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TECHNICAL ONLY? THE IMPORTANCE OF SELECTED COMPETENCES OF MANAGERS AND ENGINEERS IN INDUSTRY 4.0

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Purpose: The aim of the study was to determine which engineering and managerial competences are of high importance in enterprises operating in accordance with the assumptions of Industry 4.0.
Design/methodology/approach: The MAXQDA tool was used to analyze the acquired information, generating structured data clouds.
Findings: As a result, soft skills turned out to be the most important competences, mainly related to effective interpersonal communication, systematic learning and adaptation to change, also in the technological area.
Research limitations/implications: Quantitative research on a larger sample would be needed to examine the links between specific factors on a set of competences and adaptability to changes in workers. If respondents were to be informed about the areas most affected by the impact of Industry 4.0, more extensive and detailed qualitative research would have to be carried out focusing on this issue.
Practical implications: The information obtained in the results of the research allows to emphasize the importance of soft skills in the catalog of those that are significant in Industry 4.0 enterprises. Thanks to this, the selection of training for employees can be more adapted to the actual needs of the company.
Originality/value: The analysis of literature sources allowed to see that the previous research focused on presenting the competences of engineers and managers in relation to individual areas of industry. The research results included in the publication are a list of the most important competences of these in enterprises 4.0. This allows you to understand the key elements influencing the development of the professional path of engineers and managers during the Fourth Industrial Revolution.
Keywords: engineering competence, managerial competencies, Industry 4.0.
Category of the paper: Research papier.

1. Introduction

The concept of industry is strongly connected with the technical and technological aspects of the functioning of enterprises. As a result, strong emphasis is placed on employees having this type of competence as key to the smooth functioning of a modern production company. The aim of the research was to identify those types of competences that are perceived as particularly important by management and engineers and to confront their set with the common goal of technological improvement in the context of Industry 4.0.

For this purpose, specific objectives have been defined which concern:

- define the universal competences that every employee should have,
- identify key engineering competencies in Industry 4.0,
- identify key managerial competencies in Industry 4.0,
- the impact of education on competences used at work,
- the impact of age on the ability to adapt to industrial change,
- the impact of seniority on the skills and ability to adapt to change.

A preliminary analysis of literature and online sources showed that the research so far focused on presenting the competences of engineers and managers in relation to particular areas of industry. However, the changes in the type of competence that take place with the development of industry are also important. This represents a significant limitation in understanding the key elements influencing the development of the professional path of engineers and managers during the Fourth Industrial Revolution. The study conducted by identifying the most important competences using a qualitative approach may be the basis for developing a catalog of key ones.

The first formulation of the term Industry 4.0 appeared in Germany in 2011 during the international Hannover Messe and referred to the high-tech strategy undertaken by the German government (Silva, Barriga, 2020). Today, Industry 4.0 refers to the Fourth Industrial Revolution and its beginning is considered the second decade of the 21st century (Gonzalez, Gasco, Llopis, 2024)

2. Understanding concepts and changes in them

2.1. Industry 4.0

The definitions available generally define Industry 4.0 as a concept, strategy or set of changes that must be made in a company to improve performance (Kagermann et al., 2013; Lasi et al., 2014; Hermann et al., 2016; Gracel et al., 2017, 2018; Wyrwicka, Mrugalska, 2017; Ślusarczyk, 2018; Philbeck, Nicholas, 2018; Chou, 2018; Rossit, Tohmé, Frutos, 2019; Savage,

2022). The changes concern the technological base and organization of the company, and result from the development of new technologies. The term Industry 4.0 is a new way of doing business that focuses on automation and digitalization of manufacturing processes. The use of new technologies related to storage, processing and acquisition of data, among others by intelligent machines, affects the way the company operates and the necessary competences of employees. The impact of Industry 4.0 on the organization of work results from the support of human physical labor or its complete takeover by machines (Lasi et al., 2014).

