# A framework supporting retrofit adoption in the machine tools industry: a case study in an Italian company

Claudio Sassanelli a),b) [0000-0003-3603-9735], Alessandro Enrico Bianchi c), Paolo Rosa c) [0000-0003-3957-707X ], Federica Acerbi c) [0000-0002-0818-4620], Giorgio Mossa a)[0000-0003-4921-8150], Sergio Terzi c) [0000-0003-0438-6185]

*a) Department of Mechanics, Mathematics and Management, Politecnico di Bari, Via Orabona 4, Bari, 70125, Italy (claudio.sassanelli@poliba.it, giorgio.mossa@poliba.it)*

*b) Tech Center for Good, École des Ponts Business School of École des Ponts ParisTech (ENPC), 6 Place du Colonel Bourgoin, 75012, Paris (c.sassanelli@pontbschool.com)*

*c) Department of Management, Economics and Industrial Engineering, Politecnico di Mila-no, Piazza Leonardo da Vinci 32, Milan, 20133, Italy (alessandroenrico.bianchi@mail.polimi.it, paolo1.rosa@polimi.it, federica.acerbi@polimi.it, sergio.terzi@polimi.it)*

**Abstract**: Globalization determined significant variations in market mechanisms of manufacturing companies, including machinery and machine tools producers. Due to the environmental impact generated, these manufacturing companies aim to address sustainability, notwithstanding the hurdles and difficulties in adopting the related best practices. Considering that Product-Service Systems (PSS) are considered the most applied business models by manufacturing companies to address the sustainability scope, a case study has been conducted to explore the adoption of retrofit practices by an Ital-ian SME company operating in the machine tools industry. The objective is to develop a supporting framework that can demonstrate the sustainability of the PSS implemented by the company, even without the need for quantitative data about the environmental footprint of a machine tool. The model developed should support the decision-making process of manufacturing firms when deciding to adopt servitisation in their business strategy, with the final aim to improve the environmental sustainability of the products sold. Results show the economic and environmental impacts achieved, providing an understanding of the main drivers that push an Original Equipment Manufacturer (OEM) at offering a retrofit service. Moreover, it is shown that the developed PSS does not bring to the servitisation paradox in the firm. Finally, practical implications of Industry 4.0 technologies adoption as enablers of sustainability are provided.

**Keywords**: Smart Retrofit, PSS, Original Equipment Manufacturer, Predictive Mainte-nance, Machine Tool

## I. INTRODUCTION

Globalization determined significant variations in market mechanisms of manufacturing companies, including machinery and machine tools producers. The importance of this sector, especially for Italy, is highlighted by worldwide statistics: machine tools global demand is growing, from 88,6 billion dollars (2009) to 181 (2019). In this context, Italy is the fourth producer in the world (following China, Germany and Japan), with 8% of share of the total production and a total production worth 4,677 billion euros [1]. The so-called twin transition, involving the Industry 4.0 (I4.0) and Circular Economy (CE) paradigms, deeply affects also this industry. Machine tools are the main asset enabling during the production process both the practical adoption of circular strategies (e.g., reducing energy and water consumption, natural resources depletion and scraps) and providing data to be exploited by several I4.0 solutions (e.g., IoT, CPSs, DTs, blockchains, biga data analysis, etc.). In addition, during the years, several experts [1]–[3] argued about the adoption of PSS-inspired logics [4] within this sector, proposing retrofit as one of the most popular solution [5]–[7]. However, models able to guide companies in the application of the retrofit strategy to their product portfolios to address sustainability are needed. This work is focused on the application of retrofit by an Italian SME operating in the machine tools industry to

empower and enrich their portfolio with a bundle of services. The analysis of this process leads to a deeper understanding of both the environmental and economic benefits that the retrofit service can bring to an industry characterized by high energy and material consumption.
The structure of the paper is as following. Section 2 describes the research context. Section 3 presents the research methodology adopted. Section 4 provides the main results of the study and section 5 discusses them. Finally, Section 6 concludes the paper opening to future research oppotunities.

