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# DIGITAL TECHNOLOGIES AS SUSTAINABILITY ENABLERS

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***Abstract***
*Although sustainable practices have been addressed in Industry 4.0, sustainability as a concept started to attract attention when established as one of the critical pillars of Industry 5.0. Beyond environmental impact, its scope includes social, economic, and ecological aspects. To investigate how the use of specific digital technologies contributes to sustainable practices in manufacturing processes, the authors of this paper show a correlation between digital technologies and sustainability. The dataset used in the research represents the Serbian manufacturing sector, and the data was obtained in 2023 through the Digital Servitization Survey.*

***Keywords:*** *Industry 5.0, sustainability, digital technologies, Digital Servitization Survey.*

## 1. Introduction

Digital technologies and sustainability awareness have been developing parallelly during the last decade (Bressanelli et al., 2018). When compared to each other, both digital technologies and sustainable practices require investments. However, even though digitalization can positively impact the company's profit, sustainability positively impacts other business aspects, such as customer loyalty, brand reputation, and ESG scores, emphasized through the Industry 5.0 concept (Trstenjak et al., 2023).

When implemented, digital technologies contribute to sustainability by digitalizing specific processes and reducing waste (Mustapić et al., 2023). Additionally, the impact digital technologies have on society, in terms of upskilling and reskilling, as well as the possibilities for humans to do more cognitive than physical work, is perceived as good (Rannertshauser et al., 2022). However, the

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intensity of the impact certain digital technologies have on people, the planet, and profit is unknown.

To examine the impact that digital technologies have on sustainability in the Republic of Serbia's manufacturing sector, the authors of this paper propose the following research question:

**RQ:** *Is there any association between digital technologies and sustainability in the manufacturing sector in the Republic of Serbia?*

The authors conducted Fisher's exact test on 38 manufacturing firms from the Republic of Serbia to answer the research question. The rest of the manuscript consists of the following sections: Section 2 provides a literature review of sustainability and digital technologies; Section 3 covers the methodology used in the research; results and discussion are presented in Section 4, and Section 5 shows the main conclusions of the paper.

## 2. Literature review

### 2.1 Sustainability

Sustainability addresses people, the planet, and profit – three P's, also known as the triple bottom line (TBL) (Dhayal et al., 2023). This TBL represents a sustainability framework which supports the development and implementation of business strategies (Dhayal et al., 2023). In the context of sustainability, firms have developed corporate social responsibility (CSR), which represents the impact firms make on environmental, economic, and societal aspects (Potočan et al., 2021). Except through the three P's, sustainability is also addressed through the United Nation's *Sustainable Development Goals (SDGs)* (Wu et al., 2018)

Sustainability parameters used in this research are: (1) the company has metrics to assess the economic performance of the services, (2) the company has metrics to evaluate the environmental impact of services, (3) digital servitization is seen as a way to be sustainable, and (4) reconfigurability or upgradability is seen as a critical strategy to achieve sustainable solutions.

### 2.2 Digital technologies

Digital technologies are being developed and implemented since 2011 (Lasi et al., 2014). Due to the use of digital technologies, business models are being transformed (Martynov et al., 2019). This transformation includes digital services, which are being offered alongside physical products – a phenomenon called *digital servitization* – which has appeared together with *product-service systems* (Rakic et al., 2023). Furthermore, sustainable manufacturing practices are addressed through the Industry 4.0 concept, which emphasizes how digital technologies can contribute to sustainability (Branger & Pang, 2015). When transitioning from Industry 4.0 towards Industry 5.0, digital technologies go beyond digitalization and aim at designing a human-centric, sustainable, and resilient solutions (Golovianko et al., 2023; Slavic et al., 2024).

Digital technologies that were assessed in this research are (1) Additive Manufacturing/3D Printing, (2) Advanced Manufacturing Solutions (Cyber-physical systems, Collaborative robots), (3) Artificial Intelligence/Machine Learning, (4) Big Data Analytics, (5) Cloud Computing, (6) Cybersecurity, (7) (Industrial) Internet of Things, (8) Mixed Reality (Virtual and Augmented Reality), and (9) Simulation of Connected Machines.

