ASSESSMENT OF THE LEVEL OF INDUSTRY 4.0 IMPLEMENTATION IN ORGANIZATIONS IN POLAND

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Introduction

Industry 4.0 is transforming organizations in the digital age by modernizing industrial operations through the use of advanced technologies (Cannavacciuolo et al., 2023). Poland is seen as a developing economic hub in Europe, which faces many challenges related to modernization and diversity in business (Wisła, Włodarczyk, 2021; Jałowiec, Wojtaszek, 2022). Despite the existence of global surveys assessing awareness and the level of implementation of Industry 4.0, they do not necessarily reflect the unique circumstances and challenges facing organizations in Poland, and may present different results due to the breadth over time (Cannavacciuolo et al., 2023).

Despite the awareness of Industry 4.0 concepts and technologies, this article attempts to delve deeper into the practical implementation of Industry 4.0 solutions in Polish organizations in the manufacturing sector. The research was conducted by focusing on research gaps in the context of differential awareness, and effective implementation and future prospects for implementing Industry 4.0 in Poland.

This article brings insight into the current state of Industry 4.0 implementation in Poland, highlighting challenges and opportunities for organizations. It addresses an important research gap by assessing the degree of adoption of Industry 4.0 in Polish organizations in the manufacturing sector. Understanding this scope is key to creating informed strategies and policies.

Filling this gap provides insight into readiness, challenges and potential areas of improvement, guiding policymakers, researchers and organizations toward effective support of technological progress and competitiveness.

Introduction to Industry 4.0: Technological revolution in manufacturing

The volatile business environment, rapid technological advancements, and intense global competition compel companies to continuously search for innovative strategies. The aim of these efforts is to achieve a competitive advantage by effectively utilizing changes and new opportunities (Rogozińska-Pawełczyk, 2022). The concept of „Industry 4.0" refers to the dynamic transformation of the industrial environment, where advanced manufacturing systems interact to change the way production is manufactured and managed (Bendkowski, 2017; Cellary, 2019).

In the context of analyzing scientific literature on Industry 4.0, diverse classification schemes of the pillars of this phenomenon are observed. Common denominators of these classifications can be identified as divisions into pillars such as: autonomous robots, augmented reality, simulations, additive manufacturing, information system integration, cybersecurity, Internet of Things, cloud computing, Big Data, and artificial intelligence (Erboz, 2017; Tay et al., 2018; Trzop, 2020; Vinitha et al., 2020; Dubey, et al., 2022). Table 1 presents the definitions of each of the pillars of Industry 4.0.

Table 1. Definitions of each pillar of Industry 4.0

Pillar	Definition
Automated Robotics	Devices programmed to perform tasks without human intervention.
Augmented Reality	Technology superimposing virtual objects onto the real world in real time.
Simulations	Process of modeling real systems for analysis or testing.
Incremental Manufacturing	Creating 3D objects by layering material based on a digital model.
Integration of Information Systems	Linking disparate systems into a functional whole.
Cybersecurity	Protecting computer systems, networks, and data from digital threats.
Internet of Things (IoT)	Network of physical objects with sensors exchanging data over the Internet.
Cloud Computing	Delivering computer resources over the Internet.
Big Data	Large and complex data sets analyzed for insights.
Artificial Intelligence	Creating algorithms for human-like tasks.

Source: own elaboration based on: Erboz, 2017; Tay et al., 2018; Trzop, 2020; Vinitha et al., 2020; Dubey et al., 2022; Wolniak, 2023

The technologies discussed in Table 1 can significantly affect operational efficiency and business competitiveness. However, it is worth noting that successful implementation of the pillars of Industry 4.0 requires not only significant capital investment, but also advanced expertise and organizational changes.

Methods

The aim of this article is to assess the level of implementation of Industry 4.0 in Polish organizations . Poland was chosen as the study area because of its leading position in terms of employment of the number of people in manufacturing companies (Grzeszczyk, Rybko, 2021). To conduct a detailed analysis and verification of the stated research objective, the following hypotheses have been formulated:

H1: Large organizations in Poland are more advanced in the implementation of Industry 4.0 than small and medium-sized organizations;
H2: The majority of organizations in Poland are aware of the existence of individual pillars of Industry 4.0;
H3: The majority of organizations utilize Industry 4.0 solutions at a good level;
H4: Most organizations intend to implement/develop Industry 4.0 solutions at a good level.

