

Adoption of Artificial Intelligence and Base Technologies of Industry 4.0: A Way to Improve Business Processes

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Abstract: Our article examines selected technologies associated with the Fourth Industrial Revolution (specifically the so-called base technologies) and their extent of utilization within business processes. The research was conducted on a sample of companies operating in the Slovak Republic. Based on data from 180 companies, we assessed the extent of implementation of these technologies. The results of our study show that some Industry 4.0 technologies have already been successfully implemented in most of the surveyed companies (in particular cloud computing for data storage, cloud networks for remote access to resources, and the Internet of Things). An especially positive finding is that cybersecurity measures have been implemented to the greatest extent, which is crucial for the successful and sustainable functioning of the entire Industry 4.0, with the importance of this area continuing to grow each year. On the other hand, artificial intelligence, machine learning, and deep learning are not widely used in most companies, nor do companies currently plan to adopt them. This field, however, provides significant potential for productivity growth and process optimization, and in recent years we have also observed a marked increase in the adoption of artificial intelligence within the general population. At present, only 14% of companies have successfully implemented these technologies. According to our findings, companies that do employ artificial intelligence and machine learning use them primarily in business processes to facilitate the analysis and evaluation of large datasets.

Keywords: Industry 4.0, Base technologies, Business processes, Artificial intelligence, Cybersecurity

1. Introduction

The Fourth Industrial Revolution is considered a socio-economic phenomenon that has the potential to influence and transform all sectors, offered products and services, corporate strategies (Prim, 2022), and fundamentally affect the way in which business processes are managed and performed. Within the Fourth Industrial Revolution, it is primarily the new technologies associated with it, such as artificial intelligence, machine learning, blockchain, cloud solutions, and other technologies, that directly influence these changes. As various researchers, such as Ross and Maynard (2021), point out, at present the fundamental changes are to a large extent associated with the technological progress brought about by the Fourth Industrial Revolution, also known as Industry 4.0. As Burritt and Christ (2016) states, Industry 4.0 is used as an umbrella term referring to a group of interconnected technological advances that form the basis for the increased digitization of the business environment. Technologies of Industry 4.0 combine cyber-physical structures, such as the Internet of Things and the Internet of Services, with other technologies, including artificial intelligence, big data, machine learning, and others. (Javaid, 2022) From this perspective, it is interesting to examine various types of technologies. Therefore, the aim of this article being to focus on a specific type of Industry 4.0 technologies, namely the so-called base technologies (Industry 4.0 Base Technologies). Another interesting aspect is the extent to which companies use Industry 4.0 technologies and how this influences their competitiveness. As Merlo (2020) states, the adoption of Industry 4.0 acts as a competitive differentiator – companies moving forward with Industry 4.0 initiatives gain advantages in the form of sophisticated new capabilities and new ways of strengthening competitiveness, while others are forced to catch up. Business processes can undergo significant changes with the incorporation of Industry 4.0 technologies. In particular, the use of artificial intelligence in business processes continues to attract significant interest, as artificial intelligence can be applied to the automation of business processes and the support of companies' decision-making processes. (Gomes et al., 2022) Despite the fact that Industry 4.0 has been discussed for several years, several studies point to problematic areas of its implementation (Ferkrisari, Kantola, 2024) and also propose maturity models to support this implementation. (Wagire et al., 2020) Maturity models are used, among other things, to evaluate the success of Industry 4.0 implementation. This article aims to examine whether companies pay attention to adapting business processes to the trends of the Fourth Industrial Revolution and to assess the extent to which they thereby use artificial intelligence and selected Industry 4.0 technologies, based on a chosen maturity model. In our research, we focused on a specific set of technologies called Industry 4.0 Base Technologies, as one of their features is that they enable companies to analyse and improve business processes. At the same time, our research focused only on a selected location, i.e. companies operating in the territory of the Slovak Republic, and we did not specialize in a single sector but

approached companies from various sectors and of different sizes in order to assess whether such characteristics also influence the adoption of artificial intelligence in business processes.

