Chapter

Product Lifecycle: Social and Political Reflections from the Digital and Sustainable Perspectives

Fabio De Felice and Antonella Petrillo

Abstract

Digitalization and sustainability are the drivers of the global development of the future that have slowly conquered the agendas of governments and organizations on every continent. In this context, the pandemic has proved to be a powerful technological accelerator, helping to give a greater boost to these drivers, "guiding" leading the productive and economic sector throughout the world. Today the sustainability and digitalization represent the indispensable prerequisites to add economic, environmental, and social sovereignty. In fact, the scenario that the Coronavirus is leaving us foreshadows the need not to be satisfied with reaching targets for reducing greenhouse gas emissions, but to imagine "global" governance for the development of business models based on the new digital frontiers. Thus, what are the challenges for achieving the paradigms of sustainability and digitization in this new era? And what are the tools for a "digicircular" transformation? The aim of this chapter is to investigate these issues. To this end, it should be noted that, in this chapter, our aim is not to present an analysis of literature in the classical sense but rather political and social reflections.

Keywords: digitalization, sustainability, business, covid, environment, society, economy

1. Introduction

The pandemic has highlighted the importance of responsible use of resources in all sectors. The production sector is no exception. COVID-19 has given a push to transfer the circular paradigm from the economy to politics, precisely because the pandemic has planetary extension and repercussions. The key principle of the circular economy is the adaptation of economic cycles to natural cycles. A new paradigm is proposed as an innovative and advanced solution to combine growth in consumption and demand for goods with environmental sustainability [1]. This means rethinking the way in which we use matter and energy from design to production, from consumption to the management of the so-called "waste". In this context, with reference to the concept of waste, it would be desirable to speak of a "waste resource", thus overturning the very meaning of the term [2]. Today, it is quite clear that circular solutions will not be able to spread without the support of digital technologies and infrastructures, within an extremely broad reference perimeter: transport, ports, digital infrastructures, energy, and electricity networks [3]. Digital transformation and sustainability should provide for interaction and integration between new physical and digital technologies or artificial intelligence, internet of things, augmented reality, additive manufacturing, both on the network side and on the digitalization of processes [4]. Positive repercussions of the sustainable transition on the economy are realistically achievable only on the condition of having facilities capable of allowing the exchange of resource flows through transcontinental infrastructures. A scenario that can only be obtained under the condition of a colossal exchange of information (big data) that will make it possible to meet the needs and demand for the well-being of a world population which, from 1970 to 2017, has increased by 2 times and world consumption of materials increased by 4 times with all the consequent negative effects in terms, for example, of waste production [5]. However, there has been talking of digitalization of infrastructures since the end of the nineties, but today we are quite far from the minimum goal of digitizing the backbones and essential resources of our planet [6]. The question is: how to give a metric, a dimension, a "measurability" of the quantities that can lead us to sustainability? Today, technology could help achieve this goal; for example, thanks to the immense computing capabilities of a quantum computer (quantum computing from IBM and Google are already available today for various simulations) or the evolution of deep learning. But all this may only be possible if the data is available. The key to building economic and social resilience, therefore, lies in digitization, which is the dominant element around which the collective future takes shape [7]. Thus, what are the challenges for achieving the paradigms of sustainability and digitization in this new era? And what are the tools for a "digicircular" transformation? The aim of this chapter is to investigate these issues. To this end, it should be noted that, in this chapter, our aim is not to present an analysis of literature in the classical sense but rather political and social reflections.

The rest of the chapter is organized as follows: Section 2 intends to analyze the link between sustainability, digitalization from a product life cycle perspective; Section 3 outlines how to design a "digicircular" future; Section 4 tries to summarize some challenges for digitalization and sustainability. Finally, in Section 5 the main conclusions of the study are outlined.