## 3. Methodology

This research collected data from January 2022 until January 2023 through the “Digital Servitization Survey.” Although this survey gathered answers worldwide, the data used in this research represents answers collected from firms in the Republic of Serbia. The “Digital Servitization Survey” was structured by 15 international experts and is based on a literature review of Industry 4.0 and product service systems. The experts mentioned come from fields of *servitization*, *product-service systems*, *manufacturing engineering and operations*, and *Industry 4.0*.

The survey was distributed by e-mail and social media from January 2022 until January 2023, and 314 firms responded. Out of these 314 firms, 119 are from the Republic of Serbia. The response rate in the Republic of Serbia was 15%. When manufacturing firms were extracted, only 38 firms were left. These companies are grouped by size, manufacturing sector, and annual turnover.

Descriptive statistics and Fisher’s exact test present the relationship between digital technologies and sustainability. The authors used Fisher’s exact test instead of Chi-square due to the sample size of 38 firms and the expected cell value of five or fewer. Furthermore, codes used in this research are from DT1 to DT9 for digital technologies and from S1 to S4 for sustainability parameters.

Table 1 presents the sample distribution by company size. Most firms—16 (42%)—have 11 to 50 employees. Next, 17 firms (45%) have 51 to 250 employees, and 5 firms (13%) have more than 251 employees.

*Table 1: Sample distribution by company size*

| Firm size | *n* | % |
|---|---|---|
| 11 to 50 employees | 16 | 42 |
| 51 to 250 employees | 17 | 45 |
| More than 251 employees | 5 | 13 |

The data presented in Table 1 show that this research is mainly based on small and medium enterprises since only 5 large enterprises have participated.

Table 2 presents the sample distribution by manufacturing sector according to the NACE classification. Most companies are beverage manufacturers (NACE 11) – 7 firms (19%). Next, 5 firms (13%) come from the following sectors: the manufacture of food products (NACE 10), rubber and plastic products (NACE 22), and electrical equipment (NACE 27). Four firms (10%) are manufacturers of machinery and equipment, nowhere else classified (NACE 28), and 3 firms (8%) are manufacturers of textiles (NACE 13). Finally, all other firms that participated in the research (9 firms; 24%) come from other NACE sectors.

*Table 2: Sample distribution by manufacturing sector*

| **Manufacturing sector** | ***n*** | **%** |
|---|---|---|
| Manufacture of beverages | 7 | 19 |
| Manufacture of food products | 5 | 13 |
| Manufacture of rubber and plastic products | 5 | 13 |
| Manufacture of electrical equipment | 5 | 13 |
| Manufacture of machinery and equipment n.e.c. | 4 | 10 |
| Manufacture of textiles | 3 | 8 |
| Others | 9 | 24 |

Furthermore, this research mainly is based on data from manufacturers of beverages, food products, rubber and plastic products, and electrical equipment.

Table 3 shows the sample distribution by annual turnover, measured in millions of euros. Additionally, 14 firms (37%) earn less than 2 million annually, 18 firms (47%) earn between 2 and 10 million annually, 4 firms (10%) earn between 11 and 25 million annually, 1 firm (3%) earns between 26 and 50 million annually, and 1 firm (3%) earns more than 50 million annually.

*Table 3: Sample distribution by annual turnover*

| **Annual turnover (euros)** | ***n*** | **%** |
|---|---|---|
| Less than 2 million | 14 | 37 |
| 2 to 10 million | 18 | 47 |
| 11 to 25 million | 4 | 10 |
| 26 to 50 million | 1 | 3 |
| More than 50 million | 1 | 3 |

Analysing the annual turnover of the firms that participated in this research, it is concluded that most firms earn up to 10 million euros annually.