2. Theoretical Background

2.1 Industry 4.0 and Business Processes Improvement

The Fourth Industrial Revolution, also called Industry 4.0, brings new challenges for companies that directly affect how they operate, how they organize their business models, how they carry out business processes, how they produce and deliver their products and services, how they organize their relationships, and how they shape their competences. (Khider et al., 2025) Industry 4.0 is a term closely associated with technologies and technological progress. As with previous industrial revolutions, this revolution was not initiated by a single technology but is a synthesis of multiple technologies and technological advances. (Cabrita, 2019) Thanks to Industry 4.0, companies can use a range of digital technologies, systems, platforms, concepts, and architectures, such as artificial intelligence, augmented/virtual reality, (industrial) automation, big data, cloud computing/storage, cyber-physical systems, cybersecurity, enterprise resource planning (ERP) systems, the Industrial Internet, the Internet of Things, and intelligent/autonomous robotics. (Dos Santos et al., 2021) Whereas in the past, investments in new technologies and technological support for business processes were primarily aimed at reducing costs and increasing efficiency (Papulová et al., 2022), today this perspective shifts toward the implementation of technologies with the aim of achieving higher speed and flexibility, improving the quality of interaction with customers, and strengthening innovation. (Vaska et al., 2021) Technologies are dramatically transforming companies and entire industries, as they not only support existing processes but enable their modification and thereby directly foster not only process and organizational innovations but also innovations of business models (Papulová et al., 2022). Technology-based process improvement is shifting toward achieving new levels of competitiveness. (Javaid et al., 2022) Industry 4.0 directly affects a company's competitiveness by employing technologies that can improve business processes, for example in terms of their automation and digitization, through autonomous and intelligent systems. Industry 4.0 also enables automated, seamless, and connected networks of companies and other parties through the incorporation of the latest technologies, machinery, and infrastructure (Mahmood and Mubarik, 2020). From the perspective of process improvement in the context of Industry 4.0, the current trends in business process management include the following areas (Khider et al., 2025):

- process automation, enabled by technologies such as artificial intelligence, machine learning, and the Internet of Things (Nozari et al., 2024);
- Process digitization, which also enables the creation of new and innovative business models and organizational structures (Broccardo et al., 2024);
- process control and real-time monitoring (Ghobakhloo, 2020) contribute to information transparency and data analysis that enable higher-quality and faster decision-making (Elghaish et al., 2021);
- customer-centric processes that enable companies to deliver personalized and more efficient communication and interaction with customers (Ahmed & Shahzad, 2022).

2.2 Artificial Intelligence and Industry 4.0 Base Technologies

Industry 4.0 is often defined through technologies that are also referred to as “emerging and disruptive technologies” (Young, 2020), and attention is frequently directed to two groups of Industry 4.0 technologies: front-end technologies and base technologies (Ferrigno et al., 2023), which provide connectivity and intelligence for front-end technologies. (Frank et al., 2019) The focus on base technologies is particularly interesting in terms of opportunities to improve business processes. (Baden-Fuller and Haefliger, 2013) The front-end technologies (smart manufacturing, smart products, smart supply chain, smart working) address operational and market needs and have an end-application role in the companies' value chain, while the base technologies (Internet of Things, cloud, big data and analytics) provide connectivity and intelligence for front-end technologies. (Čater et al., 2021)

Wagire et al. (2020), within their proposed maturity model for Industry 4.0, distinguish three groups of Industry 4.0 technologies: Smart Manufacturing Technologies, Product- and Services-Oriented Technologies, and Industry 4.0 Base Technologies, and classify into the group of base technologies the following:

- Cloud computing networks for resource sharing – cloud services that enable companies to remotely access and use physical resources (e.g., devices and robots) and intangible resources (e.g., data, documents, software),

- Cloud computing networks for data storage – cloud services for the secure storage and retrieval of organizational data,
- Internet of Things – interconnected devices and sensors that communicate and interconnect machines, systems, and people,
- Internet of Services – web-based service platforms that enable the composition and delivery of digital services,
- Big data and real-time data processing – methods to collect, process, and analyze large, fast-moving datasets to support decision-making,
- Simulation tools – software for what-if scenario analysis (modeling configuration options) to develop predictive scenarios that support business decision-making,
- Artificial intelligence, machine learning, and deep learning – AI-based cognitive technologies (e.g., natural language processing, speech recognition, computer vision, object detection and recognition) that learn from data and enable personalization, automation, and process improvement,
- Industrial cybersecurity – organizational and technical measures that protect systems and data and ensure the confidentiality, integrity, and availability in industrial environments.

