Reyes Fabela, R. Pedroza Flores. (2018). *Challenges of the professional training of the industrial designer in the Fourth Industrial Revolution (4RI)*. RIDE Revista Iberoamericana Para La Investigación y El Desarrollo Educativo, 8(16), 1–22. (doi:10.23913/ride.v8i16.330)
2. Ch. Bai, P. Dallasega, G. Orzes, J. Sarkis, (2020). *Industry 4.0 technologies assessment: A sustainability perspective*. International Journal of Production Economics, 229, 107776. (doi:10.1016/j.ijpe.2020.107776)
3. H. Kagermann, W. Wahlster, J. Helbig. (2013). *Securing the future of German manufacturing industry: Recommendations for implementing the strategic initiative INDUSTRIE 4.0: Final report of the Industrie 4.0 Working Group.* Frankfurt/Main: National Academy of Science and Engineering. (https://en.acatech.de/publication/recommendations-for-implementing-the-strategic-initiative-industrie-4-0-final-report-of-the-industrie-4-0-working-group/)
4. M. Ghobakhloo. (2020). *Industry 4.0, digitization, and opportunities for sustainability*. Journal of Cleaner Production, 252, 119869. (doi:10.1016/j.jclepro.2019.119869)
5. G. Schuh, R. Anderl, J. Gausemeier, M. ten Hompel, W. Wahlster. (2017). *Industrie 4.0 Maturity Index. Managing the Digital Transformation of Companies (acatech STUDY).* Munich: Herbert Utz Verlag. (https://en.acatech.de/publication/industrie-4-0-maturity-index-managing-the-digital-transformation-of-companies/)
6. H. Kagermann, (2014). *Change Through Digitization—Value Creation in the Age of Industry 4.0*. Management of Permanent Change, 23–45. (doi:10.1007/978-3-658-05014-6_2)
7. H. Lasi, P. Fettke, H.-G. Kemper, T. Feld, M. Hoffmann, (2014). *Industry 4.0*. Business & Information Systems Engineering, 6(4), 239–242. (doi:10.1007/s12599-014-0334-4)
8. L. Urciuoli, J. Hintsa, J. Ahokas, (2013). *Drivers and barriers affecting usage of e-Customs — A global survey with customs administrations using multivariate analysis techniques*. Government Information Quarterly, 30(4), 473–485. (doi:10.1016/j.giq.2013.06.001)
9. S. Vaidya, P. Ambad, S. Bhosle. (2018). *Industry 4.0 – A Glimpse*. Procedia Manufacturing, 20, 233–238. (doi:10.1016/j.promfg.2018.02.034)
10. J. M. Müller, D. Kiel, K-I. Voigt. (2018). *What Drives the Implementation of Industry 4.0? The Role of Opportunities and Challenges in the Context of Sustainability*. Sustainability, 10(1), 247. (doi:10.3390/su10010247)

11. T. Stock, M. Obenaus, S. Kunz, H. Kohl. (2018). *Industry 4.0 as enabler for a sustainable development: A qualitative assessment of its ecological and social potential*. Process Safety and Environmental Protection, 118, 254–267. (doi:10.1016/j.psep.2018.06.026)
12. S-V. Buer, J. O. Strandhagen, F. T. S. Chan. (2018). *The link between Industry 4.0 and lean manufacturing: mapping current research and establishing a research agenda.* International Journal of Production Research, 56(8), 2924–2940. (doi:10.1080/00207543.2018.1442945)
13. I. D. L. Bogle. (2017). *A Perspective on Smart Process Manufacturing Research Challenges for Process Systems Engineers*. Engineering, 3(2), 161–165. (doi:10.1016/j.eng.2017.02.003)
14. M. W. Waibel, L. P. Steenkamp, N. Moloko, G. A. Oosthuizen. (2017). *Investigating the Effects of Smart Production Systems on Sustainability Elements*. Procedia Manufacturing, 8, 731–737. (doi:10.1016/j.promfg.2017.02.094)
15. J. Zhu, Z. Zhang, A. Lee, Y. Hua. (2019). *Measurement and analysis of corporate operating vitality in the age of digital business models*. Applied Economics Letters, 27(7), 511–517. (doi:10.1080/13504851.2019.1637511)
16. A. Rojko. (2017). *Industry 4.0 Concept: Background and Overview*. International Journal of Interactive Mobile Technologies (iJIM), 11(5), 77. (doi:10.3991/ijim.v11i5.7072)
17. Y. Liao, F. Deschamps, E. de F. R., Loures, L, F. P. Ramos. (2017). *Past, present and future of Industry 4.0 - a systematic literature review and research agenda proposal*. International Journal of Production Research, 55(12), 3609–3629. (doi:10.1080/00207543.2017.1308576)
18. V. Roblek, M. Meško, A. Krapež. (2016). *A Complex View of Industry 4.0*. SAGE Open, 6(2), 215824401665398. (doi:10.1177/2158244016653987)
19. K. Markov, P. Vitliemov. (2020). *Logistics 4.0 and supply chain 4.0 in the automotive industry.* IOP Conference Series: Materials Science and Engineering, 878, 012047. (doi:10.1088/1757-899x/878/1/012047)
20. A. Ghadge, M. Er Kara, H. Moradlou, M. Goswami. (2020). *The impact of Industry 4.0 implementation on supply chains*. Journal of Manufacturing Technology Management, 31(4), 669–686. (doi:10.1108/jmtm-10-2019-0368)
21. O. Bongomin, G. Gilibrays Ocen, E. Oyondi Nganyi, A. Musinguzi, T. Omara. (2020). *Exponential Disruptive Technologies and the Required Skills of Industry 4.0*. Journal of Engineering, 2020, 1–17. (doi:10.1155/2020/4280156)