## II. Research context: circular PSS in machine tool sector

Machinery and industrial equipment is the most addressed sector by empirical studies about digital servitization. Revamping makes the biggest progress in the use of traditional services by manufacturing firms [2], providing environmental benefits by extending the useful life of a product [1]. Sustainable Product-Service Systems (PSS) require radical-creative thinking to reduce environmental impacts and ensure a high quality of services [8]. Additional services can have positive effects on material and energy consumption during production [1], and companies can be incentivized to extend the life of the products and to manufacture them as efficiently as possible in terms of costs and materials [8]. Product-oriented PSS are widely adopted in the manufacturing sector [9]. [3] observed the behaviour of two Original Equipment Manufacturers (OEMs) operating in the machinery industry, and presenting similarities between industrial and customer services, contributing to the literature on product-oriented services. Similarly, [10] discusses the coordinating mechanisms between OEMs and Third-Party Remanufacturers (TPRs), showing that product-oriented PSS is the best coordinating mechanism between them. The upgrading of the old equipment is a value-adding alternative to the replacement of the tool, and, to this extent, [11] identified drivers, resources and capabilities composing a framework that supports manufacturers' decision making process in adopting machine tool upgrading successfully in their business. Such research does not consider the sustainability impacts that the practice could bring. Therefore, a sustainability assessment should be investigated. For companies that work with heavy hardware, the entire replacement of a machine is a huge financial investment, especially for SMEs, and usually, it turns out to be very inconvenient, due to extended machine downtime that causes unsustainable losses of income. In the manufacturing and commerce sector, SMEs are predominant, representing the 'backbone of the economy' [5]. However, they are still struggling in digitizing their business, due to manifold barriers to the introduction of such strategy [12], [13]. In the case of I4.0, smart retrofitting adds new technologies and sensors into legacy systems, supporting the transition towards smart manufacturing [5], extending the life cycle of machinery in a way that is feasible, time-saving, and requiring lower investments. Indeed, the modern sensing devices enable real-time monitoring of vast amounts of data on manufacturing processes [14], [15]. As a consequence, the company builds the ability to develop deeper post-sale relationships with customers, in which the manufacturer monitors the performance and provides maintenance services [16]. Such data can be used to implement predictive maintenance.

## III. Research methodology

The methodology applied to develop the framework is described, starting from the analysis of the literature up to its validation to the C.B. Ferrari case. All the steps have been the result of a collaboration between the researchers and the company employees, with the aim to develop a framework tailored on the company's needs but also applicable to other SMEs involved in the machine tools industry. Three phases composed the research process: conceptualization, development, and validation. Due to the lack of quantitative data about the actual environmental footprint of the machine tools of C.B. Ferrari, the objective of the first phase has been the identification in literature of extant artifact that could contribute to the building of a framework capable to highlight the sustainability aspect of the retrofit activity in a PSS-oriented machine tool. The analysis of the literature allowed the understanding of the research context, going into detail through the opportunities and issues of the equipment manufacturing industry. The research was focused on PSS business models, CE practices applied in manufacturing, smart technologies and also retrofit and predictive maintenance. The proposed framework, resulting from the second phase, was devel-oped combining the different methods selected from the literature and progressively improving the prototype through continuous interaction with the company. Finally, the framework final prototype was validated in C.B. Ferrari in phase 3.

### *A. Case selection and conduction*

C. B. Ferrari is an Italian company founded in Mornago (VA) in sixties. It started with the production of small milling machines for precision mechanics purposes and accumulating experience and knowledge in the sector, building also 5-axes machines, introducing a second plant, starting a collaboration with the aeroplane engines industry, and finally introducing a laser division. Starting from 2011, C.B. Ferrari is a member of the Bejing N°1 Machine Tool group, under the direction of Jingcheng Holding Europe GmbH. The firm is now composed of 170 workers, and the entire production is distributed in the two plants placed in Italy. Over the years, C.B. Ferrari acquired the experience and the know-how, improving the quality and the performance of its products, selling and installing more than 4500 machines for the differ-ent industrial sectors. C.B. Ferrari is a certified firm by ISO 9001:2015. Through the application of the CE principles, a working group has been created during the 2020 pandemic to study the best solutions to increase the service life of the machines pro-duced starting from 1980.