Although Wagire et al. (2020) refer to the items listed as “technologies,” this label functions as an umbrella term that encompasses a broader range of digital technologies, systems, platforms, concepts, and architectures. For the sake of terminological consistency and brevity, we use the shortened label “technologies” throughout our paper, by which we explicitly mean this broader scope (i.e., not only specific technical solutions but also related systems, platforms, and conceptual or architectural approaches).

In particular, the use of artificial intelligence in the improvement of business processes continues to attract significant interest. Artificial intelligence can be characterized as the ability of computer systems to learn, process information, and make decisions, thereby replacing activities that would ordinarily require human intelligence. (Helm et al., 2020) Recently, with the increasing possibilities for acquiring large volumes of data (Big Data), artificial intelligence has been gaining increasing importance, as it can be used to process and analyse large amounts of data almost instantly, in real time (Gomes et al., 2022), while also identifying patterns, predicting outcomes, and proposing optimizations and decisions. In the context of artificial intelligence, machine learning and deep learning are often mentioned as its subfields: they can perform complex tasks such as speech recognition and natural language processing (Gomes et al., 2022) and, thanks to their ability to “learn” and use algorithms, also provide recommendations or make decisions (Helm et al., 2020). From the perspective of improving processes in companies, AI-based process analysis and optimization can use real-time data and employ machine-learning algorithms to uncover hidden patterns, predict failures and errors, and dynamically adjust decision-making based on insights from processed data (Bubenik et al., 2025). These possibilities for the adoption of artificial intelligence help improve the efficiency of existing business processes and enable business process automation. (Gomes et al., 2022)

3. Methodology

Although we first learned about Industry 4.0 in 2011 (Adolph et al., 2016), the topic continues to evolve, and the gradual implementation of Industry 4.0 technologies in companies creates room for further research. This article aims to examine whether companies pay attention to adapting business processes to the trends of the Fourth Industrial Revolution and to assess the extent to which they thereby use artificial intelligence and selected Industry 4.0 technologies, based on a chosen maturity model. In our research, we focused on a specific set of technologies known as Industry 4.0 Base Technologies, as one of their features is that they enable companies to analyse and improve business processes. To assess the degree of adoption of artificial intelligence and selected Industry 4.0 technologies, we used part of the maturity model by Wagire et al. (2020), which directly enables the evaluation of the extent to which artificial intelligence and other Industry 4.0 Base Technologies are used. For data collection, we used structured interviews with representatives of companies operating in Slovakia, and we did not focus on a single size category or on a single sector. The structured interview comprised 8 sections based on the 8 identified areas of Industry 4.0 Base Technologies. Data were collected in the years 2022–2024, during which we obtained 180 responses. To evaluate the individual levels of technologies, a 1–5 scale based on the Likert scale was used, with each level expressing the degree or extent of technology application in the given company.

4. Results and Discussion

4.1 Evaluation of Industry 4.0 Technologies Adoption

This section presents the main findings on the extent of use of Industry 4.0 Base Technologies in the analysed set of companies. We base our analysis on the selected maturity model and evaluate implementation levels for individual technologies. We focused on the following Industry 4.0 Base Technologies: Cloud computing networks for resource sharing; Cloud computing networks for data storage; Internet of Things; Internet of Services; Big data and real-time data processing; Simulation tools; Artificial intelligence, machine learning, and deep learning; Industrial cybersecurity. The results are presented in Table 1.