2. Sustainable sovereignty: condition for digital sovereignty

Digitization and sustainability are among the most discussed topics in recent years and their simultaneous implementation will constitute the challenge and opportunity for the near future [8]. It is therefore essential to enhance the evolution over time of the links between these two and to understand if there are technologies that favor the creation of circular economies and, if so, what they are. As known the main technologies are: internet of things, cloud computing, augmented reality with artificial intelligence, additive manufacturing, horizontal and vertical integration, cybersecurity, autonomous robots, simulation/digital twin, and big data analytics [9]. From our point of view, it is interesting to analyze the link between sustainability, digitalization/technologies from a product life cycle perspective [10]. Thus, an investigation on Scopus, the largest abstract and citation database of peer-reviewed literature has been carried out in this research. The database was queried using the Boolean operators AND and OR as the following string shows: (TITLE-ABS-KEY (sustainability) AND TITLE-ABS-KEY (digitalization) OR TITLE-ABS-KEY (internet AND of AND things) OR TITLE-ABS-KEY (cloud AND computing) OR TITLE-ABS-KEY (artificial AND intelligence) OR TITLE-ABS-KEY (augmented AND reality) OR TITLE-ABS-KEY (additive AND manufacturing) OR TITLE-ABS-KEY (horizontal AND vertical AND integration) OR TITLE-ABS-KEY (cybersecurity) OR TITLE-ABS-KEY (robot) OR TITLE-ABS-KEY (simulation) OR TITLE-ABS-KEY (big AND data) AND TITLE-ABS-KEY (product AND life AND cycle)). In detail, all the articles that had the string in the title, in the abstract, and in the keywords were selected. The search returned 384 documents. The 384 papers were analyzed not with the intent of developing a detailed literature review. Rather, the purpose of this investigation was to identify challenges and future trends with respect to two aspects, the most used keywords, and publication sources. But before analyzing the above features it is remarkable to note the distribution of documents over time. Documents are distributed from 1999 to 2021 (in progress), but obviously only in the last 5 years has there been an increase in the number of publications as shown in **Figure 1**.

To underestimate the interconnections and trends relating to the concepts of sustainability and digitization from a product life cycle perspective, has been used VOS viewer software [11]. In particular, co-occurrence analysis and bibliographic coupling were performed. Analysis of keyword co-occurrence is the bibliometric method used to map the research field. The process of creating keyword networks and clustering keywords is aimed at identifying the main research fields in the area of technologies (i.e., internet of things, big data analytics and, recently, also additive manufacturing) and environmental sustainability (see **Figure 2**).

In detail, it emerged that Internet of Things technologies are mainly used to extend the life cycle of the product but they prove to be a good solution also for the management of waste collection and recovery operations in the supply chain [12–14]. While, Big Data Analytics technologies are useful to use resources efficiently, to collect or manage data relating to the life cycle of products, and to develop new business models in a circular perspective. Artificial Intelligence can contribute to the implementation of a sustainable process in accelerating the development of products, components, and the choice of sustainable materials through assisted design processes that allow rapid prototyping and testing. It also favors the implementation of circular business models [15, 16]. Additive Manufacturing can incentivize sustainability thanks to the support it offers in terms of product life cycle management, recycling processes, and digitalization of production. In other words, a factory should be designed to be completely connected: from machinery to integrated processes, which will be combined with Artificial Intelligence algorithms [17, 18]. **Figure 3** shows a bibliographic