The analysis of the articles selected from the literature and the interaction with the company enabled to identify a set of research gaps and of a market challenge that were explored through the development of a protocol of questions (Table 1) dedicated to the company's employees. Indeed, meeting the firm allowed the identification of market challenges that are not expressed in literature. In fact, the adoption of servitization modifies the business risk of the company, but investigations about the topic are not mentioned in the researches. The interviews started with more general questions about the technical procedures applied. Then, more specific questions were referred to the lack of knowledge and gaps identified in the literature.

TABLE 1. LIST OF THE QUESTIONS LINKED TO THE GAPS IDENTIFIED IN LITERATURE AND PRACTICE

| Literature gap (LG) and market challenge (MC) | Questions proposed to the firm |
|---|---|
| **Lack in the literature about the main factors that encourage the retrofit [6][8]** | Does a standard procedure exist?<br>Which are the advantages searched?<br>In which type of market does the company compete? |
| **Assessment of economic impacts of PSS development [6][17]** | According to which parameters a machine is retrofitted?<br>Do you use specific financial indicators to monitor performance? |
| **Assessment of environmental impacts of the PSS developed in the firm [5][7]** | Does the firm apply sustainable practices?<br>Are there explicit environmental objectives for developing the PSS? |
| **Lack of practical implications about Industry 4.0 technologies as enablers for sustainable practices [18]** | Which is the contribution of Industry 4.0 paradigm to the PSS?<br>Is there a technology that is the baseline for the PSS? |
| **Sectorial gap** | Questions proposed to the firm |
| **Servitizsation paradox in machine tools industry** | What is the role of Services in the company's strategy?<br>How do customers value a service?<br>Does servitizsation paradox arise? |

Three sessions of interviews (two hours each) took place in the company's headquarter. They were composed by open questions posed to the technical manager of the firm who provided the answers, also including standard procedures documents and data sheets as an integration. The case has been conducted to validate the model developed and its results are presented in sub-section 4.C, describing the processes adopted by C.B. Ferrari, and also specifying the future activities that will be implemented when the new PSS will be consolidated in the company's organization. All the activities described were validated by the company technical manager and its team.

## IV. RESULTS

### *A. Conceptualization: literature review*

The framework proposed should explain which drivers mainly affect the decision to add new services to an old machine tool. The study by [11] brings methodology and framework to assess whether the drivers listed explain the strategic choices of the firm. Then, the description of the system according to a sustainability perspective is needed, given the limitations found in literature. The study from [19] aimed at assessing and improving the sustainable characteristics of an agricultural machine (a different context than machine tools but with similar characteristics in terms of business) according to specific Life Cycle Design (LCD) strategies, previously defined by [20]. The framework proposed applies the LCD strategies to assess the activities adopted in the system, granting a reduction of the environmental impact of the tool. Finally, the results of the study are categorised according to the main impacts revealed by the research.

### *B. Development: the framework*

A schematic description of the Framework can be seen in Figure 1 below.

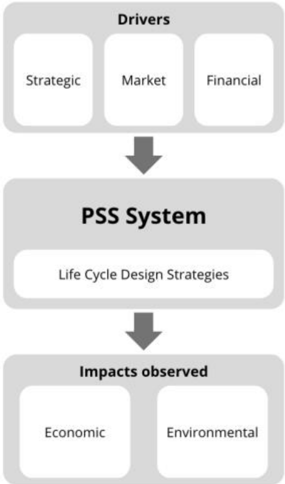


Figure 1. Structure of the framework proposed

The process begins with the identification of the main drivers that impact the decision-making process of both the OEM and the customer. [11] proposes a list of specific drivers that have been included in the strategic analysis of the company interviewed, which are the following:

- Strategic drivers: upgrading services to similar equipment provided by other competitors; possibility to market a newly developed technology a lot faster compared with new generation products' sales; positively differentiate from competitors that do not offer the upgrade option to their products;
- Market drivers: equipment may be adapted to Governmental regulations or changed customer requirements; obsolescence of old equipment's components for which spare parts are no longer available;
- Financial drivers: higher profit margins (primary financial driver); Comparatively stable revenue during an economic downturn.