2.2. Competence

Competencies can be understood in a very ambiguous way, although the term refers to three distinct trends related to employee performance, expected labor standards and attributes of the individual (Lacatan, Penuliar, 2021). The ways of understanding cited in particular trends explain competences in a narrower way as knowledge, experience, abilities, predispositions and skills required and used in the workplace (Terkowsky, Frye, May, 2019) or the characteristic elements, features - motives, skills, self-image, ways of using knowledge (Boyatzis, 2008). In a broader sense, they are presented as a combination of elements such as employee qualities, skills, abilities, knowledge, experience and sense of responsibility, which make up the ability to achieve the expected, satisfactory result of the work entrusted to him (Dubois, Rothwell, 2008).

The basic division of competences involves distinguishing them between social skills and skills necessary for the performance of the work, i.e. soft and hard skills respectively. Soft competence refers to those qualities that are responsible for interpersonal relations, i.e. communication, emotional and social skills. They are a set of conditions that determine how an individual behaves in different situations. Hard competences, also referred to as basic competences, are those that determine the ability to perform work in a given position. The difference between hard and soft is that they are measurable and concrete, i.e. verifiable (Souza, Debs, 2023). Hard competences include substantive knowledge and specialist skills that enable a good performance of the entrusted task (Dohertya, Stephens, 2023).

2.3. Engineering competence

The basis of the competence of Engineer 3.0 is his extensive technical knowledge, knowledge of the rules and adherence to standards and performance of work with high quality. The competencies attributed to 3.0 engineers are mainly hard, process and technology-related. The technical knowledge of Engineer 4.0 will have to concern not only the specifics of the production process supported by him. Expectations for 4.0 engineers will require them to take a broad view of the functioning of the company as a whole and understand the links between processes. It is anticipated that every such employee will need to know the basics of cyber security, the importance of which is growing strongly in modern companies (Gracel et al.,

2017). In the era of the Fourth Industrial Revolution, engineers are required to have extensive technical knowledge and knowledge of advanced technologies (Grabowska et al., 2022).