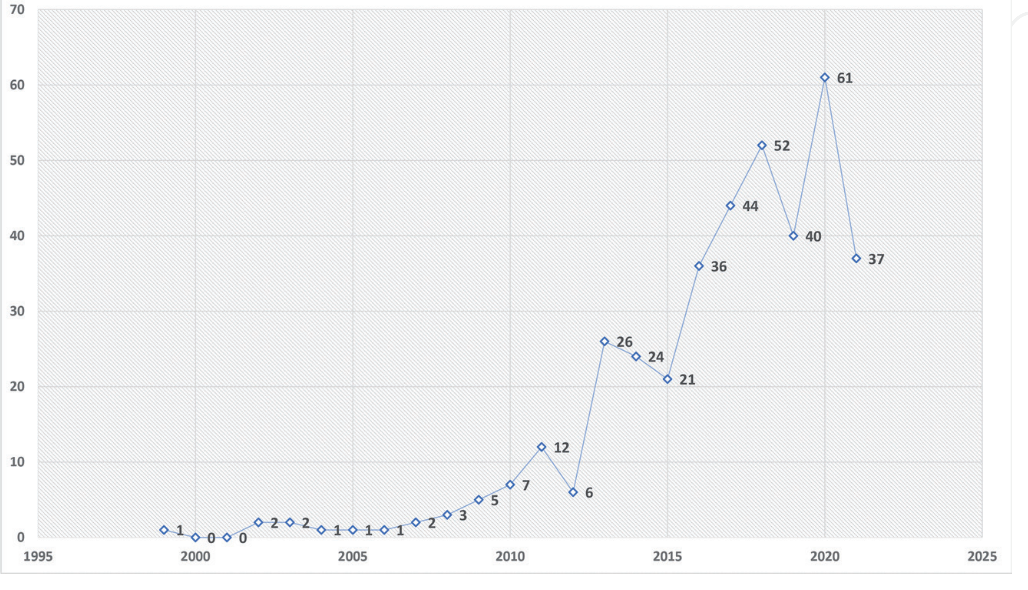

Figure 1.
Documents by years (source Scopus).

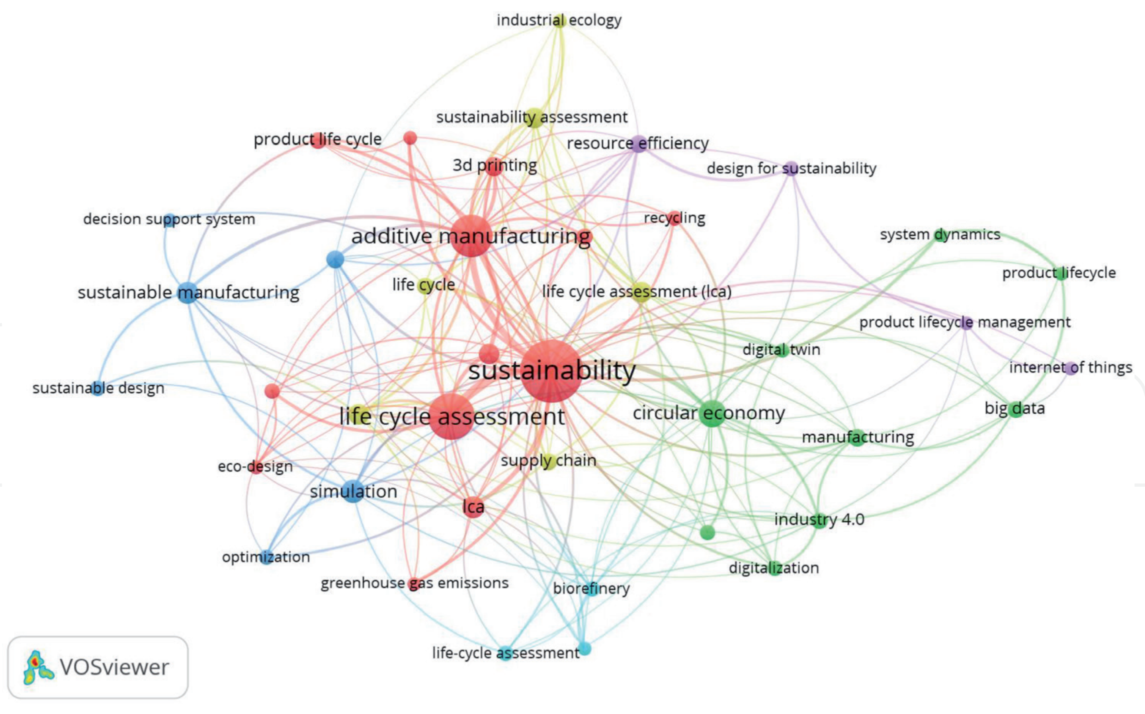

Figure 2.
Co-occurrence analysis.

