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Editorial

New Innovation, Sustainability, and Resilience Challenges in the X.0 Era

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Facing a constantly evolving industry and customers that are becoming more fastidious, companies are seeking to adapt their manufacturing methods to meet market demands [1]. Industry X.0 is the most responsive approach for companies to ensure competitiveness. We are currently talking about "Industry 4.0"and 5.0, and there will probably be 6.0, and so on. The term "Industry X.0" was coined to generalize this concept, ensuring future digital continuity and combining transformation efficiency with research.

Industry X.0 is a paradigm that first saw light in Germany during the Hanover fair, which was held in 2011 under Industry 4.0 (or the fourth industrial revolution) [1–3]. This revolution aimed to introduce new smart technologies to help industries ensure the smart aspects of their factories, improve their performance, and create an innovative, sustainable, and resilient environment.

The Industry 4.0 concept is currently the most popular topic within industrial firms, research centers, and universities [4]. Indeed, several studies have revealed and detailed the enabling technologies of Industry X.0, such as the Internet of Things, big data, artificial intelligence, modeling and simulation, 3D printing, and virtual reality [5–7]. The strength of these technologies, which has popularized Industry X.0, is their capacity to combine the physical world with the virtual with real-time interaction, allowing smart factories to coexist harmoniously with humans [8]. Furthermore, digitalization also ensures product customization, a better control and visualization of work results [9], and real-time product testing in a virtual environment considering real production constraints [10]. So far, research has shown that the three main sectors actively involved in the digitalization concept are the automotive, aerospace, and food industries [5].

In addition, Industry X.0 technologies are also used to support the evolution of lean manufacturing tools and principles [11]. As a result, many researchers have advanced the complementarity between both concepts: lean principles ensure waste elimination and standardization for a smooth implementation of Industry X.0 technologies when Industry X.0 allows the smartening and development of lean manufacturing tools [12]. The most popular applications of this fusion (Lean 4.0 [13]) are TPM 4.0, Kaizen 4.0, Kanban 4.0, automated guided vehicles (AGV), and Just-In-Time 4.0 [12,14–16].

Industry X.0 technologies have played an important role in developing the resilience of manufacturing companies, especially during the COVID-19 pandemic, through smart manufacturing practices, flexibility, reliability, robustness, and responsiveness. Through a survey with responders from various sectors, it was proven that flexible and innovative practices enabled by Industry X.0 led to a novel reconfiguration of manufacturing processes and products (volume/diversity) [17]. Moreover, Industry X.0 is an important contributor to industrial innovation, sustainability, and increased environmental, social, and economic efficiency. For example, artificial intelligence and machine learning can be used to identify solutions for environmental issues, such as waste control, resource optimization, carbon neutrality, etc. [18,19]. Furthermore, the numerous sustainable aspects of the Industry

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X.0 concept include the substitution of paperwork by digital electronic devices, smart grids, green energy management, reducing energy consumption through IoT technology, the usage of modeling software to optimize buildings, conserving materials and waste reduction through 3D printing, and the adoption of photovoltaic systems [20]. Finally, digitalization has resulted in people changing their ways of thinking about and managing their factories, highlighting the innovative aspects of Industry X.0. In fact, it provides opportunities to create new and more individualized products [21], new ways of interaction, a better understanding of customers' needs, smart goods and services, etc. [22].

Nevertheless, these technologies, as promising as they are, bring radical changes from the manufacturing to the organizational side. Their implementation comes with various challenges and barriers, mostly related to investment (cost and return on investment) and peoples' culture. Indeed, numerous companies still cannot afford to implement this new concept, not only because of its cost and implementation lead-time [23] but also due to a lack of financial support. Finally, from a cultural point of view, the reorientation towards digitalization and the use of Industry X.0 technologies requires the adoption of a spirit open to change [24].