To confirm the hypotheses, a survey was conducted using a questionnaire based on a Likert scale. The survey was conducted in a group of 73 organizations in the manufacturing sector in Poland. The questionnaire was addressed to administrative employees of these organizations.

The research involves the analysis of 40 variables related to the functioning of Industry 4.0 in organizations. Based on a literature review, 10 pillars of Industry 4.0 were identified and subsequently examined (Erboz, 2017; Tay et al., 2018; Trzop, 2020; Vinitha et al., 2020; Dubey et al., 2022): Automated robots; Augmented reality; Simulations; Incremental manufacturing; Integration of information systems; Cyber security; Internet of Things; Cloud computing; Big Data; Artificial intelligence.

The examined sample cannot be considered representative. It included 16 microenterprises, 25 small companies, 27 medium-sized companies and five large companies.

As part of the analysis of the ten key components of Industry 4.0, a series of studies were conducted in which each of the mentioned components was evaluated based on a set of three structurally organized questions:

- Question 1 – Is the organization aware of the existence of this pillar?
- Question 2 – Does the organization utilize solutions from this pillar?
- Question 3 – Does the organization plan to implement/develop this pillar?

The answers to the above questions will help assess the awareness, use and planned implementation or development of the pillars of Industry 4.0.

Results

Conducting the survey allowed us to obtain results for further analysis. Table 2 presents the statistical coefficients for the 40 variables studied.

The study's hypothesis H2 posited that most organizations in Poland are aware of the individual pillars of Industry 4.0. This awareness was measured using question 1 for each pillar, i.3., variables: 1. The average familiarity level with these pillars exceeded 3.5, indicating good awareness. The study's results confirmed hypothesis H2. The surveyed organizations showed the highest awareness in cybersecurity (4.27) and artificial intelligence (4.16). Awareness levels for other Industry 4.0 pillars ranged from 3.5 to 4.0, with the lowest in additive manufacturing (3.53) and Big Data (3.64).

The next stage of the study addressed the use of Industry 4.0 solutions in the surveyed organizations. For this purpose, hypothesis H3 was formulated as follows: Most organizations are using Industry 4.0 solutions to a good degree. The implementation of Industry 4.0 in the surveyed organizations was covered in Question 2, which includes variables: 2. Among the surveyed organizations, the highest implementation level of Industry 4.0 solutions was in cybersecurity (4.08), followed by information system integration (3.67). The remaining eight pillars had medium-level implementation, with the lowest in augmented reality (2.62), artificial intelligence (2.78), and autonomous robots (2.85). The results of the study do not support hypothesis H3, which states that the majority of organizations utilize Industry 4.0 solutions at a good level. The study indicates that such a situation only occurs in the case of two pillars of Industry 4.0; for the remaining pillars, the current level of implementation can be described as medium.

Based on the literature analysis (Grzyb, 2017; Ślusarczyk, 2019), hypothesis H1 assumes that large organizations in Poland are more advanced in implementing Industry 4.0 than small and medium-sized organizations. To analyze the differences between variables, the non-parametric Kruskal-Wallis ANOVA statistical test was used. Statistically significant differences at the significance level of α=0,05 are highlighted in bold in the table. The surveyed sample consisted of 16 micro-enterprises, 25 small companies, 27 medium-sized companies, and 5 large companies.

The advancement in the implementation of Industry 4.0 was covered by the second question for each pillar, i.e., whether the organization utilizes that particular pillar. Out of the 10 surveyed pillars, statistically significant differences in their utilization between organizations of different sizes occur only in the case of three examined pillars of Industry 4.0: incremental manufacturing, integration of information systems and Big Data. For the remaining 7 pillars, no statistically significant differences were observed between various types of organizations in terms of their size (Table 3).

