Industry 4.0 and technologies used in SMEs

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Abstract: Innovation is becoming an increasingly essential part of business. Modern technologies are increasingly penetrating everyday life, not just the business sphere. Without the implementation of new technologies, many companies will cease to exist. At best, they will lag far behind the competition. We can already see different levels of use of new technologies across individual businesses. The question also remains how to finance and subsequently evaluate these significant investments. This contribution aims to determine which technologies are most used in small and medium-sized organizations and how their choice is influenced. Attention is also paid to the reasons behind using technologies related to Industry 4.0. Data for this research were collected using an online questionnaire survey. It has been found that digitalization and cloud storage technologies are the most widely used in absolute terms. On the other hand, technologies such as Machine learning, Big data, or Virtual reality are used to a minimal extent. It has also been observed that the organization's vision is the main reason for implementing these technologies.

Keywords: Industry 4.0, Innovation, Technology, SMEs
JEL Classification: M10, O31, O32

1 Introduction

The world is currently facing many challenges related to the digital transformation called Industry 4.0, and SMEs are a significant area in this respect (Costa Melo et al., 2023; Abdulnour et al., 2022). Industry 4.0, as the fourth industrial revolution, is a big topic of the present time, and this term is associated with many modern technologies such as Robotics, Automation, 3D printing, Cloud, Virtual or Augmented reality, etc. (Wightman et al., 2023). The term comes from Germany, and its first use dates back to 2011 (Olšanová et al., 2021). Today, however, it is spread worldwide and offers many opportunities for developing businesses and the entire state or individual regions (Soukupová et al., 2020).

However, the implementation of modern technologies in enterprises also brings specific barriers. Among the most common, we can rank lack of infrastructure, personnel resistance, high investment requirements, lack of digital strategy, uncertainty, lack of adequate skills (Attiany et al., 2023), doubt about sustainability, lack of alternate solutions (Goel et al., 2022), lack of trust, lack of business model or lack of government support (Kumar et al., 2023).

Small and medium-sized enterprises' performance is influenced by several factors, one of which will undoubtedly be Industry 4.0 and new technologies. Ali Qalati et al. (2021) list three large groups of elements influencing the performance of small and medium-sized enterprises – organizational, environmental, and technological – among which we can include the outputs of the Industry 4.0 concept. Owalla et al. (2022) then propose dividing factors into two large groups, namely external and internal, with innovation and technology included in the group of internal factors. Kádarová et al. (2023) then directly points out the impact of digitalization and modern technologies on the productivity or competitiveness of small and medium-sized enterprises in the countries of the European Union. Therefore, the connection between small and medium-sized enterprises and Industry 4.0 is justified and needs to be studied more deeply.

2 Literature overview

For a better idea of the term Industry 4.0, a demonstrative list of technologies related to this term is offered, respectively, technologies used to characterize the overall level of digitalization.

- Additive manufacturing – **3D printing or scanning** (Bigliardi et al., 2020; Brodny & Tutak, 2022; Galizia et al., 2023; Semeraro et al., 2023); predictive **manufacturing** (Tubis & Grzybowska, 2022);
- Advanced manufacturing solutions – **smart sensors** (Bigliardi et al., 2020; Galizia et al., 2023), **robots, and machine-to-machine communication technologies** (Brodny & Tutak, 2022; Semeraro et al., 2023; Tobon-Valencia et al., 2022), **smart factory** (Karuppiah et al., 2022);
- **Artificial Intelligence** (Brodny & Tutak, 2022; Karuppiah et al., 2022; Tobon-Valencia et al., 2022);