# 4. Results and discussion

The use of *digital technologies* and *sustainability* according to the gathered data is presented in Figure 1. When addressing digital technologies, 3% of firms use Additive Manufacturing/3D Printing (DT1), 8% use Advanced Manufacturing Solutions (DT2), 5% use Artificial Intelligence/Machine Learning (DT3), 8% use Big Data Analytics (DT4), 11% use Cloud Computing (DT5), 8% use Cybersecurity (DT6), 11% use (Industrial) Internet of Things (DT7), 8% use Mixed Reality (DT8), and 8% use Simulation of Connected Machines (DT9). Regarding the sustainability parameters, 16% of firms have metrics to assess the economic performance of the services (S1), 11% of firms have metrics to evaluate the environmental impact of services (S2), 16% of firms see digital servitization as a way to be sustainable (S3), and 13% of firms see reconfigurability or upgradability as a critical strategy to achieve sustainable solutions (S4).

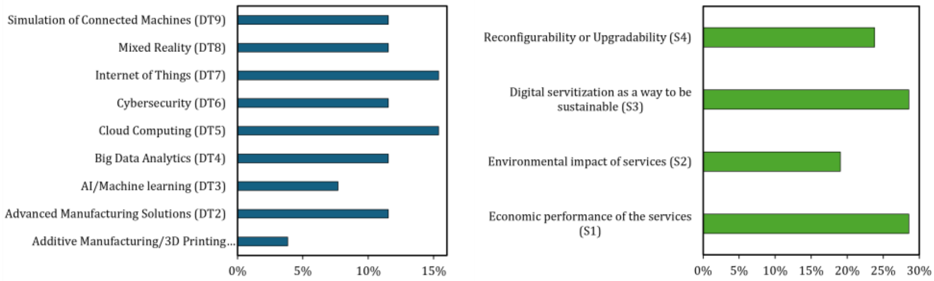


*Figure 1: The use of digital technologies and sustainability*

According to data presented in Figure 1, firms tend to focus more on sustainability than digital technologies. Table 4 presents Fisher's exact test between *digital technologies* and *sustainability parameters* expressed through log odds ratios. When intertwining DT1 and S1-S4, no association is identified. Nonetheless, a significant association is identified between S1 and DT5, S1 and DT7, S3 and DT5, and S3 and DT7.

*Table 4: Fisher's exact test between digital technologies and sustainability*

| | DT1 | DT2 | DT3 | DT4 | DT5 | DT6 | DT7 | DT8 | DT9 |
|---|---|---|---|---|---|---|---|---|---|
| **S1** | 2.875 | 4.174** | 3.587* | 4.174** | 4.762*** | 4.174** | 4.762*** | 4.174** | 4.174** |
| **S2** | 3.387 | 3.497* | 4.234** | 3.497* | 4.595** | 3.497* | 4.595** | 3.497* | 3.497* |
| **S3** | 2.875 | 4.174** | 3.587* | 4.174** | 4.762*** | 4.174** | 4.762*** | 4.174** | 4.174** |
| **S4** | 3.106 | 4.541** | 3.868* | 4.541** | 3.871** | 3.060* | 3.871** | 3.060* | 4.541** |

*Note: Values are presented of log-odds ratio; *p < 0.05; **p < 0.01; ***p < 0.001.*

Table 4 suggests a lack of association between Additive Manufacturing/3D Printing and sustainability parameters. However, metrics which assess the economic performance of the services and Cloud Computing, metrics which assess the economic performance of the services and (Industrial) Internet of Things, seeing digital servitization as a way to be sustainable and Cloud Computing, and seeing digital servitization as a way to be sustainable and (Industrial) Internet of Things significantly influence each other. There is a strong association between these digital technologies and sustainability parameters.

Figure 2 presents a Multiple Correspondence Analysis (MCA) for digital technologies and sustainability. MCA has a satisfactory variance of at least 70% (Orošnjak & Šević, 2023). Three clusters are identified in Figure 2. The blue cluster gathers only digital technologies, while the red and green clusters contain digital technologies and sustainability parameters.

Additive Manufacturing/3D Printing, Artificial Intelligence/Machine Learning, Advanced Manufacturing Solutions, Big Data Analytics, and Simulation of Connected Machines, which comprise the blue cluster, represent digital technologies usually implemented by the same company. All sustainability parameters gathered in the red cluster are used in manufacturing firms implementing Cloud Computing, Cybersecurity, (Industrial) Internet of Things, and

Mixed Reality. Finally, the green cluster gathers a negation of data used in the research.

