Advantages and Barriers of Industry 4.0 Concepts Implementation in Small and Medium Industrial Enterprises

Elena Mezentseva*

Institute of Economics, the Ural branch of RAS, 620014 Ekaterinburg, Russia

Abstract. In the context of Industry 4.0, processes in industrial production are radically reorganized, including digitalization. The subject of the research is the processes of digitalization of small and medium-sized industrial enterprises. The purpose of the study was to identify the current areas of digitalization and the implementation of Industry 4.0 at industrial SMEs. Based on the bibliographic analysis, it was revealed the need for special research for the implementation of Industry 4.0 technologies in SMEs, which will allow to transform them into smart factories. The advantages and limitations for the implementation of Industry 4.0 technologies in manufacturing SMEs are highlighted. On the basis of statistical analysis and analysis of indices, the readiness of Russian SMEs for digitalization was assessed; constraining factors, implemented digital technologies, and prospects for entering new markets were identified.

1 Introduction

Industry digitalization is a core attribute of Industry 4.0. The term Industry 4.0 describes the ongoing revolution in manufacturing around the world. Large companies have quickly taken up the challenge of Industry 4.0 and are currently working intensively to implement the appropriate technologies. Small and medium-sized enterprises (SMEs) face certain obstacles in this regard, as they often do not have the human and financial resources to systematically study the potential and risks of implementing Industry 4.0. At the same time, in most countries, SMEs form the backbone of the economy, accounting for a large share of gross domestic product and employment. The Russian Federation sets itself the task of increasing the share of small business in the economy to the level of developed countries. In this regard, it is necessary to study the opportunities and challenges of Industry 4.0 separately, taking into account the specifics of SMEs, which will create the basis for the digital transformation of traditional SMEs into smart factories [1].

The purpose of this study is to identify the current areas of digitalization and the features of Industry 4.0 achievements implementation at industrial small and medium-sized enterprises.

* Corresponding author: mezentseva_elena@mail.ru

2 Materials and methods

It should be noted that a rather limited number of scientific works are devoted to the topic of Industry 4.0 principles introduction and digitalization of industrial SMEs. We have carried out a bibliographic analysis of the WoS, Scopus and Elibrary databases on ekey words “Small and Medium Enterprises” and “Industry 4.0” and “Digitalization in Small Manufacturing Busines”. Among foreign publications, we found several articles in journals, several book chapters, most of the publications are articles in conference proceedings that are more of empirical character. We should notice that the topic “Industry 4.0 for SMEs” is gaining more and more importance for scientists engaged in engineering and industrial research.

Among the publications in Russian, there are practically no scientific works on the topic of industrial small business in the context of Industry 4.0. The same applies to statistical data on the level of digitalization of manufacturing SMEs in the Russian Federation. There is no such data. Statistical studies of the level of digitalization in the Russian Federation concern only large and medium-sized businesses. We identified the readiness of SMEs for digitalization, constraints, and the introduced digital technologies based on an analysis of ratings related to both digitalization itself and ratings that assess the business activity of SMEs.

3 Features of Industry 4.0 principles implementation in industrial enterprises

In recent years, the industrial environment has changed radically due to the introduction of the concepts and technologies of Industry 4.0 (I4.0), also known as the Fourth Industrial Revolution or Smart Manufacturing. The I4.0 concept is based on the integration of information and communication technologies (ICT) and advanced industrial technologies into the so-called cyber-physical systems aimed at creating a digital, intelligent and sustainable enterprise [2]. The main value of I4.0 is to connect products, machines and people with the environment and to integrate production, information technology and the Internet [3].

In addition, the competition in the global industry is now seriously increasing. It is no longer enough to produce faster, cheaper and with higher quality than the competitors. Businesses in the industry need to implement new types of innovative and digital manufacturing strategies to maintain their current competitive advantage over the long term. The changes associated with the 4th industrial revolution should apply to the entire production and supply chain of components, and not only, as it was before, to the process of mechanical production of products and the organization of related processes.