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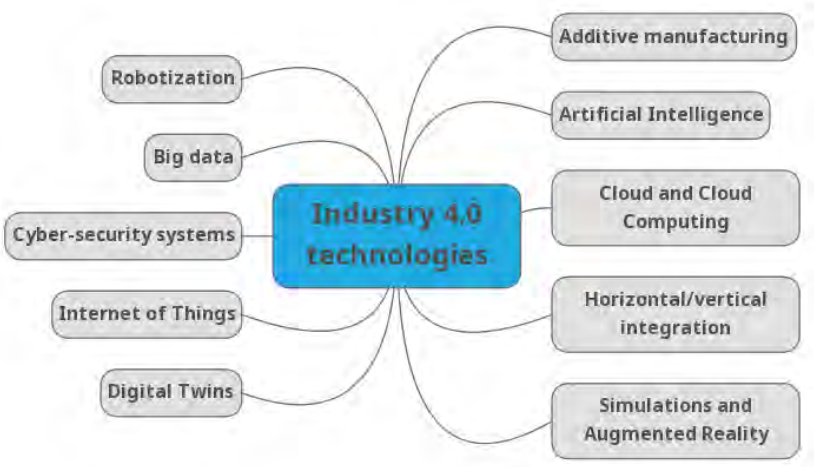
- **Augmented reality** (Bigliardi et al., 2020; Galizia et al., 2023; Karuppiah et al., 2022; Semeraro et al., 2023; Tubis & Grzybowska, 2022);
- **Big data** – analysis of data (Bigliardi et al., 2020; Brodny & Tutak, 2022; Galizia et al., 2023; Karuppiah et al., 2022; Semeraro et al., 2023; Tobon-Valencia et al., 2022);
- **Blockchain and GPS** (Karuppiah et al., 2022);
- **Cloud** (Bigliardi et al., 2020; Brodny & Tutak, 2022; Galizia et al., 2023; Semeraro et al., 2023; Tobon-Valencia et al., 2022; Tubis & Grzybowska, 2022);
- **Cyber-security and cyber-physical systems** (Bigliardi et al., 2020; Brodny & Tutak, 2022; Galizia et al., 2023; Karuppiah et al., 2022; Semeraro et al., 2023);
- **Digital skills** (Brodny & Tutak, 2022);
- **Horizontal or vertical integration** (Brodny & Tutak, 2022; Galizia et al., 2023; Karuppiah et al., 2022), **RFID** (Karuppiah et al., 2022);
- **Industrial internet** (Galizia et al., 2023);
- **Internet of Services** (Semeraro et al., 2023);
- **Internet of Things** (Bigliardi et al., 2020; Brodny & Tutak, 2022; Karuppiah et al., 2022; Semeraro et al., 2023; Tobon-Valencia et al., 2022; Tubis & Grzybowska, 2022);
- **Machine learning** (Bigliardi et al., 2020);
- **Simulation and digital twin** (Galizia et al., 2023; Semeraro et al., 2023; Tobon-Valencia et al., 2022), **simulated reality** (Tubis & Grzybowska, 2022);
- **Virtual reality** (Semeraro et al., 2023; Tobon-Valencia et al., 2022), **mixed reality** (Tubis & Grzybowska, 2022).

Figure 1 shows a diagram of the most commonly used technologies and terms related to Industry 4.0 developed based on the above list of words.

