THE RESILIENCE LEVEL OF MANUFACTURING FIRMS IN THE REPUBLIC OF SERBIA

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Abstract: *During the Covid-19 epidemic, resilience as a concept gained prominence. Firms that failed to handle the problems and changes they faced and were unable to survive had to be closed down. Only the companies who resolved them correctly were able to continue doing business. Today, resilience is frequently addressed in emerging global movements such as Industry 5.0. To thrive in today's fast-paced environment, it is essential to understand how to respond to challenges and changes. As a result, the purpose of this research is to demonstrate the level of resilience development in manufacturing enterprises in the Republic of Serbia. The data for this study came from 380 firms in the European Manufacturing Survey, which was conducted in 2018 and 2022. The findings demonstrate the amount of resilience in manufacturing firms in the Republic of Serbia prior to and during the Covid-19 epidemic. The key findings reveal a growing trend in the usage of data security measures, which increased by 30% from 2018 to 2022 in manufacturing firms.*

Key words: resilience, European Manufacturing Survey, manufacturing, data security;

1. INTRODUCTION

Today's world is characterized by fast-paced changes on a global level, not only predicted but unexpected ones as well (Gössling et al., 2020). One of the unexpected global changes certainly was the Covid-19 pandemic which forced the whole world to deal with challenges which were faced – borders were closed, travelling was not possible, and social isolation became the new normal (Raza et al., 2021). Some industries, such as tourism faced tougher challenges in comparison with other industries (Gössling et al., 2020). Many firms had to be shut down, because they were not capable enough to face new challenges in the right way and adapt their way of doing business to the new situation (Slavic, 2023). At this time, resilience as a concept started to attract more attention than before (Xu et al., 2021). Firstly introduced within ecology, this concept became relevant to different fields (Gallopín, 2006). In the manufacturing industry, resilience is referred to as a system's capability to return to the previous state after successfully standing up to affects coming from the system's environment (Sofic et al., 2022).

After surviving business challenges and circumstances brought by Covid-19, the whole manufacturing industry has realized the importance of developing the resilience level of individual firms and strengthening its capability of withstanding future unexpected changes (Javaid & Haleem, 2020). Accordingly, the authors are comparing data of 5 resilience parameters measured in 2018, and in 2022 which show the main focus areas that helped firms become strong and flexible enough to adapt to new conditions dictated by the environment. With an aim to discover which directions of development manufacturing firms have taken in order to survive unstable and unpredictable changes, authors propose these research questions:

RQ1: *What was the resilience level of Serbian manufacturing before Covid-19?*
RQ2: *What is the resilience level of Serbian manufacturing after Covid-19?*

The structure of this paper is: Section 2 provides a literature review of resilience as a concept, Section 3 explains the research methodology, while Section 4 shows the results and discussion. Last, but not least, Section 5 concludes the paper and gives future research implications.

2. LITERATURE REVIEW

The delivery of products or services that make life better for society is the focus of Industry 5.0. However, the aspects that lead to it, such as AI systems, mass personalization, bioeconomy, coworking robots and sustainable practices, are not sufficiently observed or achieved even in Industry 4.0 (Nagy et al., 2019). Nowadays, when there is appropriate knowledge and appropriate technology, it is necessary to change established practices and adopt sustainable, more resistant alternatives, in order to at least reduce the

already excessive impact of industry on nature (Đaković et al., 2020). Increasing resilience in the industry can be increased by implementing systems such as IoT-enabled ones, then AI-based management systems, renewable energy and advanced simulation (Sindhwani et al., 2022). In such a way, the focus shifts to human social aspects and leads to the creation of social value, adapting the industry to new conditions, thus achieving a bio-oriented and sustainable society. This preserves the values of humanity and the environment at the same time, which is the ultimate idea of Industry 5.0 (Lehmann et al., 2023), (Salunkhe & Berglund, 2022).

