Systematic Literature Review About Sustainable Business Models and Industry 4.0

Grazielle Fatima Gomes Teixeira(✉) and Osiris Canciglieri Junior

Polytechnic School of the Pontifical Catholic University of Paraná – PUCPR, R. Imaculada Conceição, 1155 - Prado Velho, Curitiba, PR 80215-901, Brazil
grazielle.teixeira@pucpr.edu.br

Abstract. All over the world, Industry 4.0 (I4.0) and Sustainable Development (SD) have progressively gained the interest of scholars, politicians, and other parts of society. Besides being two of the most debated topics of the last decades, they also have overlaps between their independent research fields. Some examples are reductions of environmental impacts and improvements in production technologies. This integration of technologies and sustainable advances within an industrial context can enable a set of important competitiveness forces, which results can reflect in business improvement. However, the link between I4.0, SD, and business still needs a broader understanding. Basing on this perspective, this paper proposes an update of a systematic literature review to monitor the development of the topic and to check if there has been any progress, as well as to verify whether the findings are still valid. Results point to that there are seventeen research opportunities, showing the potential of I4.0 as an enabler of sustainable business models that changes the responsibilities of companies.

Keywords: Industry 4.0 · 4th industrial revolution · Sustainability · Business model · Systematic literature review

1 Introduction

Sustainable improvements aim to revolutionize the way that products are producing and using. In this line, novel technologies emerging under the Fourth Industrial Revolution or Industry 4.0 (I4.0) are creating new opportunities for solving sustainability-related needs [1, 2]. For example, I4.0 can help factories to improve sustainability efforts through real-time control of resource consumption, increased logistical efficiency, the extension of the product lifecycles by pro-active maintenance and remanufacturing [3]. Moreover, I4.0 can stimulate mass customization and product diversification strategies [4]. This brings new sides to customer-focused approaches because information systems (IS) can have a significant role to redesign products and business processes across the enterprise to turn its results more sustainable [2, 5, 6]. As a result, it can build or regenerate a cross-linked value chain of actors that compose a business activity [2].

This argumentation helps us to understand why the overlap between Sustainability and I4.0 has been one of the most important industrial debates in recent years [7–15]. But,

Published by Springer Nature Switzerland AG 2023
F. Noël et al. (Eds.): PLM 2022, IFIP AICT 667, pp. 55–65, 2023.
https://doi.org/10.1007/978-3-031-25182-5_6

although the I4.0 revolution can be described as a facilitator for sustainable development, this union remains underdeveloped in many aspects [11, 16–22]. One of these aspects is about Sustainable Business Models (SBM) into the I4.0 revolution [7, 8, 11, 13, 23].

There is still a lack of understanding about the impacts of I4.0 in many different issues of business to redesigning value chain configurations and adoption or creation of new business models focused more on sustainability goals [17, 24–27]. Sustainability is a concept that does not have a unique definition [28]. Due to this, its concrete implementation is considered difficult because there is a high degree of complexity concerning the depth and specifications of actions [11, 28]. Likewise, I4.0 is also a paradigm whose unique definition is not possible due to its wide range of approaches [8, 22, 29]. The business model concept is an abstract representation of the value flow and the workflow of an organizational unit [30].

As Stock *et al.* [11] and Dao [6] emphasized, there is still a lack of research on how I4.0 impacts the stabilization of business models according to sustainable development objectives. Some researchers add the concept of a maturity model to try to help understand the discussion, for example, Allais *et al.* [31], Gouvinhas *et al.* [32], Gaziulusoy [33], Romero and Molina [34], Murillo-Luna *et al.* [35]. The maturity models aim to develop and build knowledge in an evolutionary way so that a company can progress more solidly and securely. Based on this argument, it can be said that the literature is scarce on these conceptions. Teixeira *et al.* [2] presented a Systematic Literature Review (RSL) between May 2015 until May 2020. However, the investigation of this theme is still necessary and relevant for both academics and society. Due to this, the purpose of this article is to present the SLR update developed by Teixeira *et al.* [2]. In summary, this article addresses the set of issues:

(Q1) *What are the opportunities for the future research agenda?*
(Q2) *Where is this matter being investigated?*
(Q3) *What is the current situation in this field of research?*

To achieve the proposed objective, the article consists of four sections, the introduction of which is the first. In the second section, the review methodology is described. The results obtained to answer the set of questions are presented in Sect. 3 and analyzed in Sect. 4. Finally, the final considerations are presented in Sect. 5.

