The use of smart technologies in enterprises

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DOI: 10.32725/978-80-7394-976-1.22

Abstract: In the fourth industrial revolution, more and more things and devices are considered smart or intelligent. Smart technologies have applications in homes and cities as well as in businesses. This paper aims to examine the use of smart technologies in enterprises. Through statistical methods, enterprises were compared by size and industry branch. A questionnaire survey of 102 enterprises was conducted in the research. The most used smart technologies in enterprises were quality, machine consumption monitoring and maintenance management. The pressure on the efficiency of intelligent technology use also strains enterprises' long-term and systematic development and management.

Keywords: smart, technologies, Industry 4.0, enterprise size, technology application
JEL Classification: M11, Q55, O33

1 Introduction

In recent years, the word "smart" has become one of the keywords in modern scientific and technological development. The term Industry 4.0 was introduced by the German Industry–Science Research Alliance (Buhr, 2017). It refers to modern and advanced production automation and covers the current progressive technologies in industrial production. The primary vision and critical concept of Industry 4.0 is an intelligent factory that monitors its environment through machines without human force (Osterrieder et al., 2020) and their sensors and makes decentralized but highly informed decisions to optimize production. It is the online interconnection of the manufacturer's internal systems and the entire value chain from suppliers on the one hand to customers on the other. Industry 4.0 is a revolution and an evolution (Asadollahi-Yazdi et al., 2020). It uses existing technologies, which have been on the market for a long time and have matured into an entirely usable and integrative state. Connecting individual devices and sharing data is the essence and driving force behind the fourth industrial revolution.

Modern technologies are increasingly used for comfortable living and home (Darby, 2018). Electronic devices are part of the Internet of Things, enabling remote communication and control, including autonomous functions. Development activities focus on automation of individual household elements, systems for remote management of devices, central control systems, communication tools, data storage and transmission, etc. In household appliances, enterprises developed new functions, smart grids, energy-saving and consumption monitoring, air condition and lighting control, solutions, security and communication systems (Li et al., 2018).

Digital technologies can improve production processes (e.g. reducing resource use) and products (e.g. longer life cycles), thus contributing to reduced industrial waste and a green transition. Green technologies combine emission reduction, energy efficiency and renewable energy technologies to fulfil carbon emission reduction (Hottenrott et al., 2016). Green technologies cover four main sectors: energy power, fuel for transportation, water purification and treatment, and clean materials (Hee-Eun, 2011). These technologies include activities with minimal environmental effects (Mohammed, 2021). Green technologies have applications in the fields of chemicals, construction, transport, energy or waste management. They all are committed to reducing the impacts of climate change, preventing its causes and developing sustainably.

Logistics 4.0 is most often used to refer to logistics innovations and applications added by cyber-physical systems (CPS) and the latest information technologies for optimization of storage capacity and transport routes (Holubčík et al., 2021). The application of automation in logistics has its most incredible application in warehouses and in the dispatch of goods, where machines can take over physically demanding and routine work for humans. Current digitized logistics addresses optimizing the flow of materials, semi-finished and finished products inside and outside plants. Robotic process automation (RPA) is increasingly becoming a standard part of logistics systems, often replacing manual transcription and order processing (Flechsig et al., 2022). Another building block of Supply Chain Logistics 4.0 is the intelligent warehouse

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management system (WMS), whose task is to provide information on the immediate status of inventory, react flexibly to current orders and communicate with the production planning system (Lototsky et al., 2019).

Similarly, the distribution and dispatch logistics are based on a system that starts with receiving goods into the warehouse and ends with transporting the final product to the end customer. Intelligent transportation systems can plan transport routes with optimum utilization of the vehicle fleet and dynamically designed transport trajectories taking into account consumption or vehicle maintenance prediction systems (Barreto et al., 2017). In Logistics 4.0, these will be fully autonomous (driverless), navigating entirely with the help of computer systems that detect the vehicle's surroundings and determine its route (Sell et al., 2019).

The conditions for maintenance of production equipment will continue to improve in the context of Industry 4.0. Manufacturers will focus more on failure-free, maintainability and other aspects, or the entire maintenance assurance. Operational reliability will need to be more closely monitored during the whole life cycle of the equipment. Predictive maintenance allows machines and robots performing production to communicate continuously and inform each other about non-standard situations. Machines self-report to maintenance personnel (or robots) and precisely define the problem (Pech et al., 2021).