In additive manufacturing, medium-sized companies are most advanced (3.44), followed by small companies

Table 2. Basic statistics for the variables studied

Pillar	No.	Variables	Mean	Median	Min	Max	Standard deviation
Automated robots	1	The organization is aware of the existence of autonomous robots.	3.96	4.00	1.00	5.00	0.81
	2	Autonomous robots are used in the organization.	2.85	3.00	1.00	5.00	1.1
	3	The organization plans to implement/develop autonomous robots.	3.49	3.00	1.00	5.00	0.88
	4	The organization has the appropriate infrastructure to properly utilize autonomous robots.	3.29	3.00	1.00	5.00	1.03
Augmented reality	1	The organization is aware of the existence of augmented reality technology.	3.82	4.00	1.00	5.00	0.86
	2	Augmented reality is used in the organization.	2.62	3.00	1.00	5.00	1.15
	3	The organization plans to implement/develop augmented reality.	2.99	3.00	1.00	5.00	0.86
	4	The organization has the appropriate infrastructure to properly utilize augmented reality.	3.03	3.00	1.00	5.00	0.96
Simulations	1	The organization is aware of the existence of simulations.	3.89	4.00	1.00	5.00	0.92
	2	Simulations are conducted in the organization.	3.32	3.00	1.00	5.00	1.14
	3	The organization plans to implement/develop simulations.	3.36	3.00	1.00	5.00	0.95
	4	The organization has the appropriate infrastructure to properly utilize simulations.	3.47	4.00	1.00	5.00	0.93
Incremental manufacturing	1	The organization is aware of the existence of additive manufacturing.	3.53	4.00	1.00	5.00	1.07
	2	Additive manufacturing is used in the organization.	3.18	3.00	1.00	5.00	1.07
	3	The organization plans to implement/develop additive manufacturing.	3.22	3.00	1.00	5.00	0.82
	4	The organization has the appropriate infrastructure to properly utilize additive manufacturing.	3.19	3.00	1.00	5.00	1
Integration of information systems	1	The organization is aware of the existence of information system integration.	3.95	4.00	1.00	5.00	0.8
	2	Information system integration is present in the organization.	3.67	4.00	1.00	5.00	0.94
	3	The organization plans to implement/develop information system integration.	3.58	4.00	1.00	5.00	0.97
	4	The organization has the appropriate infrastructure to properly utilize information system integration.	3.66	4.00	1.00	5.00	1.06
Cybersecurity	1	The organization is aware of the existence of cyber security threats.	4.27	4.00	1.00	5.00	0.79
	2	The organization has security measures in the field of cyber security.	4.08	4.00	1.00	5.00	0.92
	3	The organization plans to implement/develop cyber security.	3.88	4.00	1.00	5.00	1.01
	4	The organization has the appropriate infrastructure to properly utilize cyber security.	3.9	4.00	1.00	5.00	1.03
Internet of Things	1	The organization is aware of the existence of the Internet of Things.	3.74	4.00	1.00	5.00	1.05
	2	The Internet of Things is used in the organization.	3.29	3.00	1.00	5.00	1.18
	3	The organization plans to implement/develop the Internet of Things.	3.36	3.00	1.00	5.00	1.02
	4	The organization has the appropriate infrastructure to properly utilize the Internet of Things.	3.51	4.00	1.00	5.00	1.07
Cloud Computing	1	The organization is aware of the existence of cloud computing.	3.79	4.00	1.00	5.00	0.9
	2	Cloud computing is used in the organization.	3.25	3.00	1.00	5.00	1.12
	3	The organization plans to implement/develop cloud computing.	3.41	3.00	1.00	5.00	1.03
	4	The organization has the appropriate infrastructure to properly utilize cloud computing.	3.51	4.00	1.00	5.00	1