2 Review Methodology

Teixeira et al. [2] implemented a Systematic Literature Review (SLR) according to the procedures described by Seuring *et al.* [36], Durach *et al.* [37], and Tranfield *et al.* [38]. These procedures were reused to develop the update presented now. To keep rigorous of the result, an SLR must follow a set of steps. Durach *et al.* [37] describe six steps to build an SLR: (1) defining the research question (goal), (2) determining the required characteristics of primary studies (inclusion criteria), (3) retrieving a sample of potentially relevant literature (collect data), (4) selecting the pertinent literature (exclusion criteria), (5) synthesizing the literature (analyze data), and (6) reporting the results. Similar recommendations are made from Seuring *et al.* [36] who describe an SRL by four

elements: (1) definition - who and what (goal), (2) boundaries and limitations – when and where (inclusion criteria), (3) variables and causalities – why and how (collect data), (4) predictions – could, should and would (analyze data).

Table 1. Keyword pairwise query.

1	TITLE-ABS-KEY ((sustainability AND business model AND industry 4.0))
2	TITLE-ABS-KEY ((Sustainability AND new business model AND industry 4.0))
3	TITLE-ABS-KEY ((Sustainability AND organisation improvement AND industry 4.0))
4	TITLE-ABS-KEY ((sustainability AND maturity model AND industry 4.0))
5	TITLE-ABS-KEY ((Sustainability AND maturity evaluation AND industry 4.0))
6	TITLE-ABS-KEY ((Sustainability AND dynamic capability AND industry 4.0))
7	TITLE-ABS-KEY ((Sustainability AND strateg* AND industry 4.0))
8	TITLE-ABS-KEY ((Sustainability AND competitiveness AND industry 4.0))
9	TITLE-ABS-KEY ((Sustainability AND competition AND industry 4.0))
10	TITLE-ABS-KEY ((Sustainability AND value creation AND industry 4.0))
11	TITLE-ABS-KEY ((Sustainability AND strategic planning AND industry 4.0))
12	TITLE-ABS-KEY ((Sustainability AND product AND development AND process AND industry 4.0))
13	TITLE-ABS-KEY ((Sustainability AND product AND development AND industry 4.0))
14	TITLE-ABS-KEY ((Sustainability AND product AND industry 4.0))
15	TITLE-ABS-KEY ((Sustainability AND continuous improvement AND development AND industry 4.0))

Moreover, to secure the validity and transparency of SLR, choose a database is also an important point. In this study, were selected specific databases: Scopus and Web of Science. Then, the second step was the selection of the inclusion and exclusion criteria. In this line, the review process considered only formal literature that was written full-texts in English and peer-review published papers.

Equal as Teixeira *et al.* [2] the choice of the time cut was based on evidence found in a previous analysis that the number of publications about SBM increased during the past two decades. However, a significant concentration of publications is observed between 2016 to now because the number of studies about I4.0 is more substantial during this same period [30]. In this way, the first review was limited to find papers published between May 2015 and May 2020. This second review was extended to find papers published until February 2021. The scope of this extension is to monitor the development of the topic and to check if there has been any progress, as well as to verify whether the findings are still valid. Then, was conducted a structured keyword search executed through a pairwise query, focusing on titles, abstracts, and keywords. The same keywords were used for this second review (Table 1).

3 Results

Before answering the questions listed, the results of the survey carried out in the two databases are presented. According to Table 2, the result of this extension of the SLR reached 279 articles. This represents an increase of approximately 81.17% concerning the previous number of the first SLR. Scopus was the database that brought the most

results. Figure 1 illustrates which searches with the keywords obtained the highest and lowest results in each database.

With this, it is possible to observe that the combination of keywords 14 obtained better results in both databases and reviews. In the Scopus database, combinations of keywords with superior results was, respectively, 1, 2, 8, 13, 9, 12, and 4. The lowest results at Scopus were with keyword combinations 3, 5, 6, 10, 11 and 15. The combination of keywords 7 did not add new research.