Figure 1 The most frequently mentioned technologies related to Industry 4.0



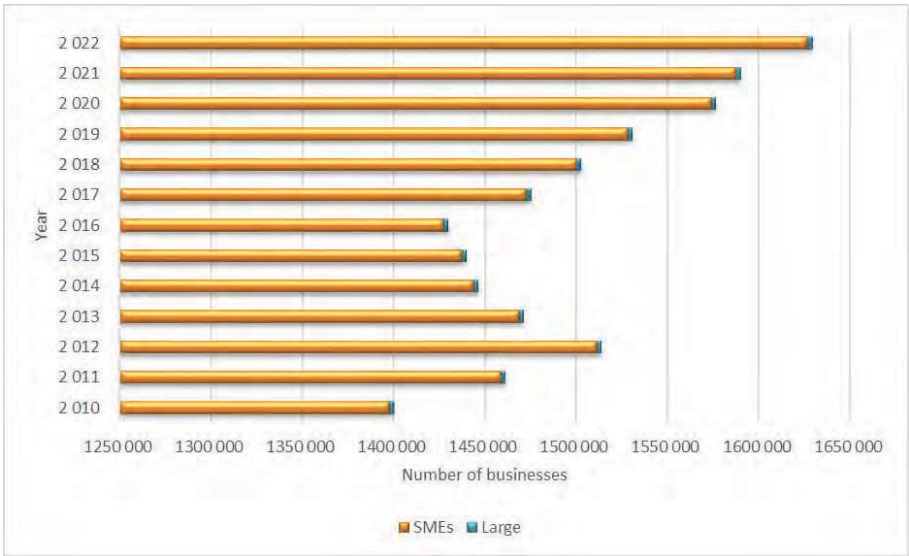
Source: Own processing

Small and medium-sized enterprises represent an integral part of the Czech economy. They also play a significant role in the European Union and worldwide. In the European Union, they represent 99 % of all businesses and provide two-thirds of jobs in the private sector. The same percentage of SMEs in all enterprises is registered in the Czech Republic. Therefore, ensuring their sufficient competitiveness should be one of the main priorities for national/supranational policies (Cordina, 2023). However, financing the implementation of new technologies can be a significant problem for such businesses. As reported by the Ministry of Industry and Trade of the Czech Republic (2021), small and medium-sized organizations are very vulnerable in financing, and finances were perceived as the most significant problem in their operation by 10 % of enterprises in 2022. However, it should be noted that before the arrival of the COVID-19 pandemic, the Czech Republic had a positive trend in this area. As in 2011, finances were a problem for 12 % of businesses, but by 2019, this share had decreased to 8 %.

The awareness of small and medium-sized enterprises about the importance of new technologies is summarized by Krajčík (2021). A general understanding of new technologies is not very high in the group of SMEs. Representatives of these organizations most often seek information themselves, e.g., in the form of conferences. However, it is alarming that most companies do not consider implementing new technologies in their strategy or plans. On the other hand, 14 % of businesses have at least started to take the first steps. However, 40 % of organizations do not see this topic as their main priority shortly. Based on their analysis of small and medium-sized enterprises, Brodny & Tutak (2022) find that the level of digitalization in the Czech Republic varies according to the enterprise size. For small businesses, the above is already true – the status and awareness of digitalization are deficient (at the level of countries such as Romania or Bulgaria). Medium-sized enterprises are already at an average level (such as Croatia or Estonia). In terms of large enterprises, the Czech Republic is among the best countries in the analysis.

To illustrate the situation in the Czech Republic, Figure 2 is offered. The evolution of the number of small and medium-sized organizations against the number of large enterprises is illustrated here. It is evident that small and medium-sized enterprises dominate in the Czech Republic, and in this comparison, we can see how low large enterprises there are. That is why it is essential to be interested in the situation of most companies in the Czech economy.

Figure 2 Comparison of the number of SMEs and the number of large enterprises in the period 2010-2022



Source: Czech Statistical Office (2023), own processing

3 Methodology

The main aim of this paper is to find out what technologies are most used by small and medium-sized enterprises in the Czech Republic and what factors determine the level of their implementation. The results are based on data collection between November 2022 and February 2023. The investigated technologies are selected based on previous research and analysis of the empirical literature.