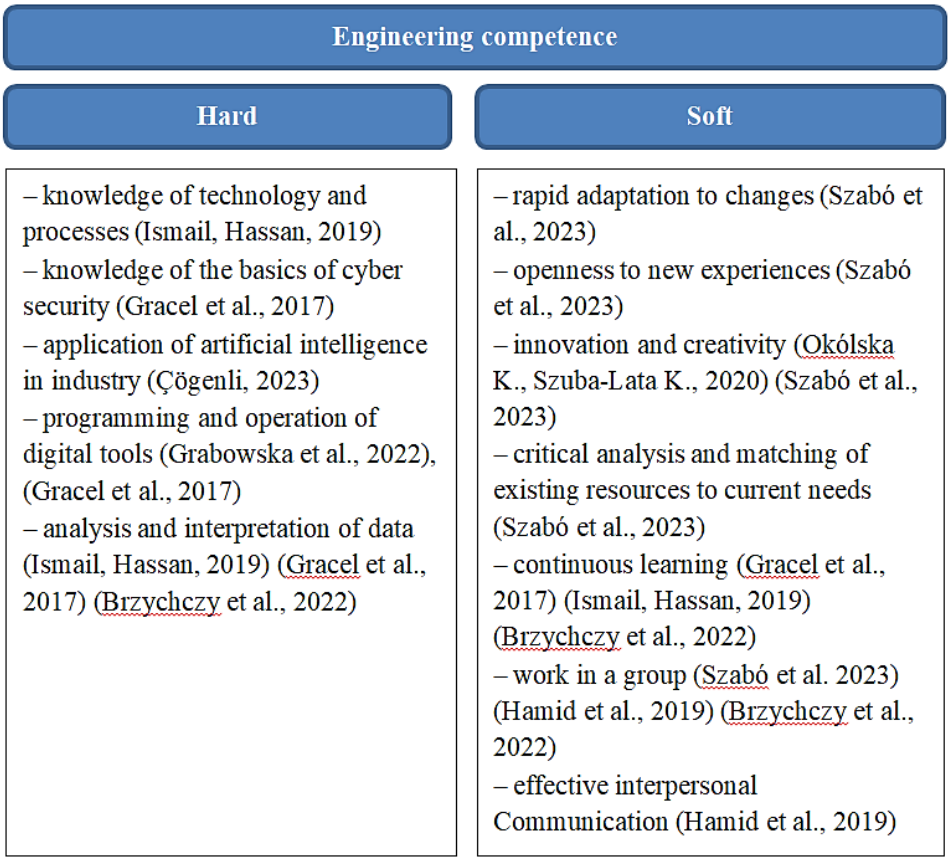

Figure 1. Summary of Engineering Competencies.

Source: own study based on: Ismail, Hassan, 2019; Gracel et al., 2017; Çögenli, 2023; Grabowska et al., 2022; Brzychczy et al., 2022; Szabó et al., 2023; Okólska, Szuba-Łata, 2020; Hamid et al., 2019).

The basic feature among the required competencies of 4.0 Engineers is the increased emphasis on soft skills, once considered "non-engineering" (Szabó et al., 2023). This is due to changes in the labor market caused by the dynamic development of available technologies. Employers pay attention to the soft skills exhibited by employees, because they influence adaptation to the working environment (Fletcher, Thornton, 2023). That is why the characteristic feature of Engineer 4.0 is openness to change. Other soft skills valued by employers in relation to modern engineers are: ability to work in a group, ability to solve problems, willingness to learn, communication skills, time management, flexibility (Fletcher, Thornton, 2023; Gracel et al., 2017). A set of engineering competencies is presented in Fig 1.

2.4. Managerial competence

4.0 managers are required to have the same competencies as managers in management positions also during the Fourth Industrial Revolution: managing people, project teams, and communicating effectively. Additional competences required by modern managers are those that support the development of not only the company, but also employees,

i.e. communication skills, openness to change, innovation, undertaking new ventures and highly developed technical competences (Gracel, Makowiec, 2018). Other soft skills that are new among the desired managerial competences mentioned by the authors are: recognition of talents, ability to set the path of development and the ability to transfer knowledge (Fig. 2).

Figure 2. Summary of Managerial Competencies.

Source: own study based on: Fletcher, Thornton, 2023; Szabó et al., 2023; Gracel, Makowiec, 2018; Torres et al., 2023; Ribeiro et al., 2021; Więcek-Janka et al., 2023.

4.0 managers face many new challenges in managing a team. Employees become more independent, change jobs more often, have a better education. This increases the focus on the way the manager works, which in the company affects the quality of the work of subordinates through appropriate motivation and commitment (Fletcher, Thornton, 2023). A study conducted by Gracel and Makowiec (2018) confirms the need for continuous training of managers who are responsible for the performance of the company. The authors also emphasize the use of necessary hard skills, as well as the increasing importance of soft skills. The most important role of a manager in Industry 4.0 is to take care of the company and employees (Fletcher, Thornton, 2023).

3. Methodology

3.1. How to obtain information

The study was conducted at the turn of 2023 and 2024. The data were collected using in-depth individual interviews (IDI), the purpose of which is to obtain information on social phenomena and processes taking place in the studied environment by obtaining their description from a specific respondent selected on the basis of criteria specified by the researcher (Jakubowski et al., 2020). In particular, aspects such as:

- work in a manufacturing company,
- knowledge and work with elements of Industry 4.0,
- the title of engineer in the case of lower levels than managerial positions (for engineering competence),
- work in a managerial position or higher (for managerial competences),
- at least 2 years of professional experience.

The interviews were conducted with six people, two of whom were employed in managerial positions and four were engineers.