Table 1: Assessment of the implementation of Industry 4.0 Base Technologies

Industry 4.0 Base Technologies	1		2		3		4		5		Average
Cloud computing networks for resource sharing	20	11.11%	12	6.67%	13	7.22%	33	18.33%	102	56.67%	4.03
Cloud computing networks for data storage	17	9.44%	11	6.11%	12	6.67%	29	16.11%	111	61.67%	4.14
Internet of Things	40	22.22%	14	7.78%	6	3.33%	22	12.22%	98	54.44%	3.69
Internet of Services	71	39.44%	22	12.22%	22	12.22%	16	8.89%	49	27.22%	2.72
Big data and real-time data processing	45	25.00%	24	13.33%	15	8.33%	24	13.33%	72	40.00%	3.30
Simulation tools	73	40.56%	25	13.89%	17	9.44%	26	14.44%	39	21.67%	2.63
Artificial intelligence, machine learning, and deep learning	108	60.00%	18	10.00%	13	7.22%	15	8.33%	26	14.44%	2.07
Industrial cybersecurity	12	6.67%	12	6.67%	11	6.11%	29	16.11%	116	64.44%	4.25
Total: Industry 4.0 Base Technologies											3.35

Source: Own elaboration.

The implementation-level values for individual Industry 4.0 Base Technologies denote:

- Level 1: Such technologies are not implemented and/or not planned.
- Level 2: Requirements for introducing such technologies are being prepared and/or have not yet been officially approved as part of the organization’s plan.
- Level 3: Such technologies are being prepared for implementation and/or are part of the officially approved organizational plan.
- Level 4: We are implementing such technologies.
- Level 5: We have successfully implemented such technologies.

Based on the results in Table 1, we see that some Industry 4.0 Base Technologies are successfully implemented (level 5) in most companies, such as Cloud computing networks for data storage (62%), Cloud computing networks for resource sharing (57%), and the Internet of Things (54%). A very positive finding is that Industrial cybersecurity are the most successfully implemented (64%), since this area is critical to the successful implementation and the sustainable operation of Industry 4.0 as a whole; its importance is increasing year by year and, in the future, will pose a major challenge, not only from the perspective of Industry 4.0. On the other hand, Artificial intelligence, machine learning, and deep learning are not used, nor are they planned to be used (level 1) in most companies (60%), although this area offers substantial room to increase productivity and optimize processes; in recent periods, we also observe a significant increase in the use of artificial intelligence among the general population. (e.g., Deloitte, 2024)

4.2 The Level of Artificial Intelligence Adoption

According to our research, 14% of the companies in our sample have artificial intelligence technologies and the associated machine learning and deep learning successfully implemented (at level 5). In our study, we also examined whether certain company characteristics affect the adoption of artificial intelligence, for example company size, years in operation, whether it is a manufacturing or a services company, whether the sector in which the company operates matters, and also whether the company is domestic or foreign (i.e., whether a

majority stake in the company is held by foreign capital). We present the results of these more detailed assessments in Table 2.

Table 2: Level of artificial intelligence (AI) adoption across different types of companies

Company characteristics	1		2		3		4		5		Average
Size:											
Micro	18	78.26%	3	13.04%	0	0.00%	1	4.35%	1	4.35%	1.43
Small	31	68.89%	6	13.33%	2	4.44%	1	2.22%	5	11.11%	1.73
Medium	23	62.16%	1	2.70%	5	13.51%	4	10.81%	4	10.81%	2.05
Large	36	48.00%	8	10.67%	6	8.00%	9	12.00%	16	21.33%	2.48
Years in operation:											
Less than 5 years	5	100.00%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	1.00
5 to 15 years	22	55.00%	7	17.50%	1	2.50%	3	7.50%	7	17.50%	2.15
More than 15 years	81	60.00%	11	8.15%	12	8.89%	12	8.89%	19	14.07%	2.09
Manufacturing:											
yes (manufacturing companies)	47	69.12%	6	8.82%	4	5.88%	4	5.88%	7	10.29%	1.79
no (non-manufacturing companies)	61	54.46%	12	10.71%	9	8.04%	11	9.82%	19	16.96%	2.24
Sector (NACE):											
Manufacturing; Mining and quarrying; Other industry;	43	69.35%	6	9.68%	3	4.84%	4	6.45%	6	9.68%	1.77
Construction	5	83.33%		0.00%	1	16.67%	0	0.00%	0	0.00%	1.33
Wholesale and retail trade; Transportation and storage; Accommodation and food service activities;	26	56.52%	9	19.57%	3	6.52%	2	4.35%	6	13.04%	1.98
Telecommunications; Computer programming, consultancy and related activities; Data processing, hosting and related activities; Information service activities;	3	20.00%	1	6.67%	4	26.67%	3	20.00%	4	26.67%	3.27
Financial and insurance activities;	10	50.00%	0	0.00%	0	0.00%	4	20.00%	6	30.00%	2.80
Real estate activities;	2	50.00%	1	25.00%	0	0.00%	0	0.00%	1	25.00%	2.25
Professional, scientific and technical activities; Administrative and support service activities;	11	64.71%	0	0.00%	2	11.76%	2	11.76%	2	11.76%	2.06
Public administration and defence; Education; Human health and social work activities;	8	80.00%	1	10.00%	0	0.00%	0	0.00%	1	10.00%	1.50

