Environmental Aspects in Production in the Context of Industry 5.0

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Abstract The paper is focused on comparing the elements of the industrial revolution Industry 4.0 and Industry 5.0. It mainly focuses on one of the elements of Industry 5.0, namely sustainability, or environmental protection using the elements and technologies of the fourth industrial revolution. The main goal is a theoretical analysis of the concept of Industry 5.0 in comparison with the elements of the fourth industrial revolution with a focus on environmental aspects in production. Based on the theoretical analysis, we selected two environmental aspects of production for research, the level of implementation of which we compared between the V4 countries. One aspect was the production rate of zero-emission vehicles and the second aspect was the level of waste production. As a result of the research, we found that Hungary, as one of the V4 countries, achieves the best results in both selected environmental aspects based on data from the EU Statistical Office. Based on the theoretical analysis, we also found that the new concept of the industrial revolution Industry 5.0 complements the elements of Industry 4.0 and thus there is a certain synergy between the machine, man and nature. Therefore, the new concept of Industry 5.0 is important for future studies, especially from the point of view of increasing awareness of environmental protection.

Keywords: Industry 5.0, Environmental Aspects, Sustainability.

JEL classification: *O32, Q55*

1 Introduction

The trend of sustainability, greening, the implementation of green elements in production and the overall emphasis on environmental protection have become one of the most important and most frequently discussed topics in recent years. It is not just a whim, but above all a growing, even alarming, situation regarding the need to protect the environment. The large amount of emissions, the increasing waste in landfills, the misuse of natural resources, the reduction of biodiversity, climate change and many

others are resulting in the deterioration of our planet and the emergence of a problem of a global nature.

It is precisely the negative changes in climate on a global scale that have raised the interest of both consumers and producers to ensure sustainability of production or environmental protection (Leong et al., 2019). Many countries and international institutions have the same interest, support, in this so-called green trend. Several countries have, for example, developed specific plans and programs within the framework of the European Union's environmental policy. They regulate the level of environmental pollution or promote the use of ecological innovations and solutions in the processes of greening (Wysocki, 2021).

As a result of the current environmental challenges, many companies are beginning to address the environmental impacts of their products and production processes in addition to economic considerations (Linke et al., 2012). The implementation of green features and eco-innovations not only results in the mitigation or elimination of environmental pollution for companies, but also in gaining a certain competitive advantage. In the same way, consumers are becoming increasingly responsible and considering the wider impacts of their purchases. Thus, eco-innovations represent an ideal solution to help businesses meet both economic and environmental goals (Wysocki, 2021).

1.1 Current status of the issue at home and abroad

The growth in the level of automation and digitization of business areas, or the implementation of elements and dynamic development of technology as a result of the Fourth Industrial Revolution, has led to a certain dehumanization of industry - from the perspective of man and nature. This is also why there has been an increased interest and awareness of the aspects of industrial humanization and sustainability (Grabowska et al., 2022).

Industry 4.0 is, above all, about automation and streamlining processes related to real-time information exchange, new technologies, cloud solutions, smart factory and many more. Its focus is therefore on effective process improvement, including the mass use of machines, but this inadvertently ignores the human costs of process optimization. The world, too, has seen a huge increase in environmental pollution in recent years. Unfortunately, Industry 4.0 does not make environmental protection a priority, nor is it the primary goal to create technologies that focus on improving the environmental sustainability of the Earth. (Nahavandi, 2019)

As a result of the continuous development of industry and technology in the context of Industry 4.0, individual methods and ways of progress are later analyzed retrospectively and examined scientifically. Any shortcomings in the development to date are revealed, or mistakes are made which, if eliminated, can be used to increase overall prosperity and sustainable production. In the context of the new concept of development, Industry 5.0 highlights the significant advances brought about by the Fourth Industrial Revolution, in the form of automation, digitalization or robotization, focusing on those activities that support economic growth, sustainable development or climate strategies in the form of environmental protection (Majerník et al., 2022).

Dautaj and Rossi (2022) state that Industry 5.0 is more focused on human quality of life. The primary goal of Industry 5.0 is to achieve a kind of synergy (cooperation, compatibility) between man, machine, robot and nature, i.e. the environment, with an emphasis also on the social side, through the elements of smart industry and elements of Industry 4.0 (Majerník et al., 2022). We could say that Industry 4.0 is technology-based, whereas Industry 5.0 is more value-based (Xu et al., 2021).