The development of Industry 4.0 should result in improved communication throughout the production lifecycle, which will benefit all parties involved. Therefore, in order to remain competitive, businesses must respond quickly and flexibly to customer requirements and produce more versions of products in small batch sizes [4]. Industry 4.0 aims, on the one hand, to introduce highly efficient and automated production processes typical of mass production, and on the other hand, to create an industrial environment where individual and customer-specific products are produced in accordance with mass customization strategies [5]. Mass customization means the production of customized products for a customer at production costs similar to those of mass production. Manufacturing based on the principles of Industry 4.0 creates conditions for the replacement of traditional structures, which are based on centralized decision-making mechanisms and rigid restrictions on individual stages of value creation. These structures are being replaced by flexible, reconfigurable

manufacturing and logistics systems that offer interactive and collaborative decision making mechanisms.

In an environment characterized by mass customization and "design for X" (Design for eXcellence)), a manufacturer should provide the customer with more features and customization options, as well as provide more flexibility, transparency and globalization of supply chains. On the other hand, it also puts manufacturing companies in a more difficult situation. It is not easy to respond quickly to the expectations and requirements of customers, it requires flexible and easily adaptable production systems [6].

4 Advantages of Industry 4.0 principles for SMEs

In recent years, a growing number of authors in European countries have turned to the topic of the of Industry 4.0 impact on SMEs in their scientific works. Matt D.T. [7] make the earliest attempt to substantiate a methodological approach to how SMEs can implement Industry 4.0. They talk about the opportunity for SMEs to use Industry 4.0 concepts to overcome the tension between the need to automate production and reduce batch sizes. E. Rauch, P. Dallasega began to study how Industry 4.0 concepts and technologies can be appropriately applied to SMEs [8]. Safar L. [9] and Muller J.M. [10] describe a specific framework for introducing new, innovative, and digital business models in SMEs. Bar K. [11] talk about the existing research gap in strategies for implementing the Industry 4.0 concepts of SMEs and offer their solution in the aspect related to supply chains.

As the previous financial and economic crisis showed, thanks to their flexibility, entrepreneurial spirit and innovative capabilities, SMEs turned out to be more resilient than large and multinational enterprises [7]. Typically, SMEs are adaptive and innovative not only in their products but also in their manufacturing practices. Recognizing the continuing competitive pressures, small organizations are becoming more proactive in improving their business operations, which is a good starting point for introducing new concepts such as Industry 4.0. The successful implementation of Industry 4.0 should take place not only at large enterprises, but also at SMEs [12]. Industry 4.0 technologies offer great opportunities for the SME sector to increase its competitiveness.

SMEs are most likely to benefit from this technological shift; they can often digitalize faster than large enterprises because it is easier for them to design and implement new IT structures from scratch [13]. Many SMEs are already focusing on digital products to find their niche in the market [14]. The integration of information and communication technologies (ICT) and modern technologies of Industry 4.0 will transform today's SMEs into smart factories with significant economic potential [15, 16].

The advances in I4.0 are especially interesting for small businesses as they imply the ability to intelligently automate a batch size one. Thanks to networked production technologies, individual production at low costs will be possible.

5 Barriers of an Industry 4.0 principles implementation in industrial SMEs

On the other hand, Industry 4.0 presents a particular challenge for businesses in general and for small and medium-sized businesses in particular. The willingness of SMEs to adapt to Industry 4.0 through new concepts, as well as the organizational capacity of SMEs to meet this challenge, are very limited. The smaller the SMEs, the higher the risk that they will not be able to benefit from this industrial revolution. This opens up the need for further research and action plans for the preparation of SMEs in a technical and organizational direction [12]. The introduction of Industry 4.0 is often fraught with difficulties, which

gives rise to the opinion among specialists that most of the manufacturing SMEs are currently not yet ready to implement the concepts of Industry 4.0 [17, 18].