The current approach to globalized production has proven to be very easily disrupted by various geopolitical changes and natural crises such as the situation with the Covid-19 pandemic. Such conditions indicated the necessity of efficient supply chains in order to achieve flexibility and resilience in production (Jankovic-Zugic et al., 2023). Ensuring precisely this resilience becomes the main need and refers to the development of stable industrial production, which could be maintained even in disturbed conditions, providing support to critical infrastructure while certain disturbances are in effect (Ivanov, 2022). By achieving resilience in strategic value chains, business processes and agile production capacities, production becomes sustainable. In this context, the adjective "resilient" is used more and more, especially if we are talking about the concept of Industry 5.0 and taking into account the consequences that the Covid-19 pandemic has left on industry and society (Rakic et al., 2022), (Sá et al., 2022).

One of the growing challenges of the developing economy concerns achieving a balance between economic growth and environmental protection. The aforementioned further imposes the optimization of production technology and continuous improvement of the product (Rakic et al., 2021), (Ćirić et al., 2016). It is considered that the digitalization of the economy, and the development of network cooperation of local small and medium-sized enterprises with the use of local and regional potentials, could be a factor of the greatest importance for industrial resilience (Saniuk et al., 2022). This also means the confirmation of the trend of orientation towards digitalization of economic processes that proved to be vulnerable during the pandemic (Ghobakhloo et al., 2022). For example, the authors pointed out how workers in Industry 5.0 themselves manage to make their work environment and supply chains more resilient based on their cognition and movement using digital technologies such as artificial intelligence (Cortés-Leal et al., 2022), (Ahmed et al., 2023), (Miloradov et al., 2022), (Bastos et al., 2022).

All of the above led to the general agreement that Industry 5.0 differs from all previous revolutions that have occurred in the industry, due to the fact that it represents a socio-technological phenomenon that involves all interested parties in order to replace the classical economic models based on consumption and profit, turned into resilient, regenerative, sustainable and circular economic models that further create value (Ghobakhloo et al., 2022), (Nayeri et al., 2023), (Al-Zubaidi et al., 2022).

3. METHODOLOGY

Data for this empirical study were gathered using the European Manufacturing Survey (EMS) and a dataset from the Serbian manufacturing sector (NACE Rev. 2 codes 10 to 33) from two rounds in 2018 and 2022. The EMS is coordinated by the Fraunhofer Institute for System and Innovation Research in Germany. The analysis dataset contains 387 observations of manufacturing firms in the Republic of Serbia. Table 1 depicts the industry sector's share of the total sample in 2018 and 2022.

Table 1: Classification of manufacturing sectors according to share on the total sample in 2018 and 2022

2018 (240 observations)		2022 (147 observations)	
Manufacturing industry	*(%)*	*Manufacturing industry*	*(%)*
Manufacture of food products	17	Manufacture of fabricated metal products, except machinery and equipment	20
Manufacture of fabricated metal products, except machinery and equipment	15	Manufacture of food products	16
Manufacture of rubber and plastic products	8	Manufacture of rubber and plastic products	8
Manufacture of electrical equipment	7	Manufacture of wearing apparel	7
Manufacture of machinery and equipment n.e.c.	6	Manufacture of machinery and equipment n.e.c.	5
Manufacture of wearing apparel	6	Manufacture of furniture	5
Others	41	Others	39

Furthermore, the sample from 2018 includes 46% of small firms (fewer than 50 employees), 43% of medium firms (between 50 and 250 employees), and 11% of big firms (more than 250 employees). Furthermore, the sample from 2022 has 52% of small firms (fewer than 50 employees), 36% of medium firms (between 50 and 250 employees), and 10% of big firms (more than 250 employees). The authors

employ comparative descriptive statistics on the resilience parameters from 2018 and 2022 for data analysis. The authors use this methodology to compare the conditions before and after the Covid-19 pandemic. According to the literature, scholars examine the five resilience parameters. R1 - Standardized and thorough work instructions, R2 - Mobile industrial robots, R3 - Collaborating industrial robots, R4 - Data Backup: Activities to raise employee data security awareness, and R5 - Product development.