The study is exploratory. In order to provide comprehensive information obtained, two different approaches were used at the same time - deductive and inductive. With regard to the deductive approach, a preliminary analysis of scientific sources enables the familiarization and use of information obtained from previous studies, the results of which have been made available. The use of an inductive approach gives the opportunity to see and present innovative opinions of respondents. The combination of theoretical knowledge with individual experiences of professionally active engineers and managers allows for a comprehensive and possibly innovative development of a catalog of competences.

3.2. Research tool

The MAXQDA program is used for comprehensive qualitative analysis and interpretation of data in text, sound and video form. It works on the basis of a system supporting content analysis (CAQDAS - Computer-Assisted qualitative Data Analysis Software), and its interface is intuitive to use, which allows for effective use of data analysis tools. The program is versatile and supports a variety of file formats. One of its key functions is the ability to categorize and encode data fragments.

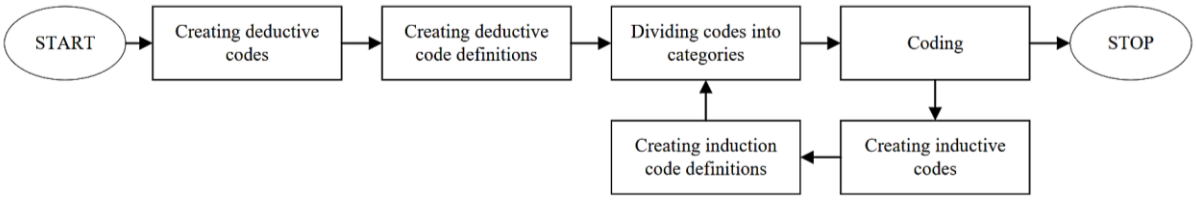

Figure 3. Code development process.

Source: own study.

Coding, the process of which is shown in Fig. 3, allows the systematic selection and grouping of relevant elements, facilitating the identification of the main themes and patterns in the analyzed material. The available solutions allow you to create and assign codes both before and during the analysis, as well as arrange them in a hierarchical way. The program enables deep code analysis through tools allowing to identify the relationships between them. Functions such as pattern search and generation of thematic reports enable organizing the data structure and directing the analysis in search of significant dependencies. The software offers advanced visualization tools such as code clouds, heat maps and diagrams. Graphical data presentations are available to help you understand and present your analysis results.

4. Results of the study

The data analysis was carried out using three code clouds created in MAXQDA program concerning respectively the competences of Engineer 4.0, the competences of Manager 4.0 and universal competences required of each employee. The generated code clouds contain managerial and engineering competencies separated by respondents. Prior to the beginning of the analysis of the interview transcripts, seventeen deductive codes with managerial competence and nine deductive codes with engineering competence were recorded based on a literature review.

As a result, three code clouds were developed. Two of them, concerning engineering and managerial competences, combine deductive codes (blue) with inductive codes (yellow), which allows to verify their occurrence in the daily professional practice of respondents. In contrast, the third cloud, which contains a compilation of universal skills codes for all employees, only presents inductive codes, since this aspect was not anticipated in the analysis at the literature review stage. The font size of each competency code indicates the relative frequency of its occurrence. As a result, the codes were ordered by the number of occurrences - from the largest to the smallest.

The number of appearances shows how many times in the interviews a competency has been encoded in a certain way. It is not limited by the number of interviews conducted or respondents, because during the interview interlocutors mentioned specific competences often several times. This is in line with the assumptions of conducting qualitative research using MAXQDA tool, where the results are based on the frequency of raising specific issues, which indicates their importance.

4.1. Engineering competence

The Engineering Competency Code Cloud (Fig. 4) consists of nine deductive codes (blue) and seven inductive codes (yellow). The most important, because the most often indicated by respondents, competence is the ability to constantly learn. It is understood as the ability and readiness to constantly acquire new skills, knowledge and to improve existing competences. It shows up primarily as participation in various activities organized by external entities, but also a high commitment to current company affairs and drawing experience from other employees.