Pillar	No.	Variables	Mean	Median	Min	Max	Standard deviation
Big Data	1	The organization is aware of the existence of Big Data.	3.64	4.00	1.00	5.00	1.03
	2	Large amounts of data (Big Data) are processed in the organization.	3.37	3.00	1.00	5.00	1.17
	3	The organization plans to implement/develop Big Data.	3.36	3.00	1.00	5.00	1.01
	4	The organization has the appropriate infrastructure to properly utilize Big Data.	3.38	3.00	1.00	5.00	1.02
Artificial intelligence	1	The organization is aware of the existence of artificial intelligence.	4.16	4.00	3.00	5.00	0.55
	2	Artificial intelligence is used in the organization.	2.78	3.00	1.00	5.00	1.31
	3	The organization plans to implement/develop artificial intelligence.	3.15	3.00	1.00	5.00	1.05
	4	The organization has the appropriate infrastructure to properly utilize artificial intelligence.	3.25	3.00	1.00	5.00	1.12

Source: author's own study

(3.16) and micro-enterprises (3.13), with large enterprises being the least advanced (2.0). In information system integration, medium-sized organizations lead (3.96), then small organizations (3.84) and micro-enterprises (3.19), with large enterprises lowest (2.8). For Big Data use, small organizations are most advanced (3.8), followed by medium-sized companies (3.37) and micro-enterprises (3.13), with large companies being least advanced (2.0).

The analysis presented indicates that the data does not support Hypothesis H1, which states: large organizations in Poland are more advanced in implementing Industry 4.0 than small and medium-sized organizations. The research shows that medium-sized companies are the most advanced in implementing Industry 4.0, and in some areas, small organizations are as well. Micro-enterprises are at a lower level of advancement, while large companies perform the worst in this regard.

In the next stage of the research, the focus was on issues related to the intentions of the surveyed organizations in terms of implementing and developing various pillars of Industry 4.0. For this purpose, Hypothesis H4 was formulated, stating that most organizations intend to implement/develop Industry 4.0 solutions at a good level. Questions about the organizations' intentions for implementing individual pillars were addressed in question 3 for each pillar, which includes variables: 3.

The research shows that only two examined pillars have future implementation or development plans scoring above 3.5: cybersecurity, the highest-rated area, and information system integration at 3.58, also highly rated for current implementation. This indicates the importance of these areas for the surveyed organizations. The assessment of the surveyed organizations' plans in all other areas falls within the average range (2.5–3.5). Among these, the least focus for future development is planned in Industry 4.0 pillars such as augmented reality (2.99), artificial intelligence (3.1), and additive manufacturing (3.22).

The research results do not support Hypothesis H4, which states that most organizations intend to implement/develop Industry 4.0 solutions at a good level. The research shows that for most organizations, their future intentions for implementing the pillars of Industry 4.0 are at an average level.

Most organizations have average plans for implementing various Industry 4.0 pillars but show potential for further technological development. This indicates that Industry 4.0 adoption is evolutionary, with organizations likely to increase their engagement as they gain experience. The research highlights that while plans are not highly advanced, there is a notable focus and commitment to areas like cybersecurity and information system integration. This could serve as a foundation for further research and refinement of Industry 4.0 implementation strategies.

Discussion

The survey results show that there is a high awareness of cybersecurity and artificial intelligence in Industry 4.0, which is related to the growing awareness of threats and the importance of AI in the industry. However, awareness varies by area, with lower awareness in areas such as incremental manufacturing and Big Data, which may indicate less knowledge or importance of these areas in organizations.

Although the average level of awareness of Industry 4.0 pillars above 3.5 is positive, awareness alone does not guarantee their successful implementation in organizations (Erboz, 2017; Sawangwong, Chaopaisarn, 2021). Areas with lower awareness can be an opportunity to increase education and outreach efforts, helping organizations better understand and appreciate the lesser-known pillars of Industry 4.0.