In the Web of Science database, combinations of keywords with superior results was, respectively, 7, 6, 9, 12, and 13. The combinations of keywords 4 and 5 did not add new research. On the contrary, the lowest results were with keyword combinations 1, 2, 3, 8, 10, 11 and 15.

Of the total number of new articles found, only 19 articles met the criteria and objectives of the SLR. Therefore, adding the results of both reviews, 55 is the final number of articles that answer the listed questions. From the analysis of the content of these new contributions, the questions were answered according to their order.

Table 2. Different between the results in each review

Keyword pairwise query	1st Review (until 2020)		2nd Review (2020 - 2021)	
	Scopus	Web of Science	Scopus	Web of Science
1	8	4	29	5
2	4	2	14	3
3	1	1	3	1
4	1	0	6	0
5	0	0	2	0
6	2	0	5	4
7	17	3	17	14
8	7	1	15	3
9	9	2	16	5
10	8	4	10	5
11	0	0	2	1
12	12	3	19	6
13	20	3	28	6
14	33	7	42	14
15	1	1	3	1
Total in each database	123	31	211	68
Result	154		279	

4 Analysis

Started by **(Q1)** *What are the opportunities for future research agenda?* not all authors present directions for future research. However, in this second SLR three new opportunities for future investigation were identified: how to manage the transition, develop a scale to measure transition, and, how to make data analytics infrastructure. With these new notes, the total of appointments to future investigations is now seventeen (see Table 3).

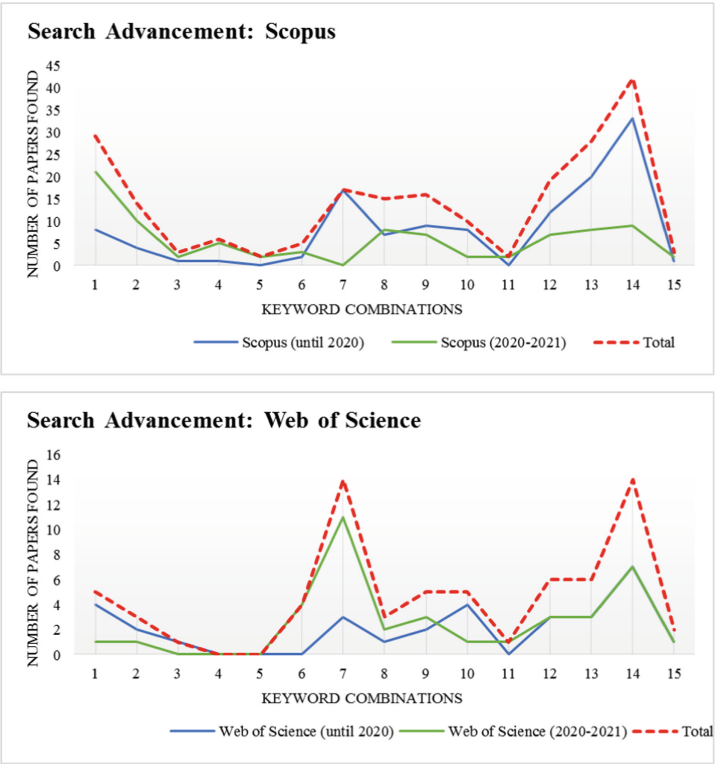

Fig. 1. Difference between the results.

Table 3. Opportunities for future research

N	%	Future research directions
1º	15,80%	Apply the study in large-scale
2º	12,00%	Analyze the different functions of the company in interaction with I4.0
3º	11,30%	How to set the TBL dmensions in the context of the I4.0
4º	9,00%	What is the impact of I4.0 on supply chain network design
5º	8,30%	How to keep job security stable
6º	7%	More research qualitative/quantitative
7º	6%	What is the impact of I4.0 on managing customer channels
8º	6%	How incorporating the I4.0 into theory about sustainable value propositions
9º	4%	How I4.0 will change the competition
10º	4%	How to measure cost-benefit analysis of I4.0 solutions
11º	3,01%	What are the policy-making efforts need to I4.0
12º	3,01%	What are the transformations in the identity of a manufacturing company promote by I4.0
13º	3,01%	How to manage the transition
14º	2,26%	What are the risks of implementing the advances in I4.0
15º	2,26%	Develop a scale to measure transition
16º	2,26%	How to make data analytics infrastructure
17º	1,50%	How to ensure data security