Thus, Industry 5.0 could be defined as an environment that complements, complements the concept of Industry 4.0. Within this environment, all activities are interconnected and contain a human-centred perspective. As mentioned above, Industry 4.0 is characterized by the depiction of the factory, which does not attach much importance to the role of the human worker, but predominantly to machines. Industry 5.0, on the other hand, is more focused on humans and their contribution to the whole industrial process, including the highlighting of human creativity. Its main task is to increase efficiency, focus on sustainability and involve humans more in the production process, which on the one hand will foster the creativity of each human individual and in the same way will move from mass production to mass personalization (Dautaj & Rossi, 2022).

One of the main challenges of Industry 5.0 is to design smart environments that are human-centric. This is a challenge where human well-being is prioritized, but in such a way that production efficiency is also maintained. This is the so-called collaboration of robots and humans who will work together to achieve the same, common goals and share the same space (Coronado et al., 2022).

The rising trend of robotization into business processes under the influence of the fourth industrial revolution (Industry 4.0), confirms the fact that investments in industrial robots are on the rise. This claim was made by the International Federation of Robotics (Heer, 2018) on its website, based on a study where, compared to 2013 and 2017, the global sales of robots increased by up to twice as much. The International Federation of Robotics (IFR) highlights many cutting-edge technologies, such as the very concept of human-machine collaboration (we refer to the term collaborative robots) or simple programming, which can help to optimize and improve the productivity of production. It is robotic automation, in the concept of collaborative robots, that IFR believes is good in that robots work with human workers instead of replacing them. Thus, we could say that collaborative robots represent a certain concept that incorporates both an element of the so-called "human touch" and, at the same time, a high quality of the production process is ensured.

The new development concept of Industry 5.0 includes the challenge of creating highly developed systems that are efficient for all participants in society and thus help to provide optimal solutions in the human-nature-machine relationship. That people would be at the center of each transformation, along with technological development, while taking care of sustainability (De Felice & Travaglioni & Petrillo, 2021).

As stated by the European Parliament Portal (2005) in its resolutions on the environmental aspects of sustainable development, there is a need to innovate and invest in innovations in technologies that are more environmentally friendly. It also stresses that innovation in environmental technologies is an important driver for sustainable development.

It is sustainability, as one of the elements of Industry 5.0, that is important for environmental protection. Industry 5.0 is about building more sustainable technological workplaces and processes through elements of the Fourth Industrial Revolution such as digitalization, robotics, artificial intelligence. A key element, as well, is the environmentalization of the economy through the implementation of technologies and best practices that are environmentally friendly or the creation of products that are environmentally friendly (Majerník et al., 2022).

Based on the above findings, we could conclude that the new concept of Industry 5.0 in a way develops Industry 4.0, which is mainly based on technological innovation, smart factories and so on. The various elements of Industry 4.0, such as digitalization, virtual reality, Big Data, Internet of Things and so on (Alvarez-Aros & Bernal-Torres, 2021), are developed by the fifth industrial revolution, complemented and, through them, strive to meet the environmental objectives set. This is due to the increase in the need to protect the environment. It also focuses on people, human labor and human creativity. It focuses on the overall humanization of industry, and also on how humans (as a human factor) can enrich the various elements of Industry 4.0 in meeting corporate objectives.

1.2 Aim of the paper and methods used

The main aim of the paper was a theoretical analysis of the concept of Industry 5.0 in comparison with the elements of the fourth industrial revolution with a focus on environmental aspects in manufacturing. As a result, two environmental aspects in manufacturing were selected and the degree of their implementation was compared among the V4 countries in the context of Industry 5.0. The V4 (Visegrad 4) countries include Slovakia, the Czech Republic, Hungary and Poland.

In order to meet the main aim we have chosen the following sub-aims:

1. To analyze the information and knowledge of the authors concerning the concepts of Industry 4.0 and Industry 5.0, their mutual comparison with a focus on the environmental aspect of Industry 5.0.
2. To specify and characterize the environmental aspects of manufacturing in the context of Industry 5.0 in the V4 countries based on data from the statistical office.
3. To summarize and interpret the findings on individual environmental aspects in manufacturing in the V4 countries, to compare them and then to formulate conclusions.