E. Rauch [8] say that in most cases the digital revolution creates significant problems for SMEs and cannot be implemented in the way it is theoretically indicated in the literature. In practice, this shift requires not only large financial resources, which is a serious problem for SMEs, but also creates difficulties from a strategic point of view. G. Orzes [18] identified a set of barriers and obstacles faced by SMEs in the implementation of Industry 4.0 and classified them into six categories: financial and economic, cultural, competencies / resources, technical, legal and implementation process.

Manufacturing companies, and especially SMEs, use the potential of I4.0 to improve shop floor productivity [19]. Very often they do not know how to answer I4.0 calls or how to start implementing the principles of the I4.0 concept [20]. The introduction of new technologies and practices for SMEs is always fraught with risk [21] and represents a serious challenge for them. A 2017 survey of manufacturing SMEs in West Virginia, USA, confirmed that SMEs face challenges in implementing smart manufacturing [22].

A literature review shows that only a few studies specifically focus on supporting the evolutionary path and paradigm shift of SMEs towards “smart manufacturing” or Industry 4.0. SMEs often face difficulties in such innovation processes due to the constant development of innovation and technology. Therefore, further research is needed to develop specific tools and models for SMEs implementing I4.0 in their companies and manufacturing shop floors. In addition, policymakers should formulate strategies to support SMEs to invest in these technologies and increase their competitiveness in the marketplace.

6 The necessary conditions for the implementation of Industry 4.0 principles in industrial SMEs

Therefore, specific research is needed to implement Industry 4.0 technologies and concepts in SMEs. SMEs will only be able to move to I4.0 if they follow the strategies and approaches developed for SMEs and implement concepts and technological solutions castomized for SMEs. It is necessary to analyze and assess the specific needs of SMEs to provide guidelines for the design of flexible and intelligent manufacturing systems for SMEs in a dynamic environment using I4.0.

The integration of ICT and cyber-physical systems with manufacturing, logistics and services into current manufacturing practices will transform today's SMEs into smarter and more adaptable businesses with significant economic potential. Previous research has shown a limited but positive impact of Industry 4.0 on the SMEs operating performance, with little investment and little experience when it relates to cloud computing [23]. Only a few papers address the specific requirements of SMEs for the implementation of such intelligent manufacturing systems, and most of them do not provide a complete list. E. Rauch [24] conducted a study concerning the design requirements for flexible and dynamic production systems for SMEs. This paper does not address the implementation of I4.0 concepts, but emphasizes the need to explore I4.0 solutions for SMEs.

The work of S. Mittal [22] is one of the few that lists the requirements of SMEs with regard to the design of intelligent manufacturing systems by implementing I4.0. According to this study, the requirements for implementing the I4.0 concept in manufacturing SMEs include: (a) the need for financial resources, (b) the need for advanced manufacturing technologies, (c) the need for industrial standards, (d) the need to include I4.0 principles in organizational culture, (e) the need to develop and involve employees in the changes associated with I4.0, (f) the need for alliances with universities and research institutes, and (g) the need to collaborate with customers and suppliers. While these results provide a good starting point for further research, they are formulated in very general terms and do not take

into account the specific requirements for developing a production system for SMEs, most of them are typical requirements of any company implementing I4.0. Thus, it can be concluded that there is still a need to study the specific requirements of SMEs for the design of smart manufacturing systems.

Based on a survey of companies and an expert survey, the article by E. Rauch [8] explores and discusses the applicability of Industry 4.0 concepts for companies of different sizes. For small businesses, concepts were highlighted to prepare the organization and people for Industry 4.0 (cultural transformation, Industry 4.0 roadmap, cybersecurity), as well as the concepts of agile manufacturing and collaboration network.

7 Digitalization and implementation of Industry 4.0. principles in small business in the Russian Federation

Let us turn to the domestic experience of studying digitalization issues and implementing the principles of Industry 4.0. in small business. There are a number of studies [25-29] devoted to the digitalization of Russian small business and its role in the digital economy. However, there are practically no studies describing these problems in relation to industrial SMEs.