Comparing with the previous review it is possible to observe that the first three possibilities remained in the same order. However, the third was the most mentioned by the new studies. Among the possibilities of research that risen in the ranking are, respectively: how to keep job security stable, more research qualitative/quantitative, what are the transformations in the identity of a manufacturing company promote by I4.0, and, what are the risks of implementing the advances in I4.0. Those possibilities of research that were least cited by the new authors are, respectively: what is the impact of I4.0 on managing customer channels, how I4.0 will change the competition, and, how to measure cost-benefit analysis of I4.0 solutions. The remaining opportunities identified followed with the same percentage.

Data to answer **(Q2)** *Where this topic is being investigated?* reveal some changes (Fig. 2). First, the predominance of authors has now reverted to authors from Italy and later from Germany. In this update, contributions by authors from Germany were one of the smallest. Compared to the previous SLR, the countries with the largest contributions are, respectively, Spain, the USA, Hungary, and India. Also, 10 new countries were added to the list, respectively, in terms of the number of authors: France, Malaysia, Portugal, Romania, Slovenia, Bangladesh, Czech Republic, Hong Kong, Lebanon, and Pakistan. The increase in the number of countries demonstrates that the interest in investigating this field of research is increasingly global. Also, it is being discussed in countries with different levels of development.

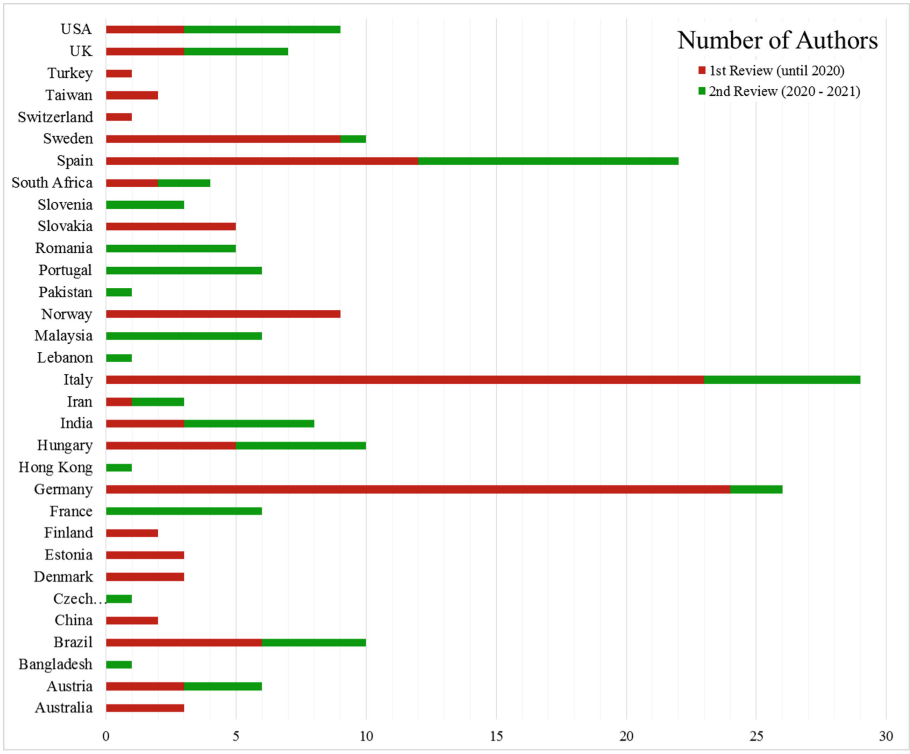

Fig. 2. Authors' affiliations countries.

According to the authors' affiliations, Fig. 3 shows which school each author is. In the first SLR, most of them were researchers in Business and Management and Industrial Engineering schools. This total number has not changed, but the number of new authors from the Industrial Engineering school is greater than those from the Business and Management school. The third school that added more authors was the School of Economics. In this second SLR, two new schools were added to the list: School of Mathematics and Computer Science. This result demonstrates that investigations are being developed by more diverse teams, expanding the multidisciplinary of discussion.