The sustainability of a machine tool derives from the combination of the embedded technology and the position of the tool within a comprehensive system. The technological element is extendable over different phases of the machine lifecycle, as it can bring improvements in the design, production or utilization phase, reducing the environmental impact of the typical phases without changing the overall system. The inclusion of the machine in a comprehensive product-oriented PSS exploits the environmental improvement potential of an energy-intensive sector such as industrial equipment production. The proposed PSS is then analyzed according to the LCD Strategies developed by Vezzoli (2008), listed according to their impact on the work: 1. Optimize the product lifespan (by a. increasing the durability and b. increasing the intensity of its usage), 2. Facilitate disassembly, 3. Minimise material and energy consumption, 4. Minimise resource toxicity and harmfulness. To support each of them, design guidelines can be detected and suggested, mainly focused on durability, usage intensity and disassembly. Minimisation of energy and material consumption have limited possibilities in the industrial equipment context, as it is strictly related to technological advancements that can be applied within the machines that reduce the material usage in production and the energy consumption in the utilisation phase. Minimisation of energy and material consumption have limited possibilities in the industrial equipment context, as it is strictly related to technological advancements that can be applied within the machines that reduce the material usage in production and the energy consumption in the utilisation phase. Finally, the overall impacts brought by the implementation of the PSS are then categorized to understand whether the environmental achievements are linked to other economic benefits, underlining that a fair transition reduces the environmental burdens generated by an industry without reducing the competitiveness of SMEs, which represent half of the European GDP and are the fundamental backbone of the European economy [22].

### *C. Validation: the case study*

According to the drivers assessed in the firm's interview, Strategic drivers are confirmed with the exception of the upgrade of competitors' equipment, as the dimensions of the company do not consent the implementation of such option. A portfolio of upgrade offerings is a relevant driver, as it strengthens customer relationships. In fact, retrofit extends the contact with the manufacturing firm and it increases the possibility for a vendor to sell a new machine tool that can work simultaneously with the older one. Market drivers are confirmed: customer firms request the service to be in line with all the latest safety Regulations, without investing an excessive amount of money; spare parts obtained by the OEM become a source of revenue, as it can set a higher price that increases its margins. Finally, according to Financial drivers, the retrofit service brings higher margins than selling new machines. Comparatively stable revenue during an economic downturn was nor confirmed or disconfirmed. The process considered applies successfully the LCD Strategies, as the guidelines are respected in the application. The retrofit process adopted applies an advanced CNC to a machine tool and the customer can benefit from the advantages provided by Industry 4.0 paradigm. Such process is enhanced by the adoption of Predictive Maintenance services during the utilization phase, addressing the lifespan extension strategy. The design and production of machine tools have not changed too much in the last decades and strong limitations must be highlighted according to the material required, the processes to follow and the energy consumed for the construction of the tool. Therefore, extending the lifespan delays resource depletion to build a machine with a similar structure but an advanced electronic part. The extension of the lifespan of the product relates to the following strategies: 1. Design for appropriate lifespan. Machine tools are built according to very strict technical requirements because of the extreme stress under which they operate in their use phase. Such limitations cover the material used for the baseline, the axes and the mechanical drives, and also the quantity consumed in the production phase and the geometric boundaries overcome in the Design phase; 2. Design for reliability. Reliability is one of the main KPIs considered to decide for the disposal of a tool. It must be granted during the design phase, as the customers are not willing to pay for a product with a low availability rate; 3. Facilitate upgrading and adaptability. The upgrading strategy consists of substituting parts that have become obsolete due to technological innovation. Therefore, a considerable part of the product remains unchanged, and it decreases its overall environmental impact; 4. Facilitate maintenance. In this context, predictive maintenance is a game-changing option, which assures constant monitoring of all the critical parameters of the machine, preventing serious breakdowns without impacting performance; 5. Facilitate repair. Such a practice is strongly related to the easiness of maintainability and predictive maintenance can give a strong effort in this sense. Moreover, design for facilitating disassembly and the inclusion of complementary repair tools can be included in the design phase; 6. Facilitate reuse. This strategy is secondary in the machine tools industry and it depends on the quality of the product manufactured in previous phases.