Quality 4.0 can be understood as a combination of new technologies, standard tools, and traditional methods to achieve superior performance, higher operational efficiency and higher quality, excellence and innovation (Antony et al., 2021). A quality management system (QMS) should focus on maintaining a complete and comprehensive product design stored in a single system. Furthermore, small and global enterprises can quickly adapt their design processes for new products, including processes throughout the supply chain network, by digitizing and automating design and manufacturing processes. A supply chain quality system is a set of relationships between customers and suppliers that create quality chains (Amoozad Mahdiraji et al., 2012). Quality is meeting a technical standard and complementing the product with appropriate after-sales services.

2 Methods

The research aimed to assess the use of smart technologies in enterprises. A sub-objective was to analyze through a statistical validation the effect of enterprise size on the application of these technologies. We tried to find out how enterprises differ in their technology use.

The data are drawn from a questionnaire survey carried out on a sample of 164 Czech enterprises in 2018. This sample is part of the third wave of research (Vrchota and Pech, 2019), and 104 enterprises participated. After adjustment, wiping, and data cleaning, 102 questionnaires were used for the analysis. The questionnaires were submitted to executives and managers of enterprises and focused on smart technologies. The questions are focused on quality management and machine maintenance, smart air conditioning and lighting control, the use of green technologies, energy consumption monitoring, smart grids (real-time energy control), and intelligent storage and transport management. The questions in the questionnaire were in the form of a Likert scale (1 - little used technology, 5 - much-used technology). The processing of the answers is based on averages, which determine the weight of each possibility.

The classification of enterprise size is based on the methodology (European Commission, 2003). The analyzed groups consist of: 13 micro enterprises (less than ten employees), 32 small enterprises (10-49 employees), 29 medium-sized enterprises (50-249 employees) and 28 large enterprises (over 250 employees). There were 44 enterprises engaged in engineering production, 19 enterprises involved in non-metallic products, plastics or chemical production, 13 enterprises engaged in electrical manufacturing, 14 enterprises focused on food products, and 12 enterprises manufacturing household goods represented in the industry.

The obtained results were first subjected to statistical analysis by Levene's test for homoscedasticity in STATISTICA software. Homoscedasticity means that the residuals are drawn from a population with constant variance. Otherwise, heteroscedasticity refers to situations where the variance of the residuals is unequal over a range of measured values. If heteroscedasticity was insignificant (H_0 could not be rejected at $p < 0.05$ for agreement of variances), then ANOVA was used to test the means differences. Otherwise, heteroscedasticity was significant, and the Kruskal-Wallis test had to be performed (Meloun & Militký, 2004). The working hypotheses of interest, which form the subject matter of the test of means (or medians) verification, are the following:

- H0: There is no difference in using smart technology according to the enterprise size.
- HA: There is a difference among enterprises in using smart technology according to the enterprise size.

Tests of means indicated whether or not there are any statistically significant differences in means (in case of ANOVA) or medians (in case of Kruskal–Wallis test). We tested these hypotheses for each of the nine observed smart technologies. Then, the differences were verified by multiple comparison tests for each size group of enterprises. This allowed us to identify which enterprises have statistical differences (for example, small and large enterprises). We set the level of significance alpha to 0.05 (5 %)for all used tests and statistical evaluations. Significant results (including the significance level reached – p-value) are presented in the text.