The process of elaboration of the paper consisted in a detailed analysis and formulation of the main objective and then the definition of individual sub-objectives, which are based on the main objective and condition its fulfilment. Within the scope of the studied issue regarding the Industrial Revolution Industry 5.0, we have processed a sufficient amount of information from the latest available scientific impact journals (WoS and SCOPUS), electronic sources from several authors and data from statistical offices. We analyzed the information in detail and later synthetically linked it into a coherent paper. The next step was to determine the research methods we used in the paper to achieve the main objective. In the final part of the paper, we chose two environmental aspects in manufacturing whose level and degree of implementation we compared in the V4 countries. We summarized the obtained results in the end and

formulated some conclusions based on the theoretical study carried out and the results found.

In order to obtain, concretize, summarize and interpret the latest knowledge on the concept of Industry 5.0 and environmental aspects in manufacturing, we used the following theoretical methods, such as synthesis method, analysis method, induction, comparison and visualization. Through the analysis method, we have thoroughly researched the issue at hand and collected sufficient domestic and foreign literature from various authors to gain an extended overview of the subject. We have defined key concepts and synthetically combined the findings into a coherent whole. In the final section, we compared the collected data and information with each other and combined them into a coherent whole through the method of induction. The method of visualization was used in the graphical processing of the data obtained from the available databases of the statistical offices.

2 Research results and discussion

In terms of the theoretical analysis carried out on Industry 5.0, we can conclude that one of the main areas addressed by the concept of the fifth industrial revolution is the creation of a cleaner environment in the form of environmental protection. That goal can be achieved through the creation of a symbiosis between nature and technological development (Coronado, 2022). As a result of environmental protection and the introduction of greener principles into businesses, we often come across the term - environmental aspect.

Environmental aspects are defined by the ISO 14001 standard as the different parts of activities, products or services that are generated in a company and also affect the environment. However, their impact can be either positive or negative, depending on the extent of their environmental impact. As the iso-tsu.sk portal states, most of the time, or it is assumed that the impact will be negative. In an enterprise, it is necessary for the management to define the individual environmental aspects, their degree and their impacts on the environment. Among the environmental aspects we can include, for example, unwanted products in processes, various accidents disasters, suppliers, complaints and many others.

In order to compare the results of the analytical study, we have chosen the following two environmental aspects in manufacturing:

1. Production of zero emission vehicles.
2. Waste production.

2.1 Production of zero emission vehicles

As a first environmental aspect in production, we have mentioned the production of zero-emission vehicles for the V4 countries.

The EU statistics office, Eurostat.eu, lists this aspect as one of the indicators of the share of zero-emission vehicles in newly registered passenger cars. Zero-emission cars

thus do not release any direct exhaust gases into the air, thus saving the environment. This category includes hydrogen fuel cell vehicles and also battery electric vehicles.

Based on the data available in the Eurostat statistical databases, we have produced the graph shown in Figure 1, which presents the production rate of zero-emission vehicles in the V4 countries. The input data are given in percentage increments of newly registered passenger cars.

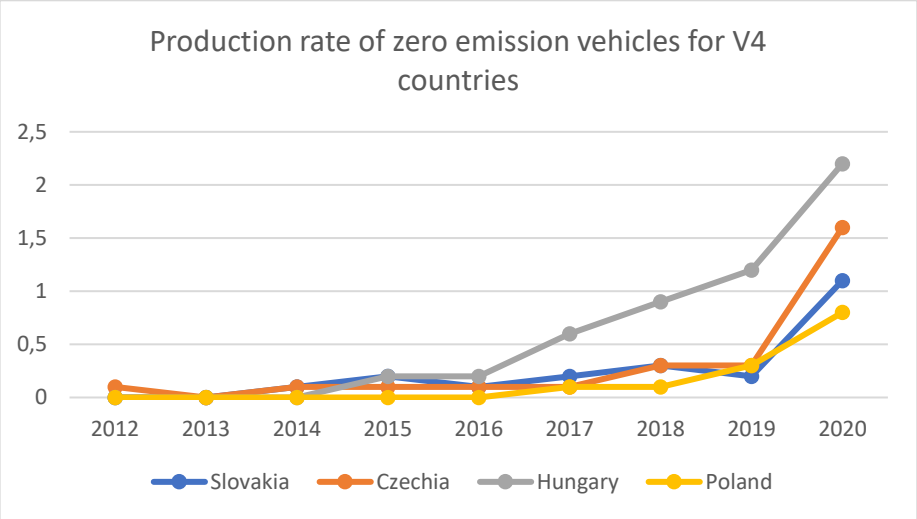

Fig. 1 Production rate of zero emission vehicles for V4 countries as a percentage of vehicles sold.