4. RESULTS AND DISCUSSION

According to proposed research question RQ1 and RQ2, this section shows results of aforementioned resilience parameters' data which were gathered both in 2018, and 2022, in Pre-Covid and Post-Covid periods. Figure 1 shows resilience parameters for different firm sizes in 2018, while Figure 2 shows the same parameters measured 4 years later, in 2022.
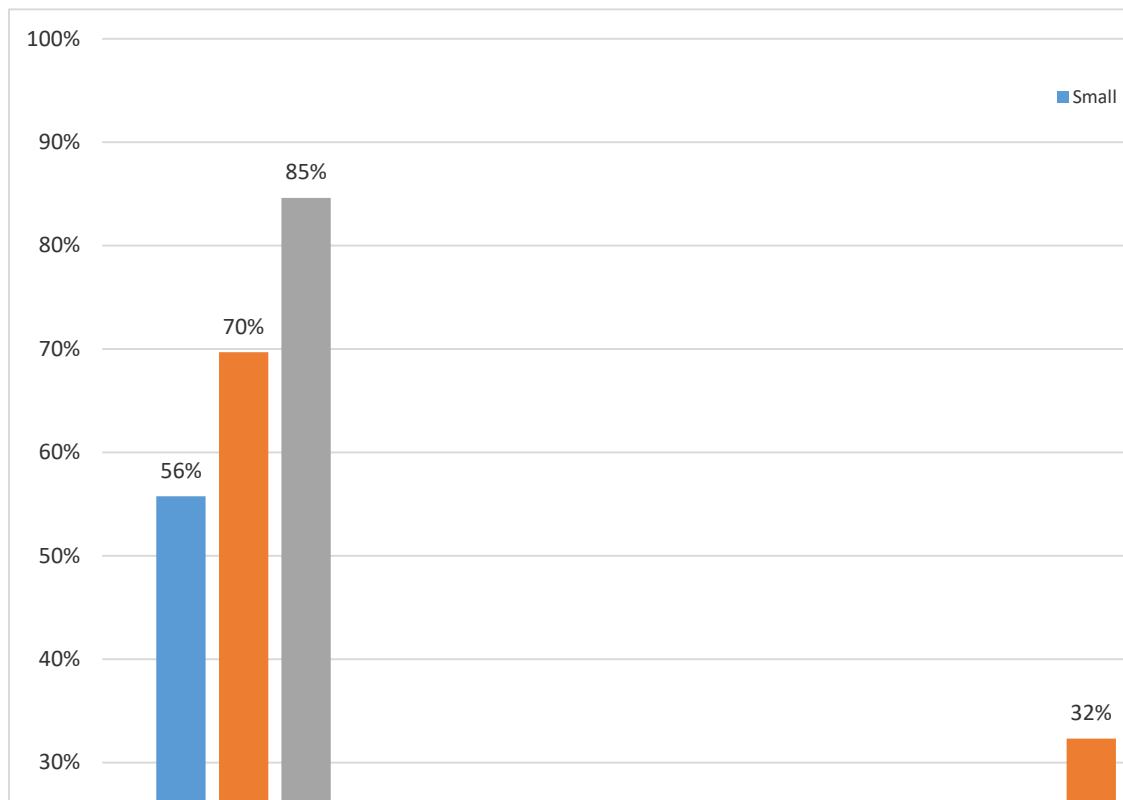