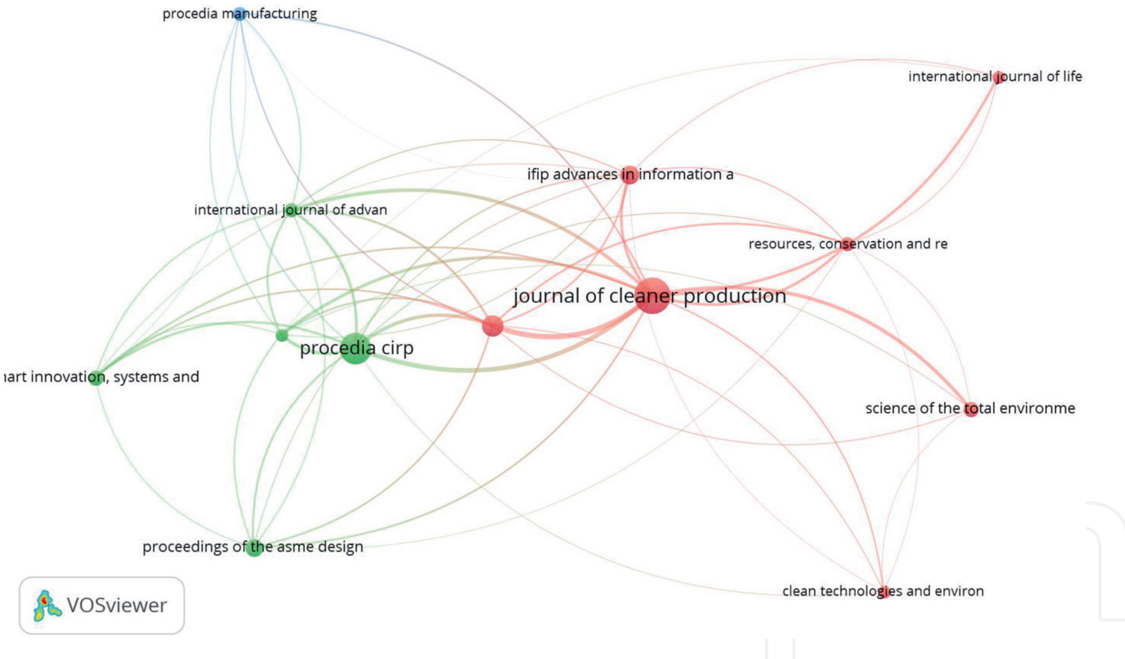

Figure 3.
Bibliographic coupling.

coupling analysis considering the sources. It emerges that the *Journal of Cleaner Production* is one of the most attractive scientific references for these issues. The result is not surprising because in the scientific community the journal is recognized as one of the best, interdisciplinary journals in which scientific works are encouraged that combine three key elements: reduction, environmental, and sustainability.

The analysis shows that there will be no emerging technology on the others, but an integration of technologies. A hybridization of digital technologies that will favor the transition towards sustainable production in view of product life cycle management is needed [1, 19, 20].

3. Designing a "digicircular" future

It is clear that digitization can be an opportunity to accelerate the sustainability processes connected to digitalization. The point now is to understand how to move from a qualitative to a quantitative approach [21]. The problem is not entirely secondary, it is indeed extremely important. In fact, many organizations and companies struggle to understand what is circular from what is not. A paradigm shift is needed. A new mindset to redesign the model for the future, adopting the circular economy model on a national and international scale. From this perspective, digital technologies represent an opportunity to identify new business models [22]. The combination of technologies helps to evolve businesses into a virtuous circle of improvement. At the same time, digital technologies help not to "make mistakes". Just think of the potential of digital twins that allow us to simulate real systems in virtual environments by comparing multiple scenarios, optimizing resources, time, and costs. However, we must be clear that there is no single model valid for all organizations and companies [23]. It is essential to know the market in order to have all the information and data necessary to define the most suitable business model. Today a large amount of data available is lacking the right information useful for making decisions and making the system as a whole predictive. However, moving to a circular economy model is a complex process that requires the use of appropriate measurement and improvement tools. The standardization processes launched for some years by the UNI and ISO commissions (UNI/CT 057 Commission and ISO/TC 323—Circular economy) provide a valid contribution in starting to speak the same common language. It is clear that methods and tools are needed to define the product and manage its evolution from the sustainability perspective. In this regard, it is essential to monitor business processes by sharing information between the internal functions with all the stakeholders (designers, suppliers, distributors, customers) [24]. Thus, quantifying sustainability in the perspective of product life cycle represent a key factor as shown in **Figure 4**.