Research has shown that cyber security is at the highest level implemented in Industry 4.0, probably due to the

Table 3. Values of studied variables with breakdown by organization size

Pillar	No.	Variables	Micro companies (n=16)	Small companies (n=25)	Medium companies (n=27)	Large companies (n=5)	p
Automated robots	1	The organization is aware of the existence of autonomous robots.	3.81	4.12	3.93	3.8	0.571
	2	Autonomous robots are used in the organization.	2.56	3.28	2.7	2.4	0.134
	3	The organization plans to implement/develop autonomous robots.	3.5	3.68	3.52	2.4	0.035
	4	The organization has the appropriate infrastructure to properly utilize autonomous robots.	3.38	3.48	3.22	2.4	0.171
Augmented reality	1	The organization is aware of the existence of augmented reality technology.	3.88	4.2	3.52	3.4	0.02
	2	Augmented reality is used in the organization.	2.63	2.92	2.41	2.2	0.38
	3	The organization plans to implement/develop augmented reality.	3.19	2.92	3.04	2.4	0.316
	4	The organization has the appropriate infrastructure to properly utilize augmented reality.	3.06	3.24	3	2	0.316
Simulations	1	The organization is aware of the existence of simulations.	3.81	4	3.93	3.4	0.619
	2	Simulations are conducted in the organization.	2.94	3.68	3.3	2.8	0.2269
	3	The organization plans to implement/develop simulations.	3.31	3.6	3.26	2.8	0.443
	4	The organization has the appropriate infrastructure to properly utilize simulations.	3.44	3.68	3.41	2.8	0.546
Incremental manufacturing	1	The organization is aware of the existence of additive manufacturing.	3.31	3.76	3.67	2.4	0.583
	2	Additive manufacturing is used in the organization.	3.13	3.16	3.44	2	0.049
	3	The organization plans to implement/develop additive manufacturing.	3.06	3.32	3.44	2	0.009
	4	The organization has the appropriate infrastructure to properly utilize additive manufacturing.	3.06	3.28	3.44	1.8	0.019
Integration of information systems	1	The organization is aware of the existence of information system integration.	3.75	4.08	4.15	2.8	0.014
	2	Information system integration is present in the organization.	3.19	3.84	3.96	2.8	0.019
	3	The organization plans to implement/develop information system integration.	3.38	3.64	3.93	2	0.002
	4	The organization has the appropriate infrastructure to properly utilize information system integration.	3.81	3.72	3.85	1.8	0.0036
Cybersecurity	1	The organization is aware of the existence of cyber security threats.	4.38	4.4	4.26	3.4	0.372
	2	The organization has security measures in the field of cyber security.	3.63	4.36	4.22	3.4	0.053
	3	The organization plans to implement/develop cyber security.	3.75	4.12	3.96	2.6	0.046
	4	The organization has the appropriate infrastructure to properly utilize cyber security.	3.56	4.24	4	2.8	0.029

Pillar	No.	Variables	Micro companies (n=16)	Small companies (n=25)	Medium companies (n=27)	Large companies (n=5)	p
Internet of Things	1	The organization is aware of the existence of the Internet of Things.	3.56	3.92	3.85	2.8	0.234
	2	The Internet of Things is used in the organization.	3.13	3.4	3.37	2.8	0.722
	3	The organization plans to implement/develop the Internet of Things.	3.25	3.64	3.3	2.6	0.271
	4	The organization has the appropriate infrastructure to properly utilize the Internet of Things.	3.31	3.72	3.63	2.4	0.101
Cloud Computing	1	The organization is aware of the existence of cloud computing.	3.81	4.04	3.81	2.4	0.032
	2	Cloud computing is used in the organization.	3.31	3.32	3.37	2	0.09
	3	The organization plans to implement/develop cloud computing.	3.5	3.44	3.59	2	0.024
	4	The organization has the appropriate infrastructure to properly utilize cloud computing.	3.5	3.72	3.63	1.8	0.009
Big Data	1	The organization is aware of the existence of Big Data.	3.38	4	3.7	2.4	0.031
	2	Large amounts of data (Big Data) are processed in the organization.	3.13	3.8	3.37	2	0.016
	3	The organization plans to implement/develop Big Data.	3.06	3.56	3.59	2	0.008
	4	The organization has the appropriate infrastructure to properly utilize Big Data.	3.31	3.56	3.52	2	0.021
Artificial intelligence	1	The organization is aware of the existence of artificial intelligence.	4.06	4.36	4.04	4.2	0.169
	2	Artificial intelligence is used in the organization.	3.13	2.68	2.63	3	0.55
	3	The organization plans to implement/develop artificial intelligence.	3.31	3.2	3.07	2.8	0.659
	4	The organization has the appropriate infrastructure to properly utilize artificial intelligence.	3.13	3.44	3.19	3	0.803