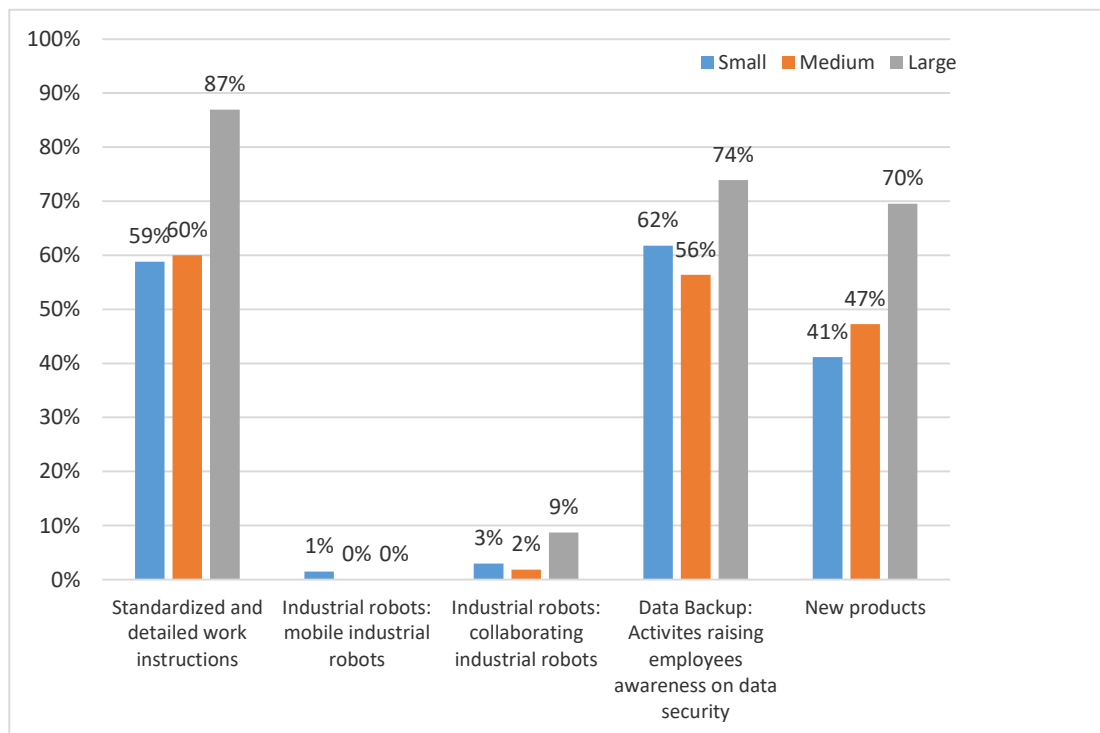*Figure 1: Resilience parameters in 2018: Before Covid-19 state*

Figure 2: Resilience parameters in 2022: After Covid-19 state

When comparing data from Figure 1 and Figure 2, significant changes are identified. When it comes to parameter R1 – Standardized and detailed work instructions, an implementation decrease is recognized – 3% of overall small firms, and 10% of overall medium firms have stopped implementing standardized and detailed work instructions, while 2% of big firms have started to implement them. Parameter R2 – Industrial robots: mobile industrial robots shows a small progress in application. Their application in small firms stayed the same, however 1% of medium firms started using them, as well as 4% of big firms. Parameter R3 – Industrial robots: collaborating industrial robots has also attracted attention in firms in 2022 – 2% of small firms, 2% of medium firms, and 5% of big firms started to apply collaborating industrial robots. The most significant changes when comparing results from the Pre-Covid and Post-Covid periods are identified in parameter R4 – Data Backup: Activities raising employees' awareness on data security. All firms, despite their size, recorded an increase in these activities – 42% of small firms, 24% of medium firms, and 24% of big firms. The last resilience parameter R5 – New products has also shown an increase of implementation in small, medium, and big firms. When talking about new products, additional 10% of small firms, 17% of medium firms, and 1% of big firms have introduced them.

5. CONCLUSION

Within the paper, two groups of data are shown, the first group consists of data collected in 2018, and the second collected in 2022, that is, we can say that the situation in small, medium and large companies before and after the situation with the Covid-19 pandemic is shown. Data concerning five parameters of resilience were observed.

Resilience was observed precisely because of its importance for the survival of manufacturing companies in modern conditions, which become increasingly demanding and unpredictable over time, as we had the situation with the pandemic. Such situations require companies to be adaptable, flexible and agile in their processes and supply chains. In addition to the infrastructure itself, the influence of the human factor on resilience has also been highlighted in the literature, as well as the need for the industry to take more account of society and its survival in the ecosystem.

By observing the data, we can see that there is a difference in the results of research questions 1 and 2, i.e., that there was an increase in the degree of resilience in Serbian manufacturing in 2022 compared to 2018. This testifies to how much Covid-19 has influenced companies to change the previous practice and thereby lead to the observed difference in the measured parameters in favor of resistance. The biggest jump in application (30%) occurred with parameter R4 - Data Backup: Activities to raise employee data security awareness, where application by small companies increased by as much as 42%, by medium and

large companies by 24%. From this we can conclude that data, that is, knowledge, is even more recognized as a valuable asset that needs to be protected in times of crisis. By 2022, companies have begun to attach more importance to data security measures and to train their employees in this direction, in order to jointly build and preserve the data essential for the survival and prosperity of the company. The application of industrial robots (R2 and R3) is also experiencing its growth. We can point out that it is interesting that the number of small and medium-sized enterprises that introduce new products has decreased, 10% for small and 17% for medium-sized enterprises, while this parameter (R5) continues to grow for large ones for 1 %. This data could result from the fact that it was more difficult for smaller systems to cope with the effects of the pandemic. This study is limited to five parameters of resilience, where a larger number of parameters could potentially be taken for future research.