A questionnaire survey was used for data collection, which took place online. The return rate was approximately 4,8 %, and 1 271 were asked for the study. Companies were approached completely randomly or without focusing on a specific industry. No sample specification criteria were applied. It can be stated that the structure of enterprises is approximately 50:50 in terms of the division between enterprises that offer services and enterprises that manufacture products. Financial and accounting companies have a significant presence in terms of services. From the point of view of companies producing products, companies from the construction and crafts sectors. The questionnaire consisted of open (2) and closed questions (12) and also included semi-open questions (5). Managers, owners, and executives of small and medium-sized organizations were addressed. The sample consisted of microenterprises (36), small enterprises (13) and medium-sized organizations (12). The core of the whole survey was the knowledge of how much organizations use selected technologies – Big Data, Machine Learning, Internet of Things, Artificial Intelligence, Smart Sensors, 3D printing and 3D scan, Cloud Storage, Robotization, Digitalization, Cyber Protection, and Virtual Reality. Usage rates were rated by respondents using a Likert scale on a scale of 0-5, where 0 meant that the company was not using the technology at all and 5 meant maximum use. Subsequently, it was observed whether the size of the enterprise (micro, small, medium) and awareness of Industry 4.0 (none, average, significant) independently affect the degree of use of automation/digitalization of activities in the enterprise, which was divided into two simple intervals (0-50%; 51-100%). The fact that these variables can impact the perception and implementation of new technologies is pointed out by Krajčík (2021) or Brodny & Tutak

(2022). It is reasonable to verify this claim. The interdependence or correlation between the two variables has not been investigated.

Two hypotheses were developed to answer the above questions, designated as "A" and "B."

$H_{0(A)}$: The size of the enterprise does not affect the degree of automation/digitalization of activities in the enterprise.

$H_{1(A)}$: The size of the enterprise affects the degree of automation/digitalization of activities in the enterprise.

$H_{0(B)}$: The level of awareness of Industry 4.0 does not affect the degree of automation/digitalization of activities in the company.

$H_{1(B)}$: The level of awareness of Industry 4.0 influences the degree of automation/digitalization of activities in the company.

The pivot table's independence test was used to evaluate the relationship between these variables. The significance level of the test was set at 5 %. All tested data can be characterized as categorical variables. This test was used because it is necessary to verify whether the first factor (within the contribution is size and awareness of Industry 4.0) affects the second factor (degree of use). Generally, the most used test for such verification is the chi-square test. The same test is used in studies, e.g., by Sujová & Simanová (2022). The general prerequisites for the test have been met, namely that more than 80 % of the elements of the table reached a theoretical frequency higher than 5, and 100 % of the characteristics of the table got a theoretical frequency higher than 2. During the test, the following formula was used to calculate the test characteristic (modified by the author):

$$\chi^2 = \sum_{i=1}^{r} \sum_{j=1}^{c} \frac{(n_{ij} - e_{ij})^2}{n_{ij}} \quad (1)$$

Where:
χ^2 Chi-square statistics
n_{ij} Observed frequencies
e_{ij} Expected frequencies

The calculated value was then compared with the critical value of the distribution (modified by the author), where:

$$\chi^2 \geq \chi^2_{(r-1)(c-1)}(1-\alpha) \quad (2)$$

Where:
$\chi^2_{(r-1)(c-1)}(1-\alpha)$ Critical value of the chi-squared distribution

, then H_0 is rejected (Mrkvička & Petrášková, 2006).

4 Results

Based on the research carried out, the technologies most frequently used by SMEs have been identified. On a scale of 0 to 5, respondents rated the technologies listed in Table 2. As can be seen from the table itself, the most commonly used technologies on a scale of 0-5 are primarily Cloud Storage (3,07), followed by Digitalization (2,85) and Cyber protection (2,33). Surprisingly, the use of the Internet of Things remains relatively in the background (1,59). On the other hand, the least used technologies are Machine learning (0,75) and Virtual reality (0,72).