An additional element to be added to the former list of strategies is the recovery of older components from the retrofitted machines. Such elements are spare parts stored in the warehouse that can be used for maintenance services on machines that are still used for not-retrofitted ones. This strategy allows an extension in the duration of an old machine by providing spare parts out of production, bringing indirectly environmental benefits even to not-retrofitted tools. The analysis of the benefits and challenges provided by the solution is important to assess Economic and Environmental impacts.

The services offered to customers are the most important strategy applied by SMEs like C.B. Ferrari, which operates in a strongly competitive market suffering the leading position of larger players and firms located outside Europe. In such a competition the price of the machine tools is set by the market and all the players involved must be aligned with it, but smaller firms face difficulties in obtaining enough margins to reduce their business risk. Therefore, servitization is the answer of smaller players to be competitive, as it increases revenues and customer loyalty. The service function has a key role in a company that operates in the machinery industry and it is a strong source of competitive advantage.

The introduction of the retrofit practice in the firm activities faces some criticalities: the main one is the need for very high-skilled workers in the retrofit department because experience is the most impactful driver to make the retrofit activity economically sustainable by the firm. They must understand which parts must be changed and which ones can still work without substitution, and they must be able to adjust any part without ordering new components that would extend the time required for the retrofit and reduce the profitability of the operation. Another criticality is to find a suitable space to set the retrofit department, but such a need can be easily addressed. On the economic side, the system enhances new sources of revenue, as the money flows gained can cover the reduction in the service price charged to customers, thus increasing the competitiveness. Spare parts recovered in previous retrofits and sold at higher price are crucial in this sense, allowing the achievement of margins that reduce the overall business risk. The experts in the firm observe that the margins brought to the company by retrofit are higher than the production of a new machine (20-30% against 10-15% of the new one). Customer loyalty is worth in the business, and it is enhanced by the continuous monitoring provided by predictive maintenance. Additionally, the shift from an emergency to a planned organization increases the efficiency in use of the resources. On environmental side, reductions in material usage and energy consumption are observed, due to the extension of the machine lifetime (that can delay the production of a newer one) and also to the more efficient utilisation of the tool and management of the breakdowns (only the components damaged will be substituted). In addition, during the utilization of the machine tool, sustainability performances will improve, given the reduced amount of non-compliant parts that, consequently, could allow a lower consumption of raw materials during the production process. The future structure brings also social impacts that should be addressed more deeply in future studies and be kept into consideration while promoting the transition of the firm's strategy.

## V. Discussion

This research work analyses the implementation of a product-oriented PSS by an OEM firm. The process is enabled by a retrofit activity applied on machines that require an upgrade to implement Industry 4.0 technologies, allowing the owner firm to benefit additional services from the OEM. On provider's side, the enlargement of the services portfolio could lead to a servitization paradox, in which the increase of income obtained by the service provision is lower than the costs sustained to provide it. Such event is not observed in the case study, on the contrary while the competition reduces the margins of the firm, the adoption of advanced services is a source of differentiation advantage that increases the customer satisfaction. Therefore, revenues are increased and the business risk is reduced. The case study analysed represents a virtuous example that other OEM companies can follow, and the framework developed offers to practitioners a methodology to follow (analysis of the context, analysis of the system proposed, impacts generated) and guidelines (objectives definition, LCD strategies) to the adoption of more sustainable practices even in energy-intensive industries with low innovation rates. It is important to mention that if Smart technologies are adopted properly, a virtuous circle can be powered. From a managerial point of view, the framework helps the company in being aware on the improvements that can be done, both at operational and systemic level, according to sustainability practices. The framework proposed does not require quantitative data to be applied, overcoming the strong limitation that the machine tools sector faces (lack of data about the actual carbon footprint of a machine lifecycle). Additionally, the most suitable actions are proposed to increase competitiveness of this sector in the market, reducing risks, and increasing the management awareness about the potential obtainable benefits in this context.