The chronologic data to answer **(Q3)** *What is the current status of this research field?* shows a growing trend, although there was a regression in 2019 (Fig. 4). The growth trend can be observed when comparing the numbers of 2020 in the first SLR with those of 2021. Even though it is in the first quarter of the year, the result is already higher. Also, the final result for 2020 is the highest in the entire sample. It is observed that 43,6% of total papers were published in the year 2015–2018 and 56,4% from 2019 until 2021.

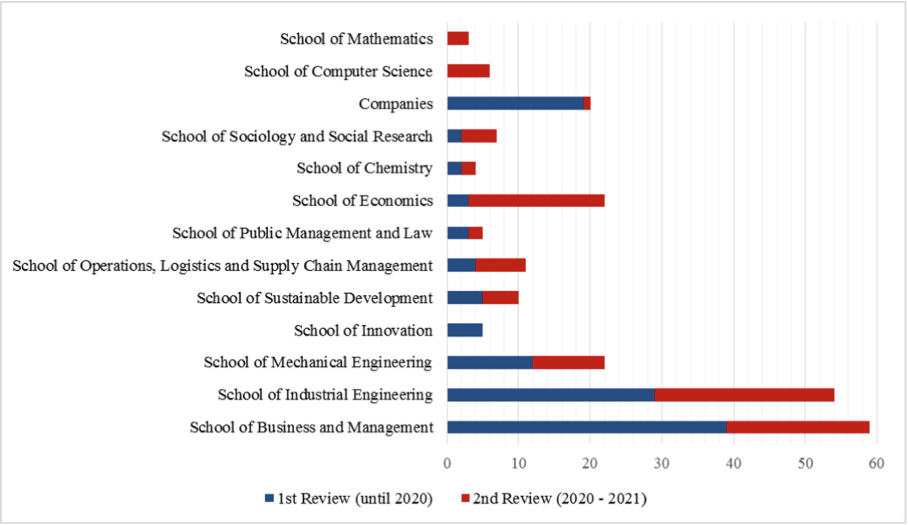

Fig. 3. Authors' affiliations school.

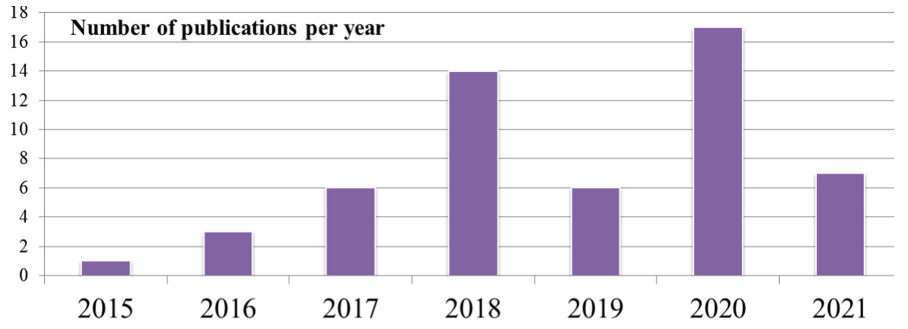

Fig. 4. Chronology of article publications.

5 Final Considerations

Results showed state of the art and a research agenda, allowing us to conclude that the topic is still legitimated but not consolidated because it is a phenomenon relatively new. Based on the relative scarce of investigations, the central importance of the study here is to be one-step further for the profound development of literature.

In addition, observing the notes for future investigations, it is possible to analyze that the study on the links between the I4.0 and the Sustainable Business Model is still at an early stage. Therefore, discussions on this topic restricted to market segments are opportunities for advancing the study. Another step forward in the discussion of the topic would be studies on the link between topics in countries with different development rates. As well as the observation of how topics could foster the creation of regulations and legislation in different industrial sectors. Regarding the new regulations, further studies

could observe whether technological advances would be able to make global trade more equitable and fair.

Due to the qualitative nature of this study, our results had some limitations. The first limitation is related to the decision to not use statistical analysis against the limited number of papers analyzed. The second limitation is related to the selection of keywords because they may have other interesting articles outside the sample that have not been reviewed.

Acknowledgments. This study was financed in part by the Coordenação de Aperfeiçoamento de Pessoal de Nível Superior - Brasil (CAPES) - Finance Code 001.