3 Research results

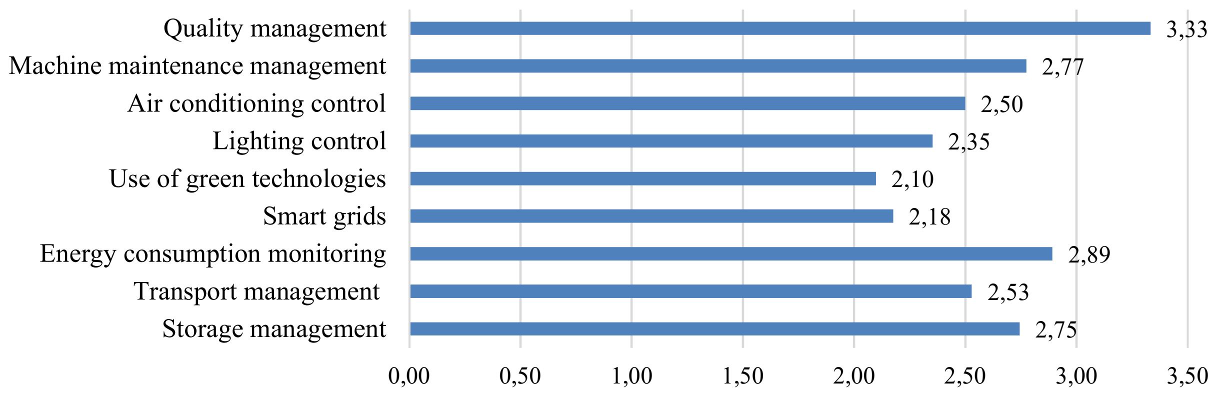
This section outlines the study's main results divided into two sections: widespread application of smart technologies and evaluation of differences between enterprises according to size.

3.1 Application of smart technologies

The widespread application of smart technologies in enterprises is depicted in Figure 1. The summary of main results obtained at various stages of the research shows that Quality management was rated the best with an average rating of 3.33. Quality is always the first thing a customer expects from a manufacturer. Enterprises have been dealing with this for a long time because products would not be competitive in the market area without achieving the necessary quality.

Smart metering is a way to measure the consumption of electricity, water, gas or heat in real-time and remotely. Sensors take regular electricity or gas consumption measurements, and the readings are sent to the Cloud, which can then be displayed in a connected app. Along with this technology is the deployment of smart grids (rating 2.18), which allow real-time regulation of electricity generation and consumption locally and globally. They involve decentralized electricity generation sources (solar and wind power plants, gas-fired microturbines etc.), allowing customers to produce and sell surplus electricity to the grid.

Figure 1 Average rating of smart technologies application



Source: Own processing

Machine maintenance management is a prerequisite for smooth production. Earlier maintenance methods were based on precisely defined maintenance deadlines based on performance (e.g. kilometres travelled) or on time worked (days). Maintenance was carried out either as routine service, intermediate administration or overhauls. It was very uneconomical because the machine's condition depended on how well the operator cared for it. Even if the device was in good condition and could continue to work, it had to undergo scheduled maintenance and be taken out of the production process for a certain period. New technologies make it possible to detect changes in the operation of a machine by comparing the vibration record of a device in good condition with a machine that deviates from this ideal condition. Maintenance is only carried out when it is needed.

The following questions include climate control (rating 2.50) and lighting control (rating 2.35). These physical factors are usually addressed simultaneously by enterprises. Particularly in today's energy crisis, it is essential to focus on this area, as there are significant savings opportunities here. For example, lights can only be switched on when someone enters a designated area. In the case of air conditioning, it is not necessary to heat the production hall in the same way in all places but to create different workplaces with segmented rubber walls and then heat them according to the nature of the work. As our survey was carried out before the energy crisis, it is clear that enterprises had not yet focused on this area or even underestimated it.

In transport management (rating 2.53), new technologies make it possible to track a vehicle's journey on roads anywhere in Europe and send the necessary information directly to digital maps at short intervals of about ten minutes based on satellite observations of cars. However, the situation has also changed in the communication with the driver. Drivers now receive instructions from their dispatcher on the route to make the journey either as short as possible or with the lowest possible diesel consumption. Nevertheless, enterprise dispatchers have a significant role in managing transport.

They have to make decisions based on a great deal of information about almost everything the driver has to do in the vehicle.

Intelligent storage management has a slightly higher rating (2.75), which is probably related to the fact that the enterprises have implemented this operation under supervision. There is a real revolution in warehousing systems today, and it is believed that eventually no workers will be needed in warehouses, and this area can be completely automated and robotized. So far, enterprises are about halfway there. It is a matter of loading and unloading operations and replacing paper-based filing and manual handling with progressively appropriate technical systems.

Enterprises reported using green technologies with the lowest rating, only 2.10. Enterprises do not yet see benefits in this area. Rather only see costs. The energy crisis will probably lead to changes, especially in constructing new buildings, where more electricity from photovoltaic panels or better water management will be needed. Rainwater must be harvested and used wherever it can replace existing drinking water consumption. Buildings will also have to be designed to prevent large heat leaks, and green plants will be more common on roofs, etc.