Information technologies affect on investment mechanisms and interactions between economic actors, causing the formation of a horizontal type of their coordination. It is important that due to improved cooperation, data processing and other technologies, it becomes possible to replace large industrial enterprises with mosaic networks of SMEs [30].

Small and medium-sized businesses in the Russian economy generated 22% of value added in 2017. According to data for 2018, it's contribution dropped to 20.2% [31]. In comparison, the share of small and medium-sized businesses in the GDP of developed countries is 50-60%. So, in the UK it is 51%, in Germany – 53%, in Finland – 60%, in the Netherlands – 63 [32]. The number of employees in Russian SMEs mid-2019 was 18.3 million in mid-2019, according to the results of the SberData survey. According to experts, this sector accounts for 25.6% of employees. At the same time, 26.3% of those employed in manufacturing are provided by SMEs.

Currently, some studies to assess the level of digitalization of small and medium-sized businesses in the Russian Federation are being conducted. Among them, we can mention the Business Digitalization Index (BDI), developed to assess the readiness of businesses for the digital economy. An all-Russian survey of representatives of SMEs (including individual entrepreneurs) was carried out by the NAFI Analytical Center [33]. In September 2019, the Index averaged 45 pp across the country out of 100 possible. This indicates that today SMEs in Russia are not sufficiently aware of the benefits of introducing digital technologies and the possibilities of improving work processes by digitalizing the company.

The specified index integrates 5 private indexes. 1) Channels for transmission and storage of information (cloud technologies, corporate mail, instant messengers, automation systems, etc.): 43% use systems automating the work of an enterprise. 2) Integration of digital technologies (artificial intelligence, Internet of things, 3D printing, use of online documents, etc.). Among the various digital technologies for doing business, the most popular are mobile applications (50%), Internet of things technologies (26%). Collaboration work documents (like Google Docs) are used by about 50% of companies. Electronic document flow – 73%. 3) Use of the Internet in sales. 54% of companies have their own websites; pages on social networks – 43%; 87% – represented on online maps; 79% use instant messengers to work with clients. 4) Information security. 34% of companies have an approved information security policy. 5) Digital learning. 28% of companies provided

training for employees in the use of digital technologies. The share of companies with digital specialists is relatively small – 12%.

The main barriers to digitalization are the disinterest of company leaders in the transition to digital format (21%) and budgetary constraints in companies for the introduction of digital technologies (20%). At the same time, entrepreneurs see advantages in business digitalization: the convenience of control over processes (34%) and an increase in the work speed (33%) come to the fore.

The least developed is the digital technologies integration index (27 pp against a total index of 45). This is due to the fact that there is still no high demand for a number of technologies from SMEs: virtual reality, the Internet of Things, 3D printing, and machine learning solutions are still tools for startups, but not for SMEs. According to experts, while AI, ML, VR / AR are poorly represented in SMEs today, more than 1/3 of enterprises already use elements of the Internet of Things. If we look at the industry structure, it is mainly logistics, that is, tracking of transport and warehouses. In the future, SMEs in all spheres will actively integrate digital solutions into their work. Solutions that are "light" in terms of cost and time to implement will spread faster: online services for teamwork (Asana, Jira, Trello), integration of products and services into platform services, and an increase in the number of mobile applications.

Promsvyazbank and “Opora Russia” publish the “Index of Small and Medium Business Business Activity (RSBI)” every quarter [34]. In 2017, in addition to standard questions for assessing the situation in small business, questions related to digital business were added to the survey. Figure 1 shows the tools that SMEs use to digitalize their activities over 3 years, where you can see an increase in the share of enterprises using them.