What is certain is that the Covid-19 virus pandemic has affected the operations of manufacturing companies of all sizes. Digital technology is recognized as needed to increase resilience, sustainability and move closer to Industry 5.0. Every company that strives for growth, development, and in situations like the pandemic, survival, must turn to greater application of sustainability parameters.

6. ACKNOWLEDGMENT

7. REFERENCES

Ahmed, T., Karmaker, C. L., Nasir, S. B., Moktadir, M. A., & Paul, S. K. (2023). Modeling the artificial intelligence-based imperatives of industry 5.0 towards resilient supply chains: A post-COVID-19 pandemic perspective. *Computers and Industrial Engineering*, *177*(January), 109055. https://doi.org/10.1016/j.cie.2023.109055

Al-Zubaidi, S. Q. D., Coli, E., & Fantoni, G. (2022). Automating Production Process Data Acquisition Towards Spaghetti Chart 4.0. *International Journal of Industrial Engineering and Management*, *13*(3), 145–157. https://doi.org/10.24867/IJIEM-2022-3-308

Bastos, T., Salvadorinho, J., & Teixeira, L. (2022). UpSkill@Mgmt 4.0 – A digital tool for competence management: Conceptual model and a prototype. *International Journal of Industrial Engineering and Management*, *13*(4), 225–238. https://doi.org/10.24867/IJIEM-2022-4-315

Ćirić, D., Lalić, B., & Gračanin, D. (2016). Managing innovation: Are project management methods enemies or allies. *International Journal of Industrial Engineering and Management*, *7*(1), 31–41.

Cortés-Leal, A., Cárdenas, C., & Del-Valle-Soto, C. (2022). Maintenance 5.0: Towards a Worker-in-the-Loop Framework for Resilient Smart Manufacturing. *Applied Sciences (Switzerland)*, *12*(22). https://doi.org/10.3390/app122211330

Đaković, M., Lalić, B., Delić, M., Tasić, N., & Ćirić, D. (2020). Systematic mitigation of model sensitivity in the initiation phase of energy projects. *Advances in Production Engineering And Management*, *15*(2), 217–232. https://doi.org/10.14743/APEM2020.2.360

Gallopín, G. C. (2006). Linkages between vulnerability, resilience, and adaptive capacity. *Global Environmental Change*, *16*(3), 293–303. https://doi.org/10.1016/j.gloenvcha.2006.02.004

Ghobakhloo, M., Iranmanesh, M., Mubarak, M. F., Mubarik, M., Rejeb, A., & Nilashi, M. (2022). Identifying industry 5.0 contributions to sustainable development: A strategy roadmap for delivering sustainability values. *Sustainable Production and Consumption*, *33*, 716–737. https://doi.org/10.1016/j.spc.2022.08.003

Gössling, S., Scott, D., & Hall, C. M. (2020). Pandemics, tourism and global change: a rapid assessment of COVID-19. *Journal of Sustainable Tourism*, *29*(1), 1–20. https://doi.org/10.1080/09669582.2020.1758708

Ivanov, D. (2022). The Industry 5.0 framework: viability-based integration of the resilience, sustainability, and human-centricity perspectives. *International Journal of Production Research*. https://doi.org/10.1080/00207543.2022.2118892

Jankovic-Zugic, A., Medic, N., Pavlovic, M., Todorovic, T., & Rakic, S. (2023). Servitization 4.0 as a Trigger for Sustainable Business: Evidence from Automotive Digital Supply Chain. *Sustainability (Switzerland)*, *15*(3). https://doi.org/10.3390/su15032217

Javaid, M., & Haleem, A. (2020). Critical components of industry 5.0 towards a successful adoption in the field of manufacturing. *Journal of Industrial Integration and Management*, *5*(3), 327–348. https://doi.org/10.1142/S2424862220500141