Table 2 Technologies used

	Statistical indicator				
Technology	**N valid**	**Mean**	**Median**	**Modus**	**Standard deviation**
Big data	61	0,93	0	0	1,55
Machine learning	61	0,75	0	0	1,30
Internet of Things	61	1,59	1	0	1,48
Artificial Intelligence	61	1,13	0	0	1,48
Smart sensors	61	1,20	1	0	1,42
3D printing/3D scan	61	1,00	0	0	1,53
Cloud	61	3,07	3	5	1,83
Robotization	61	1,34	0	0	1,67
Digitalization	61	2,85	3	4	1,69
Cyber-security	61	2,33	2	0	1,78
Virtual reality	61	0,72	0	0	1,26

Source: own processing

The question remains, however, how this distribution of technology use will change in the future. Table 3 shows how respondents think about adopting new technologies in their businesses in the near term. The potential of technologies was rated on a scale of 0-5, and in the future, Cloud Storage (3,51), Digitalization (3,34), and Cyber Protection (3,00) were identified as key for enterprise deployment. Big data and Machine learning were identified as the technologies with the lowest importance for future adoption (1,28).

Table 3 Future technologies

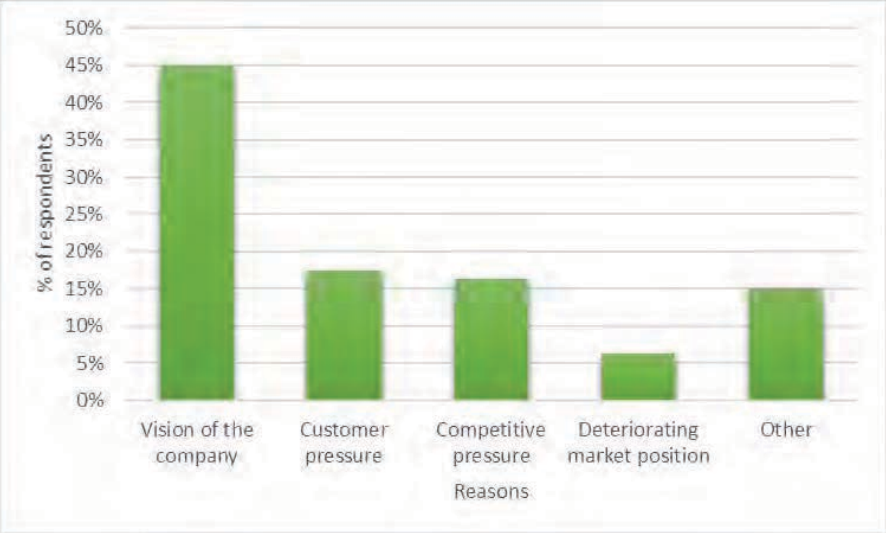
	Statistical indicator				
Technology	**N valid**	**Mean**	**Median**	**Modus**	**Standard deviation**
Big data	61	1,28	1	0	1,61
Machine learning	61	1,28	1	0	1,58
Internet of Things	61	2,15	2	0	1,88
Artificial Intelligence	61	1,79	1	0	1,78
Smart sensors	61	1,87	2	0	1,86
3D printing/3D scan	61	1,46	1	0	1,68
Cloud	61	3,51	4	5	1,74
Robotization	61	1,77	1	0	2,04
Digitalization	61	3,34	4	5	1,87
Cyber-security	61	3,00	3	5	1,85
Virtual reality	61	1,54	1	0	1,56

Source: own processing

However, it can be noted as a positive fact that for all the technologies examined, companies expect them to be more useful in the future. The highest difference between the current usage rate and the potential for deployment and use was recorded by Virtual reality (+0,82) and Smart sensors, along with Cyber protection (+0,67). On the other hand, the lowest recorded difference between the current usage rate and the potential for deployment and usage is found in Big data (+0,35).

In general, businesses claim that they support innovation and the introduction of new technologies, which are necessary for their further development. On a scale of -2 (no innovation needed) to 2 (innovation is essential), the average score for all enterprises was 0,72. Based on this knowledge, further development of technologies can be expected in the future. In addition, it is worth mentioning that companies introduce new technologies and implement innovations mainly based on internal pressures. Figure 3 shows the reasons for implementing new technologies in enterprises.