Figure 4. Code cloud for engineering competencies.

Source: own study.

Taking into account the number of indications of a given code in interviews, another is a hard competence, which is technical knowledge. It is treated as a specific form of knowledge concerning the applications, operations and operating principles of technology, tools, machines, systems, or other technical fields. Related to it are computer skills relating to computer operation, use of software, hardware, as well as various information technologies.

Two other competences, which are mentioned as often in interviews, are effective communication and the ability to adapt to changes. Communication consists in the ability to effectively communicate information, establish contacts and communicate effectively with other people. It concerns both obtaining information from people employed in the company, drawing their attention to possible shortcomings, but also various types of contacts with people outside the organization, such as customers and suppliers. Both of these aspects require the ability to adapt and respond flexibly to new situations, new conditions or changing environments. In particular, respondents meet such requirements during the implementation of projects, implementation of technology or in the situation of the need to obtain information in areas that have not been explored before. The last three competences concern the introduction of changes in the processes implemented by enterprises, often related to the need to solve problems during which an appropriately empathic approach to their employees is necessary.

4.2. Managerial competence

In the managerial competence cloud (Fig. 5) there are fourteen deductive codes (blue) and six inductive codes (yellow). Taking as key amounts of indications of individual codes in interviews, it can be seen that the emphasis here is primarily on soft skills.

Type of competence	The name of the code	Number of instances
Soft	Effective communication	9
	Anticipating and responding to events	7
	Decision-making	6
	Continuous learning	6
	Teamwork	6
	Development planning	6
	Knowledge sharing	6

Figure 5. Code cloud for managerial competencies.

Source: own study.

The most frequently mentioned here is effective communication consisting in the effective transfer of information, establishing contacts and effective communication with other people. The ease of contact with others can be of particular importance in the ability to anticipate and respond to events. This requires the ability to analyze the environment in order to notice the possibility of different situations, events, problems and to take effective action when they occur. Obtaining information is therefore crucial here. They often form the basis for decision-making, which consists in choosing one of many possible solutions by the decision-maker. Communication skills, in turn, allow to explain the basis and objectives of decisions taken.

In the case of managers, continuous learning most often concerns methods of effective management of the human team, changes or familiarization with the possibilities of supporting their work by modern technologies. In principle, all skills indicated by respondents in relation to managerial competences are associated with effective teamwork. It means working with other team members to achieve common goals, effective communication, cooperation, division of tasks among team members and supporting other team members in the implementation of their tasks is necessary. This last element is related to the transfer of knowledge, i.e. the ability to teach others and create an atmosphere that encourages asking questions.

Support for team members is also often a form of assistance in setting the path of their development, i.e. defining the direction and goals of their career. It is manifested in the provision of training and other forms of training for employees, in particular in response to their ambitions and aspirations for development.

4.3. Universal competence

The analysis of the received answers allowed to generate a cloud of codes (Fig. 6) presenting universal competences, which in the opinion of the respondents should have every employee. Five soft skills are most often identified. Most of them are skills that were indicated by respondents also in the area of engineering and managerial competences. However, they are considered crucial for all employees, only their manifestations may be slightly different.

Code	Number of coded fragments		
	Universal competence	Engineering competence	Managerial competence
Openness and adaptability to change	4	8	3
Effective communication	3	8	9
Continuous learning	3	12	6
Teamwork	3	3	6
Diligence	3	0	0

Figure 6. Code cloud for universal competencies.

Source: own study.

The only universal competence that has not been mentioned by respondents in relation to the managerial or engineering catalog is conscientiousness. It is understood as accuracy, diligence, responsibility and reliability in the approach to work and performing tasks. This approach to the tasks performed is an expectation addressed to all employees regardless of the level in the hierarchy, education or position.