## VI. Conclusions

The study proposed a framework with the objective to assess the economic and sustainability impacts of a PSS implemented by an OEM according to the LCD strategies. The adoption of the model allowed to identify the main economic and sustainable impacts generated by the inclusion of retrofit and predictive maintenance in a manufacturing firm's strategy producing machining tools. Limitations of the work are mainly the focus on a single firm, reducing the possibility to understand further impacts that may arise in a different competitive arena. Moreover, data and information gathered through the interviews were focused on the high-level description of the main activities and processes, supported by technical documentation. Additionally, no social imlplications are mentioned while the proposed framework might include this dimension too in future research. Indeed, future research can provide more quantitative data to understand deeper the role of predictive maintenance implementation in the sustainability assessment of a machine tool, including a larger sample of SMEs to assess the existence of other best practices including social-related ones.

### Acknowledgements

This study was carried out within the MICS (Made in Italy – Circular and Sustainable) Extended Partnership and received funding from the European Union Next-GenerationEU (PIANO NAZIONALE DI RIPRESA E RESILIENZA (PNRR) – MISSIONE 4 COMPONENTE 2, INVESTIMENTO 1.3 – D.D. 1551.11-10-2022, PE00000004). This manuscript reflects only the authors' views and opinions, neither the European Union nor the European Commission can be considered responsible for them.

## References

[1] F. Doni, A. Corvino, and S. Bianchi Martini, "Servitization and sustainability actions. Evidence from European

manufacturing companies," *J. Environ. Manage.*, vol. 234, pp. 367–378, Mar. 2019, doi: 10.1016/j.jenvman.2019.01.004.

[2] N. Zivlak, S. Rakic, U. Marjanovic, D. Ciric, and B. Bogojevic, "The role of digital servitization in transition economy: An SNA approach," *Teh. Vjesn.*, vol. 28, no. 6, pp. 1912–1919, 2021, doi: 10.17559/TV-20210325083229.

[3] K. Stormi, A. Lindholm, T. Laine, and T. Korhonen, "RFM customer analysis for product-oriented services and service business development: an interventionist case study of two machinery manufacturers," *J. Manag. Gov.*, vol. 24, no. 3, pp. 623–653, 2020, doi: 10.1007/s10997-018-9447-3.

[4] S. Lamperti, A. Cavallo, and C. Sassanelli, "Digital Servitization and Business Model Innovation in SMEs: A Model to Escape From Market Disruption," *IEEE Trans. Eng. Manag.*, pp. 1–15, 2023, doi: 10.1109/TEM.2022.3233132.

[5] D. Jaspert, M. Ebel, A. Eckhardt, and J. Poeppelbuss, "Smart retrofitting in manufacturing: A systematic review," *J. Clean. Prod.*, vol. 312, 2021, doi: 10.1016/j.jclepro.2021.127555.

[6] N. Rogkas *et al.*, "Upcycling obsolete mechanical equipment into innovative laboratory test rigs: A low-cost solution or a sustainable design approach?," *Proc. Des. Soc.*, vol. 1, pp. 3309–3318, 2021, doi: 10.1017/pds.2021.592.

[7] E. S. Lejardi, M. Franke, Q. Deng, and R. M. Rial, "Circularity Protocols for Extending the Useful Lifetime of Obsolete Large Industrial Equipment and Assets," in *IEEE International Conference on Emerging Technologies and Factory Automation, ETFA*, 2021, vol. 2021-Septe, doi: 10.1109/ETFA45728.2021.9613234.

[8] A. Batlles-delafuente, L. J. Belmonte-ureña, J. A. Plaza-úbeda, and E. Abad-segura, "Sustainable business model in the product-service system: Analysis of global research and associated eu legislation," *Int. J. Environ. Res. Public Health*, vol. 18, no. 19, Oct. 2021, doi: 10.3390/ijerph181910123.