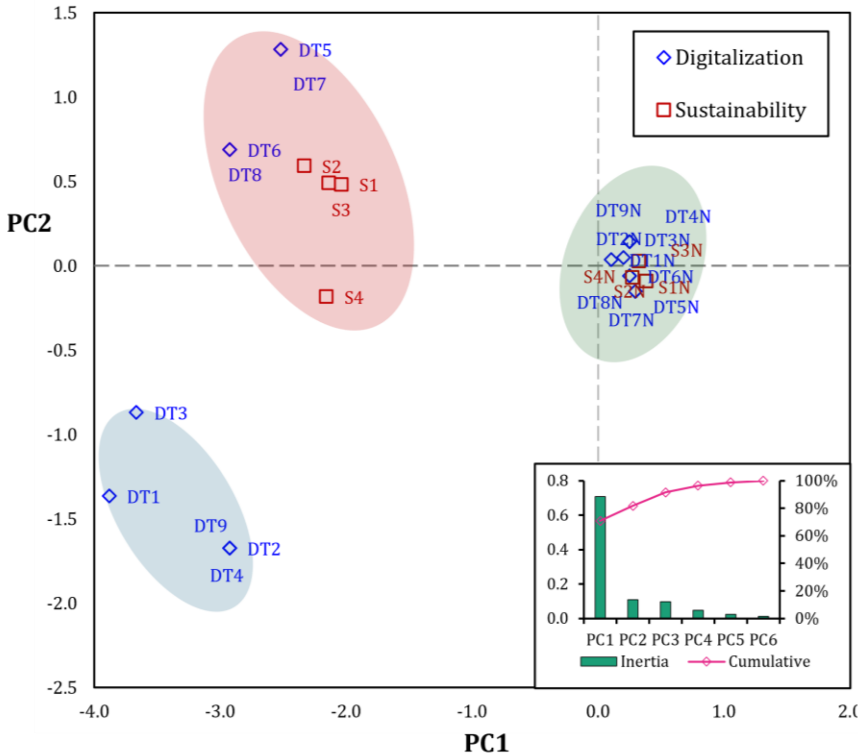


*Figure 2: MCA for digital technologies and sustainability*

## 5. Conclusions

This research has investigated the association between *digital technologies* and *sustainability* using a dataset representing the Republic of Serbia's manufacturing sector. The data used in this research was obtained through the "Digital Servitization Survey." The obtained findings suggest that digitalization has a significant association with sustainability metrics.

The high significance was identified when associating metrics which assess the economic performance of the services (S1) with Cloud Computing (DT5) and (Industrial) Internet of Things (DT7), as well as when associating seeing digital servitization as a way to be sustainable (S3) with Cloud Computing (DT5) and (Industrial) Internet of Things (DT7). Additionally, research has shown that firms likely implement the same group of digital technologies – Additive Manufacturing/3D Printing, Artificial Intelligence/Machine Learning, Advanced Manufacturing Solutions, Big Data Analytics, and Simulation of Connected. Also, the research has shown that firms that have implemented Cloud Computing, Cybersecurity, (Industrial) Internet of Things, and Mixed Reality use selected sustainability parameters.

Nonetheless, manufacturing firms in the Republic of Serbia must implement the sustainability framework according to their needs to fulfil rules and regulations and enter new markets that require certain sustainable practices. When faced with this challenge, firms already implementing digital technologies will develop sustainable strategies more efficiently.

Further research should include more sustainability parameters grouped by people, planet, and profit or environmental, economic, and societal aspects. Additionally, manufacturing and service sectors of other countries should be investigated and compared to each other to identify best practices that companies in transitioning economies apply.