5. Summary/recommendations/plans for further research

The aim of the presented research was to develop a catalog of engineering and managerial competences expected at selected positions in manufacturing companies of Industry 4.0. The literature review made it possible to develop questionnaires of interviews, which were then carried out with employees of production companies, and to encode the deductive area.

In order to develop a catalog of required 4.0 engineers and managers of 4.0 competencies, a qualitative analysis was carried out using MAXQDA tool. The results of work in the program were generated clouds of code visualizing recognized as important competences.

The conducted analysis allowed to develop a catalog of engineering and managerial competences expected at the indicated positions in Industry 4.0. The obtained results of the study coincide significantly with the content presented by the authors cited in the literature analysis.

In the case of Manager 4.0 competencies, fourteen of the seventeen key skills listed were noted in the study participants. In addition, six competences were selected, which did not manifest as significant in the content of the analyzed publications. The developed Engineer 4.0 Competency Catalog contains nine skills selected from the literature review and is supplemented by seven more.

The information obtained in the course of the interviews allowed for partial fulfillment of the specific objectives. On their basis, the universal competences that each employee should have, key engineering competences in Industry 4.0 and key managerial competences in Industry 4.0 were defined. For the purposes of examining the impact of factors such as education, age and seniority on competence or adaptability to change, the respondents' responses were not clear and these objectives were therefore considered only partially achieved. Drawing up proposals would require more interviews and more information.

The answers of the respondents indicate the importance of soft over hard competences. Respondents say that technical knowledge can be acquired by anyone, and the most important is the ability to adapt to working conditions and find oneself in a team.

The respondents' opinions on dynamic changes in the required competences emphasize mainly the effects of the introduction of modern technologies forcing employees to acquire technical expertise and corresponding management methods. This includes skills such as

coping with stress or managing a team. The respondents' answers indicated three areas in which the biggest changes occur: the scope of managerial knowledge, the approach of employees to work and the scope of technical knowledge. However, the obtained results do not allow for detailed determination of the relation of dynamic changes to the given areas. Their development requires further research.

Some of the results obtained were not unambiguous or did not allow for a thorough understanding of the issue. This is due to the limitations of the research carried out. Quantitative research on a larger sample would be needed to examine the links between specific factors on a set of competences and adaptability to changes in workers. If respondents were to be informed about the areas most affected by the impact of Industry 4.0, more extensive and detailed qualitative research would have to be carried out focusing on this issue. Both of these aspects are treated as directions for future work.

References

1. Boyatzis, R.E. (2008). Competencies in the 21st century. *Journal of Management Development, vol. 27.*
2. Chou, S.-Y. (2018). The Fourth Industrial Revolution: Digital Fusion With Internet Of Things. *Journal of International Affairs, vol. 72.*
3. Çögenli, M.Z. (2023). *Organizational Behavior in the Digital World*. Nova.
4. Dohertya, O., Stephens, S. (2023) Hard and soft skill needs: higher education and the Fintech sector. *Journal of Education and Work, vol. 36.*
5. Dubois, D., Rothwell, W. (2008). *Competence-based Human Resource Management [Zarządzanie zasobami ludzkimi oparte na kompetencjach].* Helion.
6. Fletcher, S., Thornton, K.R.V. (2023). The Top 10 Soft Skills in Business Today Compared to 2012. *Business and Professional Communication Quarterly, vol. 86.*
7. Gonzalez, R., Gasco J., Llopis, J. (2024). Towards organisation 4.0. An empirical study. *International journal of information management, vol. 75.*
8. Grabowska, S., Grebski, W., Saniuk, S. (2022). Knowledge and Skills Development in the Context of the Fourth Industrial Revolution Technologies: Interviews of Experts from Pennsylvania State of the USA. *Energies, vol. 15*(7).
9. Gracel, J., Makowiec, M. (2018). Key competences of the Manager In the era of the Fourth Industrial Revolution – Industry 4.0 [Kluczowe Kompetencje Menedżera W Dobie Czwartej Rewolucji Przemysłowej – Przemysłu 4.0]. *Acta Universitatis Nicolai Copernici. Management, vol. 44.*
10. Gracel, J., Stoch, M., Biegańska, A., Rząca, A. (2017). *The Engineers 4.0. (No) Ready for change? [Inżynierowie 4.0. (Nie) gotowi do zmian?]*. Whitepaper.