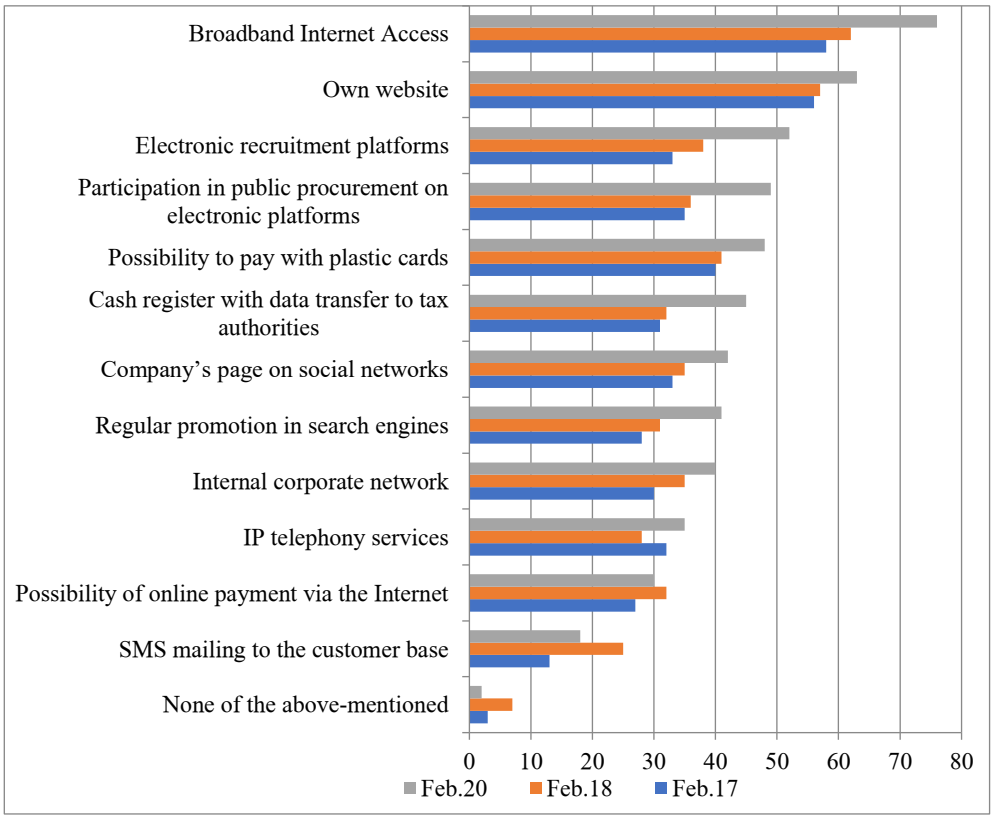

Fig. 1. Tools used by SMEs for digitalization, % of companies

The ability to provide services remotely has become a lifeline for small businesses during the period of self-isolation and quarantine. According to the May 2020 Index [34], 47% of companies had remote selling services even before the spread of the coronavirus.

The prospects for using digital technologies in SMEs in the Russian Federation are as follows. Due to digitalization, small businesses have a chance to integrate into global technological chains and enter new markets using platforms. Digital technologies allow SMEs to expand the coverage area, entering new categories of customers, and modifying their product. As a result, this allows to multiply the efficiency of the business, change its model. The availability of technologies is currently high, they can be designed, assembled from ready-made elements of ready-made services. Another important issue for SMEs entering new markets in the context of digitalization is the introduction of standards. Russian technology companies and experts need to be actively involved in international standardization work at an early stage.

7 Conclusions

Thus, we conducted a theoretical analysis and identified the advantages of implementing the concepts and approaches of Industry 4.0 in small and medium-sized industrial enterprises. We identified the prospects and limitations of applying Industry 4.0 principles for SMEs. This substantiates the need for further research in order to develop special strategies, methods and tools for the effective digitalization of industrial SMEs. These issues are especially relevant for the Russian Federation, where there are practically no studies on the digitalization of small industrial business. The analysis of statistics and business activity indices does not allow making full-scale conclusions about the implementation of Industry 4.0 at SMEs in the Russian Federation. It was revealed that SMEs are ready for the implementation of digital technologies, but they are limited by a lack of financial and labor resources of the required level. The use of digital technologies creates the basis for the formation of new business models that will allow SMEs to enter new global markets.

In the Russian Federation, given the importance of the task of the economy re-industrialization on a new digital basis, building networks of distributed industrial production, a support of small and medium-sized manufacturing businesses can become one of the most effective tools for long-term, strategic development.