Lehmann, J., Lober, A., Häußermann, T., Rache, A., Ollinger, L., Baumgärtel, H., & Reichwald, J. (2023). The Anatomy of the Internet of Digital Twins: A Symbiosis of Agent and Digital Twin Paradigms Enhancing Resilience (Not Only) in Manufacturing Environments. *Machines*, *11*(5). https://doi.org/10.3390/machines11050504

Miloradov, M., Rakic, S., Lalic, D. C., Savkovic, M., Softic, S., & Marjanovic, U. (2022). Digital Technologies as an Essential Part of Smart Factories and Their Impact on Productivity. *IFIP Advances in Information and Communication Technology*, *664 IFIP*, 179–187. https://doi.org/10.1007/978-3-031-16411-8_23

Nagy, G., Vida, G., Boros, L., & Ćirić, D. (2019). Decision trees in environmental justice research - A case study on the floods of 2001 and 2010 in Hungary. *Open Geosciences*, *11*(1), 1025–1034. https://doi.org/10.1515/geo-2019-0079

Nayeri, S., Sazvar, Z., & Heydari, J. (2023). Towards a responsive supply chain based on the industry 5.0 dimensions: A novel decision-making method. *Expert Systems with Applications*, *213*(PC), 119267. https://doi.org/10.1016/j.eswa.2022.119267

Rakic, S., Pero, M., Sianesi, A., & Marjanovic, U. (2022). Digital Servitization and Firm Performance: Technology Intensity Approach. *Engineering Economics*, *33*(4), 398–413. https://doi.org/10.5755/j01.ee.33.4.29649

Rakic, S., Visnjic, I., Gaiardelli, P., Romero, D., & Marjanovic, U. (2021). Transformation of Manufacturing Firms: Towards Digital Servitization. In *IFIP Advances in Information and Communication Technology: Vol. 631 IFIP* (Issue September). Springer International Publishing. https://doi.org/10.1007/978-3-030-85902-2_17

Raza, S. A., Qazi, W., Khan, K. A., & Salam, J. (2021). Social Isolation and Acceptance of the Learning Management System (LMS) in the time of COVID-19 Pandemic: An Expansion of the UTAUT Model. *Journal of Educational Computing Research*, *59*(2), 183–208. https://doi.org/10.1177/0735633120960421

Sá, S., Ferreira, L. P., Silva, F. J. G., Sá, J. C., Pereira, M. T., & Santos, G. (2022). The importance of subcontracting and its relationship with Lean philosophy inautomotive industry. *International Journal of Industrial Engineering and Management*, *13*(3), 186–193. https://doi.org/10.24867/IJIEM-2022-3-311

Salunkhe, O., & Berglund, F. (2022). Industry 4.0 enabling technologies for increasing operational flexibility in final assembly. *International Journal of Industrial Engineering and Management*, *13*(1), 38–48. https://doi.org/10.24867/IJIEM-2022-1-299

Saniuk, S., Grabowska, S., & Straka, M. (2022). Identification of Social and Economic Expectations: Contextual Reasons for the Transformation Process of Industry 4.0 into the Industry 5.0 Concept. *Sustainability (Switzerland)*, *14*(3). https://doi.org/10.3390/su14031391

Sindhwani, R., Afridi, S., Kumar, A., Banaitis, A., Luthra, S., & Singh, P. L. (2022). Can industry 5.0 revolutionize the wave of resilience and social value creation? A multi-criteria framework to analyze enablers. *Technology in Society*, *68*(November 2021), 101887. https://doi.org/10.1016/j.techsoc.2022.101887

Slavic, D. (2023). The main concepts of Industry 5.0: A Bibliometric Analysis Approach. *2023 22nd International Symposium INFOTEH-JAHORINA, INFOTEH 2023*. https://doi.org/10.1109/INFOTEH57020.2023.10094143

Sofic, A., Rakic, S., Pezzotta, G., Markoski, B., Arioli, V., & Marjanovic, U. (2022). Smart and Resilient Transformation of Manufacturing Firms. *Processes*, *10*(12), 1–12. https://doi.org/10.3390/pr10122674

Xu, X., Lu, Y., Vogel-Heuser, B., & Wang, L. (2021). Industry 4.0 and Industry 5.0—Inception, conception and perception. *Journal of Manufacturing Systems*, *61*(October), 530–535. https://doi.org/10.1016/j.jmsy.2021.10.006