Company characteristics	1		2		3		4		5		Average
Foreign company:											
yes	34	47.22%	5	6.94%	9	12.50%	9	12.50%	15	20.83%	2.53
no	74	68.52%	13	12.04%	4	3.70%	6	5.56%	11	10.19%	1.77
Total: Artificial Intelligence, Machine Learning and Deep Learning											2.07

Source: Own elaboration.

From the standpoint of the average level of artificial intelligence implementation, companies on average reach level 2, which means that the requirements for introducing such technologies are being prepared and/or have not yet been officially approved as part of the organization’s plan. When evaluating by company size, large companies reached a value of 2.48, only slightly above the average (2.07), which means that fewer than half of companies (41%) reach levels 3–5. By sector, we found that the highest average implementation value (3.27) was achieved by companies in Telecommunications; Computer programming, consultancy and related activities; Data processing, hosting and related activities; Information service activities, while another sector with above-average implementation was Financial and insurance activities.

If we look at other studies on the use of artificial intelligence in companies, based on a recently published Eurostat (2025) study, which examined 157,000 out of 1.54 million companies in the EU:

- In 2024, 13.48% of EU companies used AI technologies.
- In 2024, 41.17% of large EU companies used AI technologies.
- In 2024, AI was used most by companies in the information and communication sector.

These results are very similar to the findings of our study. We can concur with the conclusions of the Eurostat (2025) study that, according to our findings as well, artificial intelligence is used more in some sectors than in others, which likely suggests that AI may be more applicable to certain activities and processes. It is also noteworthy that non-manufacturing companies, on average, use this technology more than manufacturing companies (2.24 vs. 1.79). The Eurostat (2025) study indicated that, within non-manufacturing sectors, companies in Professional, scientific and technical activities exhibit a high level of AI use (30.53%). Since the Eurostat (2025) study did not separately identify Financial and insurance activities, we likewise observe a similarity here, as this is another sector with a higher rate of technology adoption. Similarly, Eurostat reports the lowest rate of technology adoption in construction, which we can confirm with our average value (1.33).

If we look at population trends (for example, Deloitte Digital Consumer Trends, UK, 2024), we can see that the use of artificial intelligence among ordinary consumers increased from 2023 to 2024. Similarly, the Eurostat (2025) study reports that from 2023 to 2024 the use of AI technologies increased by 5.45 percentage points. It can therefore be assumed that the use of artificial intelligence will continue to grow in the future. On the other hand, research by the National Bureau of Economic Research (NBER) in the US indicates that the pace of generative AI adoption is faster than for previous digital technologies (Conboye, 2025). Based on the interviews conducted, we found that the companies studied that use artificial intelligence and machine learning apply them mainly in business processes to facilitate the analysis and evaluation of large datasets, to support robotic process automation (RPA), and to automate standardized processes. Companies reported using artificial intelligence in production processes or in information and communication processes to support the processing and analysis of information, or to support communication with clients. Based on an international study by McKinsey (Singla et al., 2025), which in 2024 surveyed 1,491 respondents from 101 countries, we can see the specific business processes and areas in which AI is used in companies. The study states that 78% of companies use AI in at least one functional area (business functions), whereas in 2023 it was only 55%. The most frequently mentioned functional areas using AI are IT, marketing, sales, and service operations. Generative AI is used most in marketing; sales; product and service development; service operations; and software engineering. (Singla et al., 2025) Companies planning to introduce AI (level 3) reported that they primarily plan employee training, which is also confirmed by the Slack’s Fall 2024 Workforce Index, according to which almost one-third of workers had no AI training (Melendez, 2024), which may explain why some companies do not yet use AI. As another study indicates, the non-use of AI may lie in the fact that its benefits are not sufficiently known or clear to companies (Conboye, 2025). On the other hand, the McKinsey (Singla et al., 2025) study shows how many companies already recognize the effects of using AI, for example in the form of time savings for employees, who can use