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References

1. D.T. Matt, E. Rauch, *Industry 4.0 for SMEs. Challenges, Opportunities and Requirements* (2020)
2. H.S. Kang, Int. J. Precis. Eng. Manuf., **3(1)**, 111 (2016)
3. H. Kagermann, Recommendations for Implementing the Strategic Initiative Industrie 4.0: Securing the Future of German Manufacturing Industry. Final report of the Industrie 4.0 Working Group (2013)
4. D. Spath , *Produktionsarbeit der Zukunft – Industrie 4.0* (2013)

5. V. Modrak, D. Marton, S. Bednar, Procedia CIRP, **23**, 258 (2014)
6. P. Zawadzki, K. Żywicki, Manag. Prod. Eng. Rev., **7 (3)**, 105 (2016)
7. D.T. Matt, E. Rauch, D. Fraccaroli, ZWF, **111(1-2)**, 52 (2016)
8. E. Rauch , *Proceedings of the International Conference on Industrial Engineering and Operations Management*, 1174 (2019)
9. L. Safar , TEM J., **7(3)**, 626 (2018)
10. J.M. Muller, J. Manuf. Technol. Manag., **30(8)**, 1127 (2019)
11. K. Bar, Z.N.L. Herbert-Hansen, W. Khalid, Prod. Eng., **12(6)**, 747 (2018)
12. L. Sommer, J. Ind. Eng. Manag., **8(5)**, 1512 (2015)
13. Industry 4.0 – Challenges and Solutions for the Digital Transformation and Use of Exponential Technologies, Study of Deloitte Consulting (2015), http://www2.deloitte.com/
14. Industry 4.0 – Opportunities and Challenges of the Industrial Internet. Study of Pricewaterhouse Coopers PWC (2015), http://www.strategyand.pwc.com/
15. J. Lee, E. Lapira, Man. Lead. J., **20(1)**, 13 (2013)
16. L. Gualtieri, *IEEE International Conference on Industrial Engineering and Engineering Management (IEEM),* 1111 (2018)
17. M. Brette, Int. J. Mech., Ind. Sc. Eng., **8(1)**, 37 (2014)
18. G. Orzes, E. Rauch, *IEEE International Conference on Industrial Engineering and Engineering Management (IEEM)*, 1348 (2018)
19. D.T. Matt, E. Rauch, P. Dallasega, Procedia CIRP, **17**, 178 (2014)
20. J. Ganzarain, N. Errasti, J. Ind. Eng. Manag., **9(5)**, 1119 (2016)
21. A. Moeuf , Int. J. Prod. Res., **56(3)**, 1118 (2017)
22. S. Mittal , J. Manuf. Syst., **49**, 194 (2018)
23. A. Radziwon , Procedia Eng., **69**, 1184 (2014)
24. E. Rauch, P.R. Spena, D.T. Matt, IJIDeM, **13(1)**, 1 (2019)
25. V.Yu. Burov, N.V. Kapitonova, N.B. Kaibalina, Fundamental research, **4**, 44 (2018)
26. M.A. Dolgikh, Modern city: power, management, economy, **1**, 106 (2019)
27. M.E. Konovalova, E.P. Fomin, Economic sciences, **11(168)**, 26 (2018)
28. Yu.V. Khramov, Management of sustainable development, **1(20)**, 19 (2019)
29. V.I. Talantsev, A.K. Ravnyanskiy, Regional problems of economic transformation, **2**, 80 (2018)
30. Industry 4.0: Change management, Institute for Investment Policy Analysis, http://мниап.рф./
31. The share of small and medium-sized businesses in the gross domestic product, Rosstat, https://fedstat.ru/
32. Small and medium business sector: Russia and the world, Institute for the Economy of Growth n.a. P.A. Stolypin, https://stolypin.institute/
33. Small and Medium Business Digitalization Index, October 2019, Otkritie Bank, https://nafi.ru/
34. Russia Small Business Index (RSBI), https://www.psbank.ru