Figure 4.
Global challenges in terms of enabling factors and the value chain.

4. Challenges for digitalization and sustainability

The challenges of digitization and sustainability require an integrated approach to legislative activity and coordination and cooperation activities worldwide. In this sense, it is also necessary to promote new initiatives to regulate artificial intelligence, among others, considered as one of the main technologies useful for the development of circular models, with particular attention to the ethical implications deriving from the use of algorithms. Another aspect to be considered among the challenges for the circular economy is the development of global digital platforms as a tool for a virtuous use of resources capable of intercepting all the stakeholders in the supply chain from a global "resources" market perspective [25]. In this way it will also be possible to optimize costs and waste at the national and international level, in compliance with recognized global standards as well as customized solutions, resulting from applications of global scientific instruments. The real challenge is that everyone in their area (production, suppliers, and customers) should contribute to the "system", generating value downstream and upstream to enable the factors for the transition and thus achieve sustainable sovereignty. In fact, a globalized supply chain designed to use fewer materials is more resilient. In this way, a collaborative approach is adopted both with companies that treat waste and with suppliers of raw materials, to achieve win-win models. Producing what is needed when needed (e.g., the use of 3D printers, with the consequent decrease in the movement of materials and goods and an increase in dematerialization), thinking in terms of services and not just products, are central factors and fundamental assumptions in a vision of a globalized and integrated supply chain [26]. Obviously, in this perspective, digitization along the value chain represents an essential element for the control, planning, and forecasting of business activities that influence competitive factors from a circular economy perspective. The information generated by digital technologies supports the transition to a circular economy/sustainability through the identification of business opportunities and the enhancement of resources with a view to benefits and costs. A holistic vision of the product presupposes strategic management of data, information, processes, and resources relating to each phase, as shown in **Figure 5**.