the saved time for new activities. Respondents (especially from larger companies) reported reductions in headcount and cost savings, which is one of the most notable effects of AI adoption. (Singla et al., 2025)

5. Conclusion

As with previous industrial revolutions, it was not tools, machines, or technologies, but the transformation of companies and society that constituted the real change. Even in the past, these processes were neither abrupt nor sudden. It took some time for companies to find the right use of new opportunities and align them at the level of product, process, and organizational changes. Across the industrial revolutions, it took decades to achieve the full utilization of the relevant tools, machines, or technologies. Although Industry 4.0 is no longer an entirely new topic and many companies have already implemented numerous Industry 4.0 technologies, our survey results still show differences. Some of the technologies have already been successfully implemented in most of the surveyed companies (in particular, cloud computing networks for data storage; cloud computing networks for resource sharing; and the Internet of Things), whereas artificial intelligence, machine learning, and deep learning are not widely used in most companies, nor did most companies, at the time of the data collection, plan to adopt them.

A limitation of our research is that we focused on a smaller sample of companies, and that the situation in the adoption of new technologies is constantly changing, with the degree of use increasing year by year. Future research could therefore focus on examining the causes of the low adoption of certain Industry 4.0 technologies (e.g., artificial intelligence or simulation tools) and on evaluating whether the rate of use (particularly of artificial intelligence) will continue to increase. It would also be advisable for further research to examine whether the use of artificial intelligence is more suitable for certain types of processes in terms of the division into core, support, and management processes, and possibly for specific processes such as customer communication, performance measurement analysis, and decision support. As other studies also show, the use of artificial intelligence is increasing and is creating potential for companies to achieve significant productivity gains and process optimization. In this context, future research should focus on the management aspects that ensure the successful implementation of these technologies.

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Ethics declaration: This study involved primary data collection through surveys of company representatives about selected managerial practices. The research was non-interventional, minimal-risk, and conducted with competent adult professionals (18+). The study did not involve animals or clinical data. At the time the study was initiated and conducted, the authors' institution did not require or recommend prior review/approval by an ethics committee. Accordingly, no formal ethics clearance or approval was sought or obtained.

Before participation, all respondents (company contact person) were informed about the purpose, scope, procedures, and expected benefits; the right to withdraw at any time without penalty (withdrawal possible until batch anonymization); the expected duration; foreseeable risks and discomforts (assessed as minimal) and mitigation measures; and the contact details of a designated research-team contact for any questions or concerns.

Company identities and data related to organizational practices and processes at the company level were kept confidential in reporting, data were collected and analyzed in aggregate, and any illustrative material was edited to remove identifying details.

No sensitive personal data were collected. Personal identifiers were not included in the analytical dataset. Survey data were anonymized (with any personal data processed only prior to anonymization), stored securely (encrypted, access-controlled), accessed only by the research team (two researchers), and handled in accordance with GDPR and institutional data-protection procedures. Anonymity and confidentiality of both individual participants and company-identifying records were maintained throughout.

The authors affirm that they carefully evaluated and ensured compliance with ethical standards for research involving human participants and that participants' rights and protections were upheld throughout the study.

The results were not commercially exploited.

AI declaration: The authors used an AI language model ChatGPT (model GPT-5 Thinking, OpenAI) solely to help with translation, stylistic revision, and grammar/spell-checking to improve clarity and consistency. AI tools were not used to draft entire sections of text, formulate arguments or conclusions, generate research ideas, collect/clean/analyze data, perform statistical tests, write code or produce figures/tables, or generate/verify references. All AI-assisted edits were treated as suggestions; the authors reviewed, revised, and approved all changes and take full responsibility for the final manuscript. No other AI systems were used.

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