Figure 3 Reasons for implementation of Industry 4.0



Source: Own processing

The next step was to evaluate the working hypotheses. The first hypothesis was formulated as follows:

$H_{0(A)}$: The size of the enterprise does not affect the degree of automation/digitalization of activities in the enterprise.

$H_{1(A)}$: The size of the enterprise affects the degree of automation/digitalization of activities in the enterprise.

To evaluate it, the independence test in the pivot table was used. It was found that the test characteristic χ^2 reaches 4,478. When compared to the critical value of the distribution $\chi^2_{(r-1)(c-1)}(1-\alpha)$ at significance level α = 0,05 and (r−1)(c-1) degrees of freedom, it was found that $\chi^2 < \chi^2_{(r-1)(c-1)}(1-\alpha)$. In the supplementary calculation, it was observed that the relation $p{-}value > \alpha$ holds here. For this reason, the null hypothesis about the independence of the size of the enterprise and the degree of automation/digitalization in the enterprise is not rejected. There is no evidence of a dependence between an organization's size and how strongly it implements new technologies.

The second working hypothesis was constructed as follows:

$H_{0(B)}$: The level of awareness of Industry 4.0 does not affect the degree of automation/digitalization of activities in the company.

$H_{1(B)}$: The level of awareness of Industry 4.0 influences the degree of automation/digitalization of activities in the company.

A test of independence in a pivot table was also used to evaluate it. It was found that the test characteristic χ^2 reaches 5,580. When compared to the critical value of the distribution $\chi^2_{(r-1)(c-1)}(1-\alpha)$ at significance level α = 0,05 and (r−1)(c-1) degrees of freedom, it was found that $\chi^2 < \chi^2_{(r-1)(c-1)}(1-\alpha)$. In the supplementary calculation, it was observed that the relation $p{-}value > \alpha$ also holds here. For this reason, the null hypothesis about the independence of Industry 4.0 awareness and the degree of automation/digitalization in the company is not rejected. There was no evidence of interdependence between the awareness of top managers and responsible persons about new technologies and the degree of their use in the organization.

5 Conclusions

The main aim of this paper was to find out what technologies are most used by small and medium-sized enterprises in the Czech Republic. Secondary attention was then focused on whether the selected variables influence the level of implementation of these new technologies. Based on the evaluation of the questionnaire survey, it was found that three technologies are most often used by small and medium-sized enterprises – Cloud, Cyber protection, and digitalization. Moreover, these technologies are expected to remain the most widely used. In contrast, it was found that the least implemented in enterprises are Machine learning and Virtual reality. In the future, enterprises expect to make the most minor use of Big data and Machine learning. The vision of the enterprise is the main reason for implementing new technologies. Other, less important reasons are the pressure of competition or customers. However, it was found that the size of the enterprise does not affect the degree of automation in SMEs. There was also no dependence between Industry

4.0 knowledge and the adoption rate of new technologies. It is essential to point out that the conclusions drawn from the above can primarily be applied to companies represented in the questionnaire survey. However, according to the low number of respondents, the results of this research can hardly be generalized.

Last but not least, the limitations and barriers of this research must not be forgotten. It is also appropriate to outline possible directions of research in the future. The study was conducted in a defined area, the Czech Republic. Data collection was also limited in time between 2022 and 2023. As a limitation, the entire investigation was carried out online. Several other future research can be carried out, e.g., focused only on a selected sector most strongly affected by this concept. A study with a larger sample of respondents is also appropriate.

The article's authors believe that the selected technologies cannot be directly linked to the field of business in all cases. It is obvious that, for example, digitalization technologies, the cloud, and cyber-protection are suitable and relevant for companies operating in all service and production sectors. At the same time, the authors must point out that the selected technologies, such as big data and machine learning, have a strong connection especially to companies operating in the ICT sector. Robotization and smart sensors then offer a direct relationship with manufacturing companies. It is, therefore, appropriate in the future to observe the development of technologies based on individual sectors.

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