Figure 1 presents the rate of newly registered zero-emission vehicles. As can be seen, among the V4 countries, Hungary has the largest share, with a vehicle production rate that increased by up to 2.2% in 2020, which represents the largest increase among the V4 countries over the period under review. On the other hand, Poland had the smallest percentage, with 0.8%, a difference of up to 1.4% compared to Hungary.

The increasing trend of this environmental aspect is also confirmed by a study carried out on the 2030 Agenda published by the Statistical Office of the Slovak Republic (2019), which shows that the number of CO2 emissions produced by new passenger cars has decreased compared to 2007. This is even in all V4 countries, including Poland. As for the biggest decrease, it was recorded in the Czech Republic, where the decrease was up to 19.4%, followed by Hungary with a decrease of 18.1% and finally Poland and Slovakia.

The rate of production of zero-emission vehicles, and the associated decline in CO2 emissions produced from new passenger cars, confirms the concern for environmental protection. New technologies for vehicle production can contribute to sustainable development and production.

2.2 Waste production

The second environmental aspect of production in the context of Industry 5.0 was the level of waste production in the V4 countries.

In the framework of the 2030 Agenda for Sustainable Development, which was developed by all UN member states, representatives of the business community, the civil sector and members of the academic community, one of the targets or indicators is the production of waste, excluding mineral waste. In order to ensure sustainable production and consumption, it is necessary to create fundamental changes in waste management, since it is the amount of waste produced that represents a significant loss of resources in the form of materials and energy.

As stated by Eurostat (2020), waste disposal can cause serious impacts and environmental problems. As an example, they cite landfill, where it takes up a large amount of space and can therefore cause pollution of soil, water and air, and at the same time, the burning of waste can introduce harmful emissions into the air. It is also a long-term policy objective to reduce the amount of waste generated and to achieve higher levels of waste recycling.

Based on the available statistical data on waste generation in the European Union countries, as reported by Eurostat, we have produced the graph shown in Figure 2. Specifically, we have selected only data relating to the V4 countries. The input figures are given in kilograms per capita. The Eurostat collects the data every two years. The present graph presents the evolution of waste generation for each V4 country individually between 2008 and 2018.

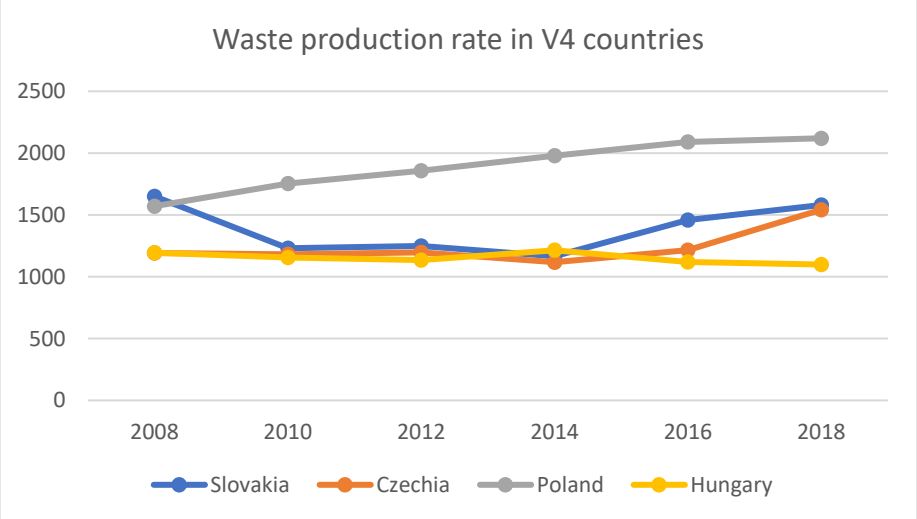

Fig. 2 Waste production rate in kilograms

Based on Figure 2 above, we could conclude that the environmental aspect, the waste generation rate, has a predominantly upward trend, which in this case is not a very good indicator. The only country within the V4 countries whose curve has a decreasing