3.2 Differences between enterprises

Table 1 summarises the differences between enterprises by size, showing the average rating of enterprises. The results show that large enterprises have higher ratings for using smart technologies. On the contrary, managers of micro and small enterprises reported that they do not implement these technologies much. It may be mainly due to higher financial requirements or a lack of information about the possibilities of their use. According to the results, it was also found that large, medium and small enterprises use smart technologies most in quality management. In this case, it may be mistake-proofing devices, Internet of Things, RFID, artificial intelligence and machine learning for big data analytics. Large and medium-sized enterprises also needed energy consumption monitoring and storage management technology. Small enterprises often use machine maintenance management (2.59) and air condition control (2.50). Micro enterprises primarily use quality management (2.00) and energy consumption monitoring (2.08).

Table 1 Evaluation of smart technologies application according to the enterprises' size

Smart technology application	**Micro enterprises**	**Small enterprises**	**Medium enterprises**	**Large enterprises**
Quality management	2.00	3.28	3.21	4.14
Machine maintenance management	1.69	2.59	2.79	3.46
Air condition control	1.77	2.50	2.24	3.11
Lighting control	1.46	2.03	2.28	3.21
Use of green technologies	1.31	1.81	2.28	2.61
Smart grids (real-time energy control)	1.15	1.84	2.14	3.07
Energy consumption monitoring	2.08	2.28	2.86	4.00
Transport management	1.31	2.38	2.72	3.07
Storage management	1.08	2.31	2.90	3.86

Source: Own processing

We further tested working hypotheses that there is no difference in using smart technology according to the enterprise size. We evaluated the differences for all technologies studied. First, we used Levene's test to investigate whether the residuals are drawn from a population with constant variance. The results of the homoscedasticity tests are shown in Table 2. Only in the case of air condition control (p-value = 0.0942) was it impossible to reject the hypothesis of matching variances - homo. Thus, in this case, analysis of variance (ANOVA) was used to test for the consistency of means. The study of variance shows that there are differences between the enterprises for air conditioning. Otherwise, for other technologies were, heteroscedasticity for smart technology applications conclusive. Thus, it was necessary to use the Kruskal-Wallis ANOVA test. From the results in Table 2, it is clear that for all technologies, differences were found between groups of firms by size. Thus, we can conclude that differences between enterprises were found in all the technologies studied. Furthermore, we performed a multiple pairwise comparison analysis to more accurately identify differences.

Table 2 Differences in the evaluation of smart technologies application according to the enterprises' size

	Levene's test		**Variance analysis**		**Kruskal–Wallis ANOVA**	
Smart technology application	**F**	***p*-value**	**F**	***p*-value**	**H**	***p*-value**
Quality management	4.5923	0.0047*	-	-	18.3394	0.0004*
Machine maintenance management	4.7092	0.0041*	-	-	13.4763	0.0037*
Air condition control	2.1886	0.0942	3.6409	0.0154*	-	-
Lighting control	5.4505	0.0017*	-	-	16.1861	0.0010*
Use of green technologies	8.2746	0.0001*	-	-	9.2328	0.0264*
Smart grids (real-time energy control)	8.7066	0.0000*	-	-	20.2019	0.0002*
Energy consumption monitoring	4.1064	0.0086*	-	-	29.0639	0.0000*
Transport management	5.6896	0.0012*	-	-	13.0352	0.0046*
Storage management	11.8088	0.0000*	-	-	32.2990	0.0000*

Source: Own processing

Pairwise comparison results showed the following findings:

- Quality management. Results show differences between micro and large enterprises (*p*-value = 0.0003). Small enterprises apply costly quality management systems to a lesser extent despite the lack of financial and human resources that are typical for them.
- Machine maintenance management. The pairwise comparison reveals differences between micro and large enterprises (*p*-value = 0.0031). The biggest challenge for micro-enterprises in implementing smart maintenance is the development of their information systems and platforms for their connection to mobile applications. Although, with the advent of the Cloud, many functions can be implemented through IT services.
- Air condition control. The LSD pairwise comparison test show differences between micro and large enterprises (*p*-value = 0.0034), medium-sized and large enterprises (*p*-value = 0.0155). In smaller companies, air conditioning is used more for technological or production reasons. It is not often used for administrative purposes or to improve the working environment.
- Lighting control. Results show differences between micro and large enterprises (*p*-value = 0.0025), small and large enterprises (*p*-value = 0.0240). Lighting control is often used to save energy. Large enterprises are more likely to use it due to the larger production scale.
- Green technologies. Pairwise comparisons indicate differences between micro and large enterprises (*p*-value = 0.0490). Even green technologies are used more by large enterprises with sufficient capacity to implement them.
- Smart grids. Pairwise comparison show differences between micro and large enterprises (*p*-value = 0.0005), small and large enterprises (*p*-value = 0.0170). Smart grids tend to be built by large energy utilities due to high acquisition costs. Therefore, differences were also evident between large and medium-sized enterprises.
- Energy consumption monitoring. Pairwise comparison show differences between micro and large enterprises (*p*-value = 0.0003), small and large enterprises (*p*-value = 0.0000), medium-sized and large enterprises (*p*-value = 0.0151). Currently, it transpires that energy monitoring is still the domain of large enterprises that use SCADA systems for central monitoring of industrial processes.
- Transport management. Pairwise comparison show differences between micro and large enterprises (*p*-value = 0.0044), micro and medium-sized enterprises (*p*-value = 0.0377). Electromobility, autonomous cars and other technological innovations in the transport sector seem to be more the domain of large companies.
- Storage management. Pairwise comparison show differences between micro and large enterprises (*p*-value = 0.0000), small and large enterprises (*p*-value = 0.0017), micro and medium-sized enterprises (*p*-value = 0.0029). The financial complexity of smart warehouse technologies creates a gap between businesses. Smaller enterprises use manual warehousing, while semi-automatic or fully automatic systems use large enterprises.

Overall, we can conclude that differences between micro, small and large enterprises were mostly found. These findings are based on large enterprises' advantages over small ones. Large enterprises are more successful in digital transformation. Small and medium-sized enterprises are vital financial support initiatives (Rupeika-Apoga et al., 2022). Small businesses have a disadvantage in terms of staffing for smart projects, high costs and lack of finance, little market knowledge and institutional obstacles that are likely to affect their innovation activities (Arza & López, 2021).

4 Conclusions

New technologies are constantly being mentioned in the professional press, but it is forgotten to emphasize that new technologies are not the target. The target must be the restructuring of the Czech economy and production. It will enable the production of products with higher added value. The new technologies should not merely increase the output of the existing production lines several times over but allows the transition to new energy sources that will produce ever less harmful emissions. Thus, they contribute to the European Union's strategic commitment to becoming the first continent to become carbon neutral by 2050.

Our research confirms that large enterprises play a significant role in applying new technologies. In contrast, small and medium-sized enterprises remain somewhat reticent to adopt these new developments. It is understandable, as new technologies require high investments with long-term returns. Clearly, the entire car industry is switching to electric cars. This fundamental change will affect thousands of smaller subcontractors working with these large multinationals. Similarly, major production-technology revolutions are taking place in the steel, construction and other industries. The EU is also supporting these efforts with large financial loans and grants to ensure that the competitiveness of European enterprises remains high even in these challenging conditions.

For small and medium-sized Czech enterprises, this implies that they cannot continue to wait or make only minor organizational adjustments. They must change their strategies fundamentally if they have not already done so. New technologies also bring the need for new professions; the old ones will quickly disappear. There is still a shortage of workers in the labour market. It will be up to the enterprises to retain the existing workers and retrain them for the necessary future professions.

Acknowledgement

This research was funded by "EF-150-GAJU 047/2019/S", supported by the University of South Bohemia in Ceske Budejovice.