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## REFERENCES

[1] Branger, J., & Pang, Z. (2015). From automated home to sustainable, healthy and manufacturing home: A new story enabled by the Internet-of-Things and Industry 4.0. *Journal of* Management *Analytics*, *2*(4), 314–332. https://doi.org/10.1080/23270012.2015.1115379

[2] Bressanelli, G., Adrodegari, F., Perona, M., & Saccani, N. (2018). Exploring How Usage-Focused Business Models Enable Circular Economy through Digital Technologies. *Sustainability*, *10*(3), 639. https://doi.org/10.3390/su10030639

[3] Dhayal, K. S., Giri, A. K., Kumar, A., Samadhiya, A., Agrawal, S., & Agrawal, R. (2023). Can green finance facilitate Industry 5.0 transition to achieve sustainability? A systematic review with future research directions. *Environmental Science and Pollution Research*, *30*(46), 102158–102180. https://doi.org/10.1007/s11356-023-29539-w

[4] Golovianko, M., Terziyan, V., Branytskyi, V., & Malyk, D. (2023). Industry 4.0 vs. Industry 5.0: Co-existence, Transition, or a Hybrid. *Procedia Computer Science*, *217*, 102–113. https://doi.org/10.1016/j.procs.2022.12.206

[5] Lasi, H., Fettke, P., Kemper, H.-G., Feld, T., & Hoffmann, M. (2014). Industry 4.0. *Business & Information Systems Engineering*, *6*(4), 239–242. https://doi.org/10.1007/s12599-014-0334-4

[6] Martynov, V. V., Shavaleeva, D. N., & Zaytseva, A. A. (2019). Information technology as the basis for transformation into a digital society and industry 5.0. *In 2019 International Conference" Quality Management, Transport and Information Security, Information Technologies"(IT&QM&IS)* (pp. 539-543). IEEE.. https://doi.org/10.1109/ITQMIS.2019.8928305

[7] Mustapić, M., Trstenjak, M., Gregurić, P., & Opetuk, T. (2023). Implementation and Use of Digital, Green and Sustainable Technologies in Internal and External Transport of Manufacturing Companies. *Sustainability*, *15*(12), 9557. https://doi.org/10.3390/su15129557

[8] Orošnjak, M., & Šević, D. (2023). Benchmarking Maintenance Practices for Allocating Features Affecting Hydraulic System Maintenance: A West-Balkan Perspective. *Mathematics*, *11*(18), 3816. https://doi.org/10.3390/math11183816

[9] Potočan, V., Mulej, M., & Nedelko, Z. (2021). Society 5.0: Balancing of Industry 4.0, economic advancement and social problems. *Kybernetes*, *50*(3), 794–811. https://doi.org/10.1108/K-12-2019-0858

[10] Rakic, S., Medic, N., Leoste, J., Vuckovic, T., & Marjanovic, U. (2023). Development and Future Trends of Digital Product-Service Systems: A Bibliometric Analysis Approach. *Applied System Innovation*, *6*(5), 89. https://doi.org/10.3390/asi6050089

[11] Rannertshauser, P., Kessler, M., & Arlinghaus, J. C. (2022). Human-centricity in the design of production planning and control systems: A first approach towards Industry 5.0. *IFAC-PapersOnLine*, *55*(10), 2641–2646. https://doi.org/10.1016/j.ifacol.2022.10.108

[12] Slavic, D., Romero, D., Pezzotta, G., Marjanovic, U., Savkovic, B., Popan, I. A., & Rakic, S. (2024). Towards Human-Centric Digital Services: A Development Framework. In M. Thürer, R. Riedel, G. Von Cieminski, & D. Romero (Eds.), *Advances in Production Management Systems. Production Management Systems for Volatile, Uncertain, Complex, and Ambiguous Environments* (Vol. 732, pp. 184–197). Springer Nature Switzerland. https://doi.org/10.1007/978-3-031-71637-9_13

[13] Trstenjak, M., Hegedić, M., Tošanović, N., Opetuk, T., Đukić, G., & Cajner, H. (2023). Key Enablers of Industry 5.0—Transition from 4.0 to the New Digital and Sustainable System. In H. Kohl, G. Seliger, & F. Dietrich (Eds.), *Manufacturing Driving Circular Economy* (pp. 614–621). Springer International Publishing. https://doi.org/10.1007/978-3-031-28839-5_69

[14] Wu, J., Guo, S., Huang, H., Liu, W., & Xiang, Y. (2018). Information and Communications Technologies for Sustainable Development Goals: State-of-the-Art, Needs and Perspectives. *IEEE Communications Surveys & Tutorials*, *20*(3), 2389–2406. https://doi.org/10.1109/COMST.2018.2812301