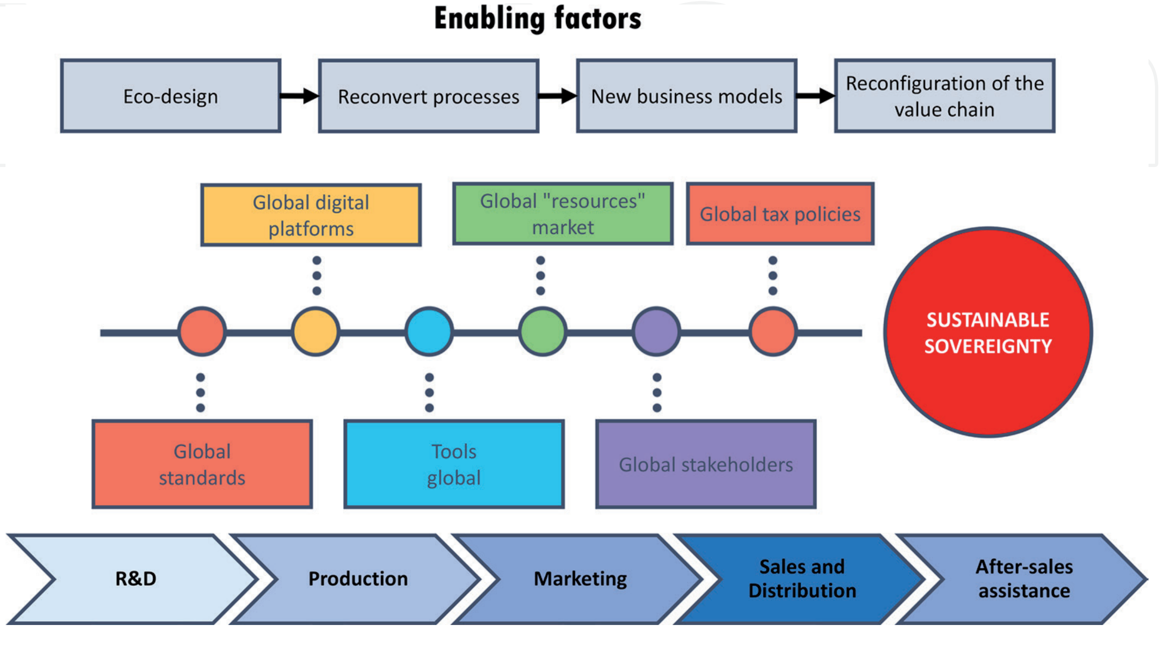

Figure 5.
Enabling factors of Sustainable Soverignty.

In other words, "digicircular actions" horizon can be summarized as follows: (1) Create a taxonomy for the international circular economy; (2) Integrate environmental, social, and economic policies; (3) Promote standards and certifications; (4) Use transparent tools (LCA, EPD, ...) and (5) Strengthen measures for the development of the bioeconomy.

5. Conclusions

Digital and Sustainable are among the most discussed topics in recent years and their simultaneous implementation will be a challenge and opportunity for the near future. Digital transitions should help redraw the boundaries of our world in a more "*sustainable*" way. Of course, technology itself does not mobilize itself towards transformations of sustainability, since a strong political will is needed to create pathways capable of engaging these perspectives. Furthermore, digital technologies are not innocent in the progressive worsening of the state of our planet and the growth of greenhouse gas emissions. Therefore, there is also a topic related to the impact of digital technologies. The perception of the relationship between risk and benefit remains a complicated aspect to assess. However, in the long term, the benefits will outweigh the risks, as it is easy to imagine if the use of technologies is accompanied by responsible use. In conclusion, the present study underlines the link between sustainability and digitalization and make people understand that correct management of the life cycle requires innovation. Technologies, in fact, are able to optimize the use of resources, reducing waste, simplifying processes, and making the use of infrastructures sustainable. It is, therefore, necessary to connect these two issues to achieve what will be the smart sustainable factories capable of bringing a triple economic, environmental and social advantage.

Conflict of interest

The authors declare no conflict of interest.

Author details

Fabio De Felice and Antonella Petrillo*
Department of Engineering, University of Naples "Parthenope", Naples, Italy

*Address all correspondence to: antonella.petrillo@uniparthenope.it

References

[1] Adisorn T, Tholen L, Götz T. Towards a digital product passport fit for contributing to a circular economy. Energies. 2021;**14**(8):2289

[2] Ajwani-Ramchandani R, Figueira S, Torres de Oliveira R, Ramchandani A, Schuricht L. Towards a circular economy for packaging waste by using new technologies: The case of large multinationals in emerging economies. Journal of Cleaner Production. 2021;**281**:1-15. DOI: 10.1016/j.jclepro.2020.125139

[3] Zheng P, Wang Z, Chen C-H, Pheng Khoo L. A survey of smart product-service systems: Key aspects, challenges and future perspectives. 2019;**42**:65-80. DOI: 10.1016/j.aei.2019.100973

[4] De Felice F, Petrillo A. An interdisciplinary framework to define strategies for digitalization and sustainability: Proposal of a 'digicircular' model. IET Collaborative Intelligent Manufacturing. 2021;**3**(1): 75-84

[5] Prasara AJ, Gheewala SH. An assessment of social sustainability of sugarcane and cassava cultivation in Thailand. Sustainable Production and Consumption. 2021;**27**:372-382

[6] Atılgan Türkmen B, Budak Duhbacı T, Karahan Özbilen Ş. Environmental impact assessment of ceramic tile manufacturing: A case study in Turkey. Clean Technologies and Environmental Policy. 2021;**23**(4): 1295-1310

[7] Peng W, Su D, Wang S. Development of an innovative ict infrastructure for an eco-cost system with life cycle assessment. Sustainability. 2021;**13**(6): 3118

[8] Son D, Kim S, Jeong B. Sustainable part consolidation model for customized products in closed-loop supply chain with additive manufacturing hub. Additive Manufacturing. 2021;**37**:1-10. DOI: 10.1016/j.addma.2020.101643