character is again Hungary. We can see that compared to 2014 the waste generation rate has decreased, namely by 115 kilograms. We can also see that the waste generation rate in Poland was already high right at the beginning of the period under review, namely in 2008. For Slovakia, we can see a significant decrease in waste generation right at the beginning of the period under study, namely from 2008 to 2010, when it dropped from a production of 1650 kg to 1230 kg.

The results achieved in the research are confirmed by the study conducted on the 2030 Agenda published by the headquarters of the Statistical Office of the Slovak Republic (2019), which states that as of 2016, an increase in waste generation was recorded in two V4 countries, Poland and the Czech Republic, and in Poland even by 33%. However, in terms of waste recycling rates, we can observe the highest increase since 2010 in the Czech Republic, where it has increased by up to 10 percentage points.

2.3 Analysis of research results in the context of Industry 5.0 and discussion

On the basis of the above results, we could conclude that among the V4 countries, Hungary achieved the best results. Compared to the other three countries, it achieved the highest values in our selected environmental aspects. As regards the production rate of zero-emission vehicles, there was an increase of up to 2.2% compared to the previous year. In terms of waste production, it had a decrease of 420 kg per capita compared to the previous year.

The action plan for the circular economy, presented by the European Commission in Brussels in March 2020, also speaks of the need to introduce new sustainable and more ecologically acceptable solutions. It represents one of the main pillars of the European Green Deal - the new European program for sustainable growth. It represents several measures throughout the entire life cycle of products and focuses on an ecological future. One of the measures is to reduce the production of waste in electronics and ICT. The emphasis is on extending the life of products through the modernization of individual components or reusability.

As the portal GX Solutions (2021) reports, technologies that bring automation and electronization have also entered waste management. The transfer of data and technologies to waste collection increases the efficiency of waste management and the quality of services provided. The essence of mass collection is that the consumer only pays for what he throws away. And that motivates people to environmental behavior. Digitization of containers, electronic waste collection, monitoring and planning are possible through GPS and RFID technologies.

We also meet ecological goals in the automotive industry. Many car companies have developed production programs and plans aimed at reducing or eliminating CO2 emissions. For example, Toyota is one of the pioneers for zero-emission vehicles. It has developed a strategy for when it wants to achieve climate neutrality by 2050. The goal of this strategy is to help customers choose technologies that are more environmentally friendly (touchIT, 2022).

Based on the data obtained from the EU Statistical Office, we could conclude that the environmental aspect we investigated, the production of vehicles with zero emissions, had an upward trend in all V4 member states. This means that interest in

environmental protection is growing, which is also supported by automobile companies with their ecological plans regarding the production of vehicles with zero emissions.

Worse results in terms of environmental protection among the V4 member states were achieved in the second investigated environmental aspect – waste production. The curve should have a downward trend. However, only the waste production curve in Hungary had a decreasing character. This may be due to the fact that the strategic plans of car companies regarding the protection of the environment were developed before the plans for the elimination of waste.

3 Conclusion

Within the framework of the Industry 5.0 concept, we have focused on one of the main elements that differentiate it from, or complement, Industry 4.0, and that is environmental protection. Not only the V4 Member States, but also other countries are affected by the need to introduce eco-friendly and sustainable innovations. The level of implementation of ecological elements in business processes is certainly influenced by the legislation and developed programs of each country within the framework of the Sustainable Development Goals (Wysocki, 2021).

Industry 5.0 is a relatively new concept of industry, which complements and develops elements of Industry 4.0, such as digitalization, automation, smart factory, Big Data, etc., In cooperation with them, it is mainly oriented towards environmental protection, environmental innovation and value creation in the form of social orientation, focusing on people, their needs, creativity. The main objective is to create sustainable principles in production and development using elements of technological development.