Source: author's own study

growing awareness of digital threats. Areas such as cyber security and information systems integration are relatively well implemented. Similar results were achieved in their article by Gonzales, Quinonero, and Vega (2021), whose survey results showed an implementation level of pillars such as Information Systems Integration at 3.95 and cyber security at 4.4, indicating high awareness of their importance not only in Poland. In other areas, however, the level of implementation is lower, suggesting the need for a more balanced approach and allocation of resources among the different pillars of Industry 4.0 (Mayer, Oosthuizen, 2022).

Failure to confirm Hypothesis H3 could mean that the implementation of Industry 4.0 technologies varies by industry sector and organization. The low level of implementation of technologies like artificial intelligence and augmented reality points to the need for better education and awareness within organizations. Lack of understanding of the potential of these technologies can limit their effectiveness and innovation (Ghobakhloo et al., 2021). Research suggests that organizations should implement Industry 4.0 in a thoughtful and customized manner, as not every pillar is equally relevant to every organization (Dubey et al., 2022; Piccarozzi et al., 2022).

Comparing the research results of this article with the research conducted on behalf of PSI Poland, „Gotowość firm produkcyjnych do wdrożenia rozwiązań Przemysłu 4.0" (2019) a concordance of conclusions was observed in the context of the ease of adaptation of medium-sized companies to the new solutions of Industry 4.0. The research shows that large companies are not always at the forefront of implementing Industry 4.0 technologies, which may be due to their complex, hierarchical structures that hinder rapid adaptation. Large companies often have difficulty integrating new technologies and may prefer to maintain

the status quo, while smaller companies may be more open to experimenting and adapting to change.

It is also worth noting the changes over the past few years, where in a study conducted in 2020 by Pech and Vrchota (2020), results were presented that determined the dominance of large enterprises in terms of the implementation of Industry 4.0. In hindsight, it is clear that it is small and medium-sized enterprises that are able to more easily break through the barriers to implementing the concept.

The study has practical implications that organizations should focus on increasing readiness to implement Industry 4.0 in areas with lower ratings, which can increase competitiveness and innovation. It is important to invest in knowledge and technology to gain an edge in a dynamic industrial environment. Industry 4.0 encompasses not only technology, but also processes and organizational culture, which requires organizations to build flexible structures and continuously adapt their strategies to the changing technological environment.

The article points out that implementing Industry 4.0 is an evolutionary process, where organizations gradually increase their commitment to these technologies, gaining experience and confidence. This is in line with organizational learning theory, which suggests that organizations learn from experience and adjust their actions (Rahmani et al., 2023). The study confirms that the learning curve is crucial in the adaptation and implementation of advanced technologies.

The study found that small and medium-sized organizations are more advanced in implementing Industry 4.0 than large companies, which may be due to their ability to learn and adapt by observing industry experience. Areas such as cybersecurity and information systems integration are particularly advanced, indicating the greater absorptive capacity of these organizations to effectively assimilate and apply knowledge. The theory of absorptive capacity emphasizes that organizations with greater absorptive capacity are more effective at identifying, assimilating and applying external knowledge, which is reflected in higher levels of implementation of the various pillars of Industry 4.0 (Klun et al., 2016; Kim, Park, 2023).

Conclusions

The article deals with assessing the implementation of Industry 4.0 in Polish organizations. A survey was conducted on a sample of 73 organizations to test four hypotheses. The results do not confirm hypothesis H1, according to which large organizations in Poland are more advanced in implementing Industry 4.0 than small and medium-sized companies. It turns out that small and medium-sized companies dominate in this area. Hypothesis H2 was confirmed – the majority of organizations in Poland are aware of the individual pillars of Industry 4.0. Hypothesis H3 was not confirmed, as only in two pillars (cyber security and IT systems integration) the level of implementation can be described as good. Hypothesis H4 was also not confirmed: organizations plan to implement Industry 4.0 pillars at an average level.