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References

1. Rojko, A. *Industry 4.0 Concept: Background and Overview*; iJIM; ECPE European Center for Power Electronics e.V.: Nuremberg, Germany, 2017; Volume 11, No. 5.
2. Marzano, G.; Martinovs, A. Teaching Industry 4.0. Society. Integration. Education. In Proceedings of the International Scientific Conference, Rēzekne, Rēzekne, Latvija, 22–23 May 2020; Volume 2.
3. Kagermann, H.; Wahlster, W.; Helbig, J. *Recommendations for Implementing the Strategic Initiative INDUSTRIE 4.0*; Final Report of the Industrie 4.0 WG; Acatech: Munich, Germany, 2013.
4. Liao, Y.; Deschamps, F.; Loures, E.D.F.R.; Ramos, L.F.P. Past, present and future of Industry 4.0—A systematic literature review and research agenda proposal. *Int. J. Prod. Res.* **2017**, *55*, 3609–3629. [CrossRef]
5. Gallab, M.; Bouloiz, H.; Kebe, S.A.; Tkiouat, M. Opportunities and challenges of the industry 4.0 in industrial companies: A survey on Moroccan firms. *J. Ind. Bus. Econ.* **2021**, *48*, 413–439. [CrossRef]
6. Sishi, M.; Telukdarie, A. Implementation of Industry 4.0 technologies in the mining industry—A case study. *Int. J. Min. Miner. Eng.* **2020**, *11*, 1–22. [CrossRef]
7. Frank, A.G.; Dalenogare, L.S.; Ayala, N.F. Industry 4.0 technologies: Implementation patterns in manufacturing companies. *Int. J. Prod. Econ.* **2019**, *210*, 15–26. [CrossRef]
8. Wagner, T.; Herrmann, C.; Thiede, S. Industry 4.0 Impacts on Lean Production Systems. *Procedia CIRP* **2017**, *63*, 125–131. [CrossRef]
9. Gajsek, B.; Marolt, J.; Rupnik, B.; Lerher, T.; Sternad, M. Using Maturity Model and Discrete-Event Simulation for Industry 4.0 Implementation. *Int. J. Simul. Model.* **2019**, *18*, 488–499. [CrossRef] [PubMed]
10. Lima, F.; Nogueira de Carvalho, C.; Acardi, B.S.; Gomes dos Santos, E.; Bastos de Miranda, G.; Maia, R.F.; Massote, A.A. Digital manufacturing tools in the simulation of collaborative robots: Towards Industry 4.0. *Braz. J. Oper. Prod. Manag.* **2019**, *16*, 261–280. [CrossRef]
11. Marinelli, M.; Deshmukh, A.A.; Janardhanan, M.; Nielsen, I. Lean manufacturing and Industry 4.0 combinative application: Practices and perceived benefits. *IFAC-PapersOnLine* **2021**, *54*, 288–293. [CrossRef]
12. Naciri, L.; Mouhib, Z.; Gallab, M.; Nali, M.; Abbou, R.; Kebe, A. Lean and industry 4.0: A leading harmony. *Procedia Comput. Sci.* **2022**, *200*, 394–406. [CrossRef]
13. Schwab, K. *The Fourth Industrial Revolution: What It Means, How to Respond*; World Economic Forum: Davos, Switzerland, 2016.
14. Kolberg, D.; Zühlke, D. Lean Automation enabled by Industry 4.0 Technologies. *IFAC-PapersOnLine* **2015**, *48*, 1870–1875. [CrossRef]
15. Mayr, A.; Weigelt, M.; Kühl, A.; Grimm, S.; Erll, A.; Potzel, M.; Franke, J. Lean 4.0—A conceptual conjunction of lean management and Industry 4.0. *Procedia CIRP* **2018**, *72*, 622–628. [CrossRef]
16. El Abbadi, L.; El Manti, S.; Houti, M.; Elrhanimi, S. Kanban System for Industry 4.0 Environment. *Int. J. Eng. Technol.* **2018**, *7*, 60–65.
17. Bianco, D.; Bueno, A.; Filho, M.G.; Latan, H.; Ganga, G.M.D.; Frank, A.G.; Jabbour, C.J.C. The role of Industry 4.0 in developing resilience for manufacturing companies during COVID-19. *Int. J. Prod. Econ.* **2023**, *256*, 108728. [CrossRef]
18. Tiwari, K.; Khan, M.S. Sustainability accounting and reporting in the industry 4.0. *J. Clean. Prod.* **2020**, *258*, 120783. [CrossRef]
19. Javaid, M.; Haleem, A. Industry 4.0 applications in medical field: A brief review. *Cur. Med. Res. Pract.* **2019**, *9*, 102–109. [CrossRef]
20. Javaid, M.; Haleem, A.; Singh, R.P.; Suman, R.; Gonzalez, E.S. Understanding the adoption of Industry 4.0 technologies in improving environmental sustainability. *Sustain. Oper. Comput.* **2022**, *3*, 203–217. [CrossRef]

21. Arnold, C.; Kiel, D.; Voigt, K.I. How the industrial internet of things changes business models in different manufacturing industries. *Int. J. Innov. Manag.* **2016**, *20*, 1640015. [CrossRef]
22. Ibarra, D.; Ganzarain, J.; Igartua, J.I. Business model innovation through Industry 4.0: A review. *Procedia Manuf.* **2018**, *22*, 4–10. [CrossRef]
23. Qin, J.; Liu, Y.; Grosvenor, R. A Categorical Framework of Manufacturing for Industry 4.0 and beyond. *Procedia CIRP* **2016**, *52*, 173–178. [CrossRef]
24. Charle, P. *Industry 4.0: The Connected Factory*, 9th ed.; Gimélec: Paris, France, 2013.