References

1. Esmaeilian, B., Sarkis, J., Lewis, K., Behdad, S.: Blockchain for the future of sustainable supply chain management in Industry 4.0. Resour. Conserv. Recycl. **163**, 105064 (2020)
2. Teixeira, G.F.G., Junior, O.C., Szejka, A.L.: Future research agenda to understanding the sustainable business model in Industry 4.0. In: Rossit, D.A., Tohmé, F., Mejía Delgadillo, G. (eds.) ICPR-Americas 2020. CCIS, vol. 1407, pp. 357–371. Springer, Cham (2021). https://doi.org/10.1007/978-3-030-76307-7_27
3. Ghosh, D., Sant, T.G., Kuiti, M.R., Swami, S., Shankar, R.: Strategic decisions, competition and cost-sharing contract under Industry 4.0 and environmental considerations. Resour. Conserv. Recycl. **162**, 105057 (2020)
4. Fathi, M., Ghobakhloo, M.: Enabling mass customization and manufacturing sustainability in Industry 4.0 context: a novel heuristic algorithm for in-plant material supply optimization. Sustainability **12** (2020)
5. Butler, T.: Compliance with institutional imperatives on environmental sustainability: building theory on the role of green IS. J. Strat. Inf. Syst. **20**, 6–26 (2011)
6. Dao, V., Langella, I., Carbo, J.: From green to Sustainability: information technology and an integrated sustainability framework. J. Strat. Inf. Syst. **20**, 63–79 (2011)
7. García-Muiña, F.E., Medina-Salgado, M.S., Ferrari, A.M., Cucchi, M.: Sustainability transition in industry 4.0 and smart manufacturing with the triple-layered business model canvas. Sustainability **12**, 2364 (2020)
8. Rosa, P., Sassanelli, C., Urbinati, A., Chiaroni, D., Terzi, S.: Assessing relations between circular economy and Industry 4.0: a systematic literature review. Int. J. Prod. Res. **58**(6), 1662–1687 (2020). https://doi.org/10.1080/00207543.2019.1680896
9. Ghobakhloo, M.: Determinants of information and digital technology implementation for smart manufacturing. Int. J. Prod. Res. 1–22 (2019)
10. Kamble, S.S., Gunasekaran, A., Dhone, N.C.: Industry 4.0 and lean manufacturing practices for sustainable organisational performance in Indian manufacturing companies. Int. J. Prod. Res. 1–19 (2019)
11. Stock, T., Obenaus, M., Kunz, S., Kohl, H.: Industry 4.0 as enabler for a sustainable development: a qualitative assessment of its ecological and social potential. Process Saf. Environ. Prot. **118**, 254–267 (2018). https://doi.org/10.1016/j.psep.2018.06.026
12. Stock, T., Seliger, G.: Opportunities of sustainable manufacturing in Industry 4.0. In: Seliger, G., Kohl, H., Mallon, J. (eds.) 13th Global Conference on Sustainable Manufacturing - Decoupling Growth From Resource Use, Procedia CIRP, pp. 536–541 (2016)