The research implies that large organizations need to intensify their Industry 4.0 technology implementation to stay competitive. The advancement of small and medium-sized enterprises in this area suggests they should invest further, supported by tax incentives, grants, or training. Additionally, the average implementation level of Industry 4.0 pillars highlights the necessity for standards and certifications to assess and enhance implementation quality.

The academic article notes the incomplete representativeness of the survey sample, which limits the possibility to fully understand the situation of Industry 4.0 implementation across Poland. It points out that the survey is a one-off and does not take into account changes over time, which opens the field for further research on the level of Industry 4.0 implementation in Poland.

The publication enriches the theoretical understanding of Industry 4.0 organizational awareness by assessing the various pillars and identifying areas of varying levels of knowledge. It contributes to the discussion of policy implications for Industry 4.0 adoption by identifying areas that require additional support or incentives, which can inform potential interventions for faster technology adoption. The article also highlights specific challenges in pillars such as augmented reality, additive manufacturing and artificial intelligence, providing a basis for further theoretical research in these areas.

By highlighting specific challenges in implementing these technologies, the research offers practical implications for organizations seeking to improve their preparedness and competitiveness. Moreover, the emphasis on the evolutionary nature of Industry 4.0 adoption aligns with Organizational Learning Theory, contributing to the understanding of how organizations learn from experience and gradually engage with advanced technologies. Overall, the paper underscores the importance of continuous monitoring, evaluation, and adaptation of organizational strategies in response to the dynamically changing technological landscape in the context of modern industry and management practices.

Future research in the domain of Industry 4.0 implementation presents promising avenues for exploration. Building upon the current findings, we could delve into the specific factors influencing organizations' varying levels of awareness and implementation across different pillars. Understanding the reasons behind the lower levels of implementation in areas such as artificial intelligence and augmented reality would contribute to developing targeted interventions and strategies. Additionally, longitudinal studies could offer a more comprehensive view of the evolving landscape, capturing changes in technological advancements and organizational responses over time.

There are some limitations of the study worth mentioning. The research appears to be a one-time study, providing a snapshot of the current state of Industry 4.0 implementation. A longitudinal study would be more effective in capturing the dynamic nature of technological advancements and organizational changes over time. The study focuses on 10 specific pillars of Industry 4.0. There are also other concepts how the pillars of Industry 4.0 can be operationalized.

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Ocena poziomu wdrożenia Przemysłu 4.0 w organizacjach w Polsce

Streszczenie

Publikacja zawiera wyniki badań empirycznych w zakresie wdrożenia Przemysłu 4.0 w organizacjach w Polsce ze szczególnym uwzględnieniem wpływu zaawansowanych technologii. Wyniki badań kwestionują panujące przekonanie, że większe organizacje są bardziej zaawansowane w zakresie implementacji Przemysłu 4.0. W badaniach postawiono cztery hipotezy, analizując dane zebrane od 73 organizacji w Polsce. W publikacji poddano kompleksowej ocenie wdrożenia Przemysłu 4.0 z naciskiem na zaawansowane technologie, takie jak: rzeczywistość rozszerzona, sztuczna inteligencja i robotyka. Wyniki wskazują, że mniejsze organizacje często wykazują wyższe poziomy implementacji analizowanych aspektów Przemysłu 4.0 w porównaniu do ich większych odpowiedników. Pomimo powszechnej świadomości koncepcji Przemysłu 4.0, istnieje znaczna luka między jej świadomością a skutecznym wdrożeniem. Szczególnie skutecznie wdrożonym obszarem w badanych organizacjach jest cyberbezpieczeństwo, prawdopodobnie z powodu zwiększonej świadomości zagrożeń cyfrowych. Jednak inne technologie, takie jak rzeczywistość rozszerzona, sztuczna inteligencja i robotyka, wykazują niższe poziomy wdrożenia, sugerując występowanie barier ich praktycznego zastosowania. Badanie ujawnia również zróżnicowany poziom gotowości różnych sektorów do przyjęcia nowych technologii Przemysłu 4.0.

Słowa kluczowe

Przemysł 4.0, filary Przemysłu 4.0, cyberbezpieczeństwo, sztuczna inteligencja