11. Hermann, M., Pentek, T., Otto, B. (2016). Design Principles for Industrie 4.0 Scenarios. *49th Hawaii International Conference on System Sciences (HICSS).* IEEE.
12. Ismail, A.A., Hassan, R. (2019). Technical Competencies in Digital Technology towards Industrial Revolution 4.0. *Journal of Technical Education and Training, vol. 11.*
13. Jakubowski, J., Piontek, D., Stępińska, A. (2020). *International empirical Research on populist Political Communication – methodological and organizational challenges, Research on populist Discourse: Selected approaches, Scientific [Międzynarodowe badania empiryczne nad populistycznym komunikowaniem politycznym – wyzwania metodologiczne i organizacyjne, Badania nad dyskursem populistycznym: wybrane podejścia].* Publishing House of the Faculty of Political Science and Journalism.
14. Kagermann, H., Helbig, J., Hellinger, A., Wahlster, W. (2013). Recommendations for Implementing the Strategic Initiative INDUSTRIE 4.0: Securing the Future of German Manufacturing Industry. *Final Report of the Industrie 4.0 Working Group, Forschungsunion.*
15. Lacatan, L.L., Penuliar, G.M. (2021). Coompetency-Based Mapping Tool in Personnel Management System using Analytical Hierarchy Process. *ACM International Conference Proceeding Series, MLMI '21: Proceedings of the 2021 4th International Conference on Machine Learning and Machine Intelligence.*
16. Lasi, H., Fettke, P., Kemper, H.G., Feld, T., Hoffmann, M. (2014). Industry 4.0. *Business & Information Systems Engineering, vol. 6.*
17. Philbeck, T., Nicholas, D. (2018). The fourth industruial revolution: shaping a new era. *Journal of International Affairs, vol. 72.*
18. Rossit, D.A., Tohmé, F., Frutos, M. (2019). Industry 4.0: Smart Scheduling. *International Journal of Production Research, vol. 57, no. 12.*
19. Savage, G. (2022). *Industry 4.0 Is Here, Breaking down the Barriers to Industry 4.0 in the North.* Australian Strategic Policy Institute.
20. Silva, F.L., Barriga, G.D.C. (2020). Industry 4.0 Digital Strategy, and the Challenges for Adoption the Technologies Led by Cyber-Physical Systems in Proceedings. *25th International Joint Conference on Industrial Engineering and Operations Management – IJCIEOM.*
21. Ślusarczyk, B. (2018). Industry 4.0: Are We Ready? *Polish Journal of Management Studies, vol. 17.*
22. Souza de A.S.C., Debs, L. (2023). Identifying Emerging Technologies and Skills Required for Construction 4.0. *Buildings, vol. 13.*
23. Szabór, P., Mlkva, M., Marková, P., Samáková, J., Janík, S. (2023). Change of Competences in the Context of Industry 4.0 Implementation. *Applied Sciences, vol. 13.*
24. Terkowsky, C., Frye, S., May, D. (2019). Online engineering education for manufacturing technology: Is a remote experiment a suitable tool to teach competences for Working 4.0? *European Journal of Education, vol. 54.*

25. Więcek-Janka, E., Werner-Lewandowska, K., Radecki, A. (2023). Expert's Model of Managerial Competencies for Engineer 4.0 (EMMCE). *Management and Production Engineering Review, vol. 1(14).*

26. Wyrwicka, M.K., Mrugalska, B. (2017). *Industry 4.0 – Towards Opportunities and Challenges of Implementation.* 24th International Conference on Production Research.