13. Cornelis, J., de Man, J., Strandhagen, O.: An Industry 4.0 research agenda for sustainable business models. Procedia CIRP **63**, 721–726 (2017). https://doi.org/10.1016/j.procir.2017.03.315
14. Kiel, D., Müller, J.M., Arnold, C., Voigt, K.-I.I.: Sustainable industrial value creation: benefits and challenges of Industry 4.0. Int. J. Innov. Manag. **21**(08), 1740015 (2017)
15. Peukert, B., et al.: Addressing sustainability and flexibility in manufacturing via smart modular machine tool frames to support sustainable value creation. Procedia CIRP **29**, 514–519 (2015)
16. Bai, C., Dallasega, P., Orzes, G., Sarkis, J.: Industry 4.0 technologies assessment: a sustainability perspective. Int. J. Prod. Econ. **229**, 107776 (2020)
17. Felsberger, A., Qaiser, F.H., Choudhary, A., Reiner, G.: The impact of Industry 4.0 on the reconciliation of dynamic capabilities: evidence from the European manufacturing industries. Prod. Plan Control 1–24 (2020)
18. Ghobakhloo, M.: Industry 4.0, digitisation, and opportunities for sustainability. J. Clean. Prod. **252**, 119869 (2020)
19. Varela, L., Araújo, A., Ávila, P., Castro, H., Putnik, G.: Evaluation of the relation between lean manufacturing, Industry 4.0, and sustainability. Sustainability **11**, 1–19 (2019)
20. Beier, G., Niehoff, S., Xue, B.: More sustainability in industry through industrial internet of things? Appl. Sci. **8**(2), 219 (2018)
21. Kamble, S.S., Gunasekaran, A., Gawankar, S.A.: Sustainable Industry 4.0 framework: a systematic literature review identifying the current trends and future perspectives. Process Saf. Environ. Prot. **117**, 408–425 (2018)
22. Müller, J.M., Kiel, D., Voigt, K.-I.K.-I.: What drives the implementation of Industry 4.0? The role of opportunities and challenges in the context of sustainability. Sustainability **10**, 247 (2018)
23. Porter, M.E., Heppelmann, J.E.: How smart, connected products are transforming competition. Harv. Bus. Rev. **92**, 64 (2014)
24. Díaz-Chao, Á., Ficapal-Cusí, P., Torrent-Sellens, J.: Environmental assets, industry 4.0 technologies and firm performance in Spain: a dynamic capabilities path to reward sustainability. J. Clean. Prod. **281**, 125264 (2021). https://doi.org/10.1016/j.jclepro.2020.125264
25. Mattera, M., Gava, L.: Facing TBL with IoT: creating value and positively impacting business processes. Soc. Responsib. J. (2021)
26. Godina, R., Ribeiro, I., Matos, F., Ferreira, B.T., Carvalho, H., Peças, P.: Impact assessment of additive manufacturing on sustainable business models in industry 4.0 context. Sustainability **12**(17), 7066 (2020). https://doi.org/10.3390/su12177066
27. Lardo, A., Mancini, D., Paoloni, N., Russo, G.: The perspective of capability providers in creating a sustainable I4.0 environment. Manag. Decis. **58**(8), 1759–1777 (2020). https://doi.org/10.1108/MD-09-2019-1333
28. Teixeira, G.F.G., Canciglieri Junior, O.: How to make strategic planning for corporate sustainability? J. Clean. Prod. **230**, 1421–1431 (2019)
29. Piccarozzi, M., Aquilani, B., Gatti, C.: Industry 4.0 in management studies: a systematic literature review. Sustainability **10**(10), 3821 (2018). https://doi.org/10.3390/su10103821
30. Nosratabadi, S., Mosavi, A., Shamshirband, S., Zavadskas, E.K., Rakotonirainy, A., Chau, K.W.: Sustainable business models: a review. Sustainability **11**, 1–30 (2019)
31. Allais, R., Roucoules, L., Reyes, T.: Governance maturity grid: a transition method for integrating sustainability into companies? J. Clean. Prod. **140**, 213–226 (2017)
32. Gouvinhas, R.P., Reyes, T., Naveiro, R.M., Perry, N., Filho, E.R.: A proposed framework of sustainable self-evaluation maturity within companies: an exploratory study. Int. J. Interact. Des. Manuf. (IJIDeM) **10**(3), 319–327 (2016). https://doi.org/10.1007/s12008-016-0322-7
33. Gaziulusoy, A.I.: A critical review of approaches available for design and innovation teams through the perspective of sustainability science and system innovation therories. J. Clean. Prod. **107**, 366–377 (2015)

34. Romero, D., Molina, A.: Towards a sustainable development maturity model for green virtual enterprise breeding environments. IFAC Proc. Volumes **19**(3) (2014)
35. Murillo-Luna, J.L., Garcés-Ayerbe, C., Rivera-Torres, P.: Barriers to the adoption of proactive environmental strategies. J. Clean. Prod. **19**(13), 1417–1425 (2011)
36. Seuring, S., Yawar, S.A., Land, A., Khalid, R.U., Sauer, P.C.: The application of theory in literature reviews – illustrated with examples from supply chain management. Int. J. Oper. Prod. Manag. **41**(1), 1–20 (2020)
37. Durach, C., Kembro, J., Wieland, A.: A new paradigm for systematic literature reviews in supply chain management. J. Supply Chain Manag. **53**(4), 67–85 (2017)
38. Tranfield, D., Denyer, D., Smart, P.: Towards a methodology for developing evidence-informed management knowledge by means of systematic review. Br. Acad. Manag. **14**(3), 207–222 (2003)