[9] C. Sassanelli, S. D. C. Fernandes, H. Rozenfeld, J. M. H. Da Costa, and S. Terzi, "Enhancing Knowledge Management in the PSS Detailed Design: a case study in a food and bakery machinery company," *Concurr. Eng. Res. Appl.*, pp. 1–14, 2021, doi: https://doi.org/10.1177/1063293X21991806.

[10] Y. Xia, D. Tan, and B. Wang, "Use of a product service system in a competing remanufacturing market," *Omega (United Kingdom)*, vol. 102, 2021, doi: 10.1016/j.omega.2020.102387.

[11] M. A. Khan, O. Stoll, S. West, and T. Wuest, "Equipment upgrade service provision in the context of servitization: drivers, capabilities, and resources," *Prod. Plan. Control*, vol. 0, no. 0, pp. 1–19, 2022, doi: 10.1080/09537287.2022.2063199.

[12] C. Leona Niemeyer, I. Gehrke, K. Müller, D. Küsters, and T. Gries, "Getting small medium enterprises started on industry 4.0 using retrofitting solutions," *Procedia Manuf.*, vol. 45, pp. 208–214, 2020, doi: 10.1016/j.promfg.2020.04.096.

[13] C. Sassanelli, M. Rossi, and S. Terzi, "Evaluating the smart maturity of manufacturing companies along the product development process to set a PLM project roadmap," *Int. J. Prod. Lifecycle Manag.*, vol. 12, no. 3, pp. 185–209, 2020, doi: 10.1504/IJPLM.2020.109789.

[14] M. Zoll, D. Jack, and M. W. Vogt, "Evaluation of Predictive-Maintenance-as-a-Service Business Models in the Internet of Things," 2018, doi: 10.1109/ICE.2018.8436272.

[15] C. Sassanelli, M. Rossi, G. Pezzotta, D. A. de J. Pacheco, and S. Terzi, "Defining Lean Product Service Systems (PSS) features and research trends through a systematic literature review," *Int. J. Prod. Lifecycle Manag.*, vol. 12, no. 1, pp. 37–61, 2019, doi: http://dx.doi.org/10.1504/IJPLM.2019.104371.

[16] M. E. Porter and J. E. Heppelmann, "How Smart, Connected Products Are Transforming Companies," *Harv. Bus. Rev.*, vol. 93, no. 10, pp. 96–114, 2015, doi: 10.1017/CBO9781107415324.004.

[17] J. P. Seclen-Luna, P. Moya-Fernández, and Á. Pereira, "Exploring the effects of innovation strategies and size on manufacturing firms' productivity and environmental impact," *Sustain.*, vol. 13, no. 6, pp. 1–18, 2021, doi: 10.3390/su13063289.

[18] S. Atif, S. Ahmed, M. Wasim, B. Zeb, Z. Pervez, and L. Quinn, "Towards a conceptual development of industry 4.0, servitisation, and circular economy: A systematic literature review," *Sustain.*, vol. 13, no. 11, 2021, doi: 10.3390/su13116501.

[19] S. Banerjee and R. M. Punekar, "A sustainability-oriented design approach for agricultural machinery and its associated service ecosystem development," *J. Clean. Prod.*, vol. 264, p. 121642, 2020, doi: 10.1016/j.jclepro.2020.121642.

[20] C. Vezzoli, *Design for environmental sustainability: Life cycle design of products*. 2008.

[21] A. Neri, E. Cagno, and A. Trianni, "Barriers and drivers for the adoption of industrial sustainability measures in European SMEs: Empirical evidence from chemical and metalworking sectors," *Sustain. Prod. Consum.*, vol. 28, pp. 1433–1464, 2021, doi: 10.1016/j.spc.2021.08.018.

[22] European Commission, "Communication COM(2020) 103 final - SME Strategy for a sustainable and digital Europe." pp. 1–64, 2020.