The concept of the fifth industrial revolution represents a kind of synergy between machine (technology), man and nature. While Industry 4.0 could be described as technological, Industry 5.0 is more value-based. These are values, such as economic growth, sustainable development or climate strategies in the form of environmental protection, as well as the social side, the orientation towards the humanization of industry and the emphasis on the value of humans in achieving corporate goals in collaboration with technology.

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References

1. Agenda 2030. https://agenda2030.statistics.sk/Agenda2030/na-uvod/, last accessed 2022/06/01.
2. Alvarez-Aros, E., Bernal-Torres, C.: Technological competitiveness and emerging technologies in industry 4.0 and industry 5.0. Engineereing Sciences. 93 (1), (2021).
3. Coronado, E et al.: Evaluating quality in human-robot interaction: A systematic search and classification of performance and human-centered factors, measures and metrics towards an industry 5.0. Journal of Manufacturing Systems. 63, pp. 392-410 (2022).
4. Dautaj, M., Rossi, M.: Towards a New Society: Solving the Dilemma Between Society 5.0 and Industry 5.0. In Canciglieri Junior, O., Noël, F., Rivest, L., Bouras, A. (eds) Product Lifecycle Management. Green and Blue Technologies to Support Smart and Sustainable Organizations. PLM 2021. IFIP Advances in Information and Communication Technology, Springer, Cham. 639, pp. 523 – 536 (2021).
5. De Felice, F., Travaglioni, M., Petrillo, M.: Innovation Trajectories for a Society 5.0. Data MDPI. 6 (11), 1–30 (2021).
6. European Comission. https://ec.europa.eu/commission/presscorner/detail/en/ip_20_420, last accessed 2022/10/15.
7. European Parliament. https://www.europarl.europa.eu/doceo/document/TA-6-2006-0020_SK.html, last accessed 2022/05/30.
8. Eurostat. https://ec.europa.eu/eurostat/cache/egd-statistics/, last accessed 2022/06/03.
9. Grabowska, S., Saniuk, S., Gajdzik, B.: Industry 5.0: improving humanization and sustainability of Industry 4.0. Scientometrics. Springer (2022).
10. GX Solutions. https://gxsolutions.sk/2021/09/14/smart-odpady-mnozstvovy-zber-novej-generacie-automatizacia-zberu-odpadu/, last accessed 2022/10/15.
11. Heer, C.: Global industrial robot sales doubled over the past five years – IFR reports. https://ifr.org/downloads/press2018/2018-10-18_Press_Release_IFR_WR_2018_Industrial_Robots_ENG.pdf, last accessed 2022/05/24.
12. ISO-STU. https://www.iso-tsu.sk/novinky/41-iso-14001-environmentalne-aspekty-vplyvy, last accessed 2022/05/24.
13. Leong, W. D. et al.: Lean and Green Manufacturing - a Review on its Applications and Impacts. Process Integration and Optimization for Sustainability 2(1), 5–23 (2019).
14. Linke, B. et al.: Establishing Greener Products and Manufacturing Processes. International Journal of Precision Engineering and Manufacturing 13 (7), 1029–1036 (2012).
15. Majerník, M. et al.: Sustainable Development of the Intelligent Industry from Industry 4.0 to Industry 5.0. Advances in Science and Technology Research Journal 16 (2), 12–18 (2022).
16. Nahavandi, S.: Industry 5.0-A Human-Centric Solution. Sustainability 11 (16), 1 – 13 (2019).
17. Štatistický úrad Slovenskej republiky: Krajiny Vyšehradskej skupiny. Vybrané indikátory udržateľného rozvoja Agendy 2030. 54 p. (2019).
18. Štatistický úrad Slovenskej republiky: Slovenská republika a ciele udržateľného rozvoja Agendy 2030. Bratislava, 129 p. (2016).
19. TouchIT. https://touchit.sk/toyota-nadalej-investuje-do-rozvoja-dopravy-s-nizkymi-a-nulovymi-emisiami/441231, last accessed 2022/10/15.
20. Xu, X. et al.: Industry 4.0 and Industry 5.0-Inception, conception and perception. Journal of Manufacturing Systems. New Zealand: The University of Auckland 61, 530 – 535 (2021).
21. Wysocki, J.: Innovative Green Initiatives in the Manufacturing SME Sector in Poland. Sustainability 13 (4), 1–20 (2021).