[9] Riedelsheimer T, Gogineni S, Stark R. Methodology to develop Digital Twins for energy efficient customizable IoT-Products. International Journal of Precision Engineering and Manufacturing-Green Technology. 2021;**98**:258-263. DOI: 10.1007/s40684-021-00354-3

[10] Travaglioni M, Ferazzoli A, Petrillo A, De Felice F, Piscitelli G. Digital manufacturing challenges through open innovation perspective. Procedia Manufacturing. 2020;**42**: 165-172

[11] Biggi G, Giuliani E. The noxious consequences of innovation: What do we know? Industry and Innovation. 2020;**28**(1):19-41

[12] Khalid M, Peng Q. Sustainability and environmental impact of additive manufacturing: A literature review. Computer-Aided Design and Applications. 2021;**18**(6):1210-1232

[13] Riedelsheimer T, Neugebauer S, Lindow K. Progress for life cycle sustainability assessment by means of digital lifecycle twins—A taxonomy. In: Sustainable Production, Life Cycle Engineering and Management. Singapore: Springer; 2021. pp. 329-345

[14] Chen X, Despeisse M, Johansson B. Environmental sustainability of digitalization in manufacturing: A review. Sustainability. 2020;**12**(24): 10298

[15] Zheng P, Li X, Peng T, Wang Y, Zhang G. Industrial smart product-service system development for lifecycle sustainability concerns. IET

Collaborative Intelligent Manufacturing. 2020;**2**(4):197-201

[16] He B, Li F, Cao X, Li T. Product sustainable design: A review from the environmental, economic, and social aspects. Journal of Computing and Information Science in Engineering. 2021;**20**:110-122. DOI: 10.1115/1.4045408

[17] Aziz NA, Adnan NAA, Wahab DA, Azman AH. Component design optimisation based on artificial intelligence in support of additive manufacturing repair and restoration: Current status and future outlook for remanufacturing. Journal of Cleaner Production. 2021;**296**:10-26. DOI: 10.1016/j.jclepro.2021.126401

[18] Zheng P, Wang Z, Chen C-H. Smart product-service systems: A novel transdisciplinary sociotechnical paradigm. Advances in Trans disciplinary Engineering. 2019;**10**: 234-241

[19] Siedler C, Dupont S, Zavareh MT, Zink KJ, Aurich JC. Maturity model for determining digitalization levels within different product lifecycle phases. Production Engineering. 2021;**15**(3-4): 431-450

[20] Lo CK, Chen CH, Zhong RY. Smart product-service systems: A novel transdisciplinary sociotechnical paradigm. Advanced Engineering Informatics. 2019;**10**:234-241. DOI: 10.1016/j.aei.2021.101297

[21] He B, Shao Y, Wang S, Gu Z, Bai K. Product environmental footprints assessment for product life cycle. Journal of Cleaner Production. 2019;**233**:446-460. DOI: 10.1016/j.jclepro.2019.06.078

[22] Oliveira AS, Silva BCS, Ferreira CV, Machado BAS, Coelho RS. Adding technology sustainability evaluation to product development: A proposed methodology and an assessment model. Sustainability. 2021;**13**(4):2097

[23] Liu M, Fang S, Dong H, Xu C. Adding technology sustainability evaluation to product development: A proposed methodology and an assessment model. Journal of Manufacturing Systems. 2021;**58**: 346-361

[24] Pirola F, Boucher X, Wiesner S, Pezzotta G. Digital technologies in product-service systems: A literature review and a research agenda. Computers in Industry. 2020;**123**:24-36. DOI: 10.1016/j.compind.2020.103301

[25] Robul Y, Lytovchenko I, Tchon L, Khanova O, Omelianenko O. Digital marketing tools in the value chain of an innovative product. International Journal of Scientific and Technology Research. 2020;**9**(4):158-165

[26] Liu Y, Zhang Y, Ren S, Wang Y, Huisingh D. How can smart technologies contribute to sustainable product lifecycle management? Journal of Cleaner Production. 2020;**249**:1-6. DOI: 10.1016/j.jclepro.2019.119423