References

Amoozad Mahdiraji, H., Arabzadeh, M., & Ghaffari, R. (2012). Supply chain quality management. *ManagementScience Letters*, *2*(7), 2463–2472. DOI: 10.5267/j.msl.2012.07.020

Antony, J., McDermott, O., & Sony, M. (2021). Quality 4.0 conceptualization and theoretical understanding: A global exploratory qualitative study. *The TQM Journal*. DOI: 10.1108/TQM-07-2021-0215

Arza, V., & López, E. (2021). Obstacles affecting innovation in small and medium enterprises: Quantitative analysis of the Argentinean manufacturing sector. *Research Policy*, *50*(9), 104324. DOI: 10.1016/j.respol.2021.104324

Asadollahi-Yazdi, E., Couzon, P., Nguyen, N. Q., Ouazene, Y., & Yalaoui, F. (2020). Industry 4.0: Revolution or Evolution? *American Journal of Operations Research*, *10*(06), 241–268. DOI: 10.4236/ajor.2020.106014

Barreto, L., Amaral, A., & Pereira, T. (2017). Industry 4.0 implications in logistics: An overview. *Procedia Manufacturing*, *13*, 1245–1252. DOI: 10.1016/j.promfg.2017.09.045

Buhr, D. (2017). *Social Innovation Policy for Industry 4.0*. Friedrich Ebert Stiftung.

Darby, S. J. (2018). Smart technology in the home: Time for more clarity. *Building Research & Information*, *46*(1), 140–147. DOI: 10.1080/09613218.2017.1301707

European Commission. (2003). *Recommendation of 6 May 2003 Concerning the Definition of Micro, Small and Medium-Sized Enterprises. Text with EEA Relevance, Notified Under Document Number C (2003) 1422.* European Commission.

Flechsig, C., Anslinger, F., & Lasch, R. (2022). Robotic Process Automation in purchasing and supply management: A multiple case study on potentials, barriers, and implementation. *Journal of Purchasing and Supply Management*, *28*(1), 100718. DOI: 10.1016/j.pursup.2021.100718

Hee-Eun, K. (2011). Defining Green Technology. In *The Role of the Patent System in Stimulating Innovation and Technology Transfer for Climate Change* (s. 15–20). Nomos Verlagsgesellschaft mbH. https://www.jstor.org/stable/j.ctv941r23.5

Holubčík, M., Koman, G., & Soviar, J. (2021). Industry 4.0 in Logistics Operations. *Transportation Research Procedia*, *53*, 282–288. DOI: 10.1016/j.trpro.2021.02.040

Hottenrott, H., Rexhäuser, S., & Veugelers, R. (2016). Organizational change and the productivity effects of green technology adoption. *Resource and Energy Economics*, *43*, 172–194. DOI: 10.1016/j.reseneeco.2016.01.004

Li, M., Gu, W., Chen, W., He, Y., Wu, Y., & Zhang, Y. (2018). Smart Home: Architecture, Technologies and Systems. *Procedia Computer Science*, *131*, 393–400. DOI: 10.1016/j.procs.2018.04.219

Lototsky, V., Sabitov, R., Smirnova, G., Sirazetdinov, B., Elizarova, N., & Sabitov, Sh. (2019). Model of the Automated Warehouse Management and Forecasting System in the Conditions of Transition to Industry 4.0. *IFAC-PapersOnLine*, *52*(13), 78–82. DOI: 10.1016/j.ifacol.2019.11.137

Meloun, M., & Militký, J. (2004). *Statistická analýza experimentálních dat* (2.). Academia.

Mohammed, S. I. (2021). Advantages of Green Technology to Mitigate the Environment Problems. *IOP Conference Series: Earth and Environmental Science*, *779*(1), 012133. DOI: 10.1088/1755-1315/779/1/012133

Osterrieder, P., Budde, L., & Friedli, T. (2020). The smart factory as a key construct of industry 4.0: A systematic literature review. *International Journal of Production Economics*, *221*, 107476. DOI: 10.1016/j.ijpe.2019.08.011

Pech, M., Vrchota, J., & Bednář, J. (2021). Predictive Maintenance and Intelligent Sensors in Smart Factory: Review. *Sensors*, *21*(4), 1470. DOI: 10.3390/s21041470

Rupeika-Apoga, R., Bule, L., & Petrovska, K. (2022). Digital Transformation of Small and Medium Enterprises: Aspects of Public Support. *Journal of Risk and Financial Management*, *15*(2), 45. DOI: 10.3390/jrfm15020045

Sell, R., Rassõlkin, A., Wang, R., & Otto, T. (2019). Integration of autonomous vehicles and Industry 4.0. *Proceedings of the Estonian Academy of Sciences*, *68*(4), 389. DOI: 10.3176/proc.2019.4.07