Available online at www.sciencedirect.com

ScienceDirect

Procedia Computer Science 180 (2021) 394–403

Procedia Computer Science

www.elsevier.com/locate/procedia

International Conference on Industry 4.0 and Smart Manufacturing

Industry 4.0 tools in lean production: A systematic literature review

Tommaso Gallo[a]*, Chiara Cagnetti[a], Cecilia Silvestri[a], Alessandro Ruggieri[a]

[a]Department of Economy, Engineering, Society and Management (DEIM), University of Tuscia, via del Paradiso, 47, Viterbo, 01100, Italy

Abstract

The present article focuses its attention on the tools of the Industry 4.0 with the purpose to analyze how these tools can be useful for the companies to increase factors like efficiency and productivity. In the age of the fourth industrial revolution, companies try to know how they can approach to the Industry 4.0, keeping attention on the tools which will be able to increase their results over time. This it will be possible if the companies will be able to integrate, not only the concept of Industry 4.0 with Lean Production, but even the human factor with the tools of the fourth industrial revolution. This integration will allow to increase companies' performance and to get higher results than competitors, increasing even their productivity and flexibility. The aim of the study is to know what tools of the Industry 4.0 are used by the companies, what are the reasons that push companies to use these tools and what advantages are from their use. The results achieved will show that the most important I4.0 tools integrated with lean production will be IoT and Big Data, which will allow companies to improve their flexibility and productivity. Finally, the human factor, as reported from some authors in the section 7, will be another important element which will allow companies to get great results.

Keywords: Industry 4.0, Lean Production, IoT, Big Data

1. Introduction

Industry 4.0 was introduced for the first time in Germany in 2011 [33] and it's the result of the technological progress of the fourth industrial revolution. Industry 4.0 is identified as an intelligent industry, able to digitize the production processes of the companies using the technical results of the third industrial revolution. Industry 4.0 keeps its attention on Cyber – physic systems (CPS) and it integrates intelligent technologies and data exchange, it

* *E-mail address:* tommaso.gallo@unitus.

1877-0509
10.1016/j.procs.2021.01.255

helping automated control so as to make the company increasingly flexible and sustainable. The aim of the Industry 4.0 is to increase the level of management and competitiveness, betting on the convergence between the physical and virtual world (CPS) [28]. Industry 4.0 helps constant changes even inside the companies, these changes introduced the concept of Society 5.0: this concept was introduced by Japanese government in 2015, which bets on a future super smart company. Yet, the concept of Industry 4.0, inside of the companies, is nothing if it doesn't integrate with the concept of Lean Production [19, 21-22]. The success of an Industry 4.0 system is strongly correlated to that of Lean Production and the growth of the business performance depends by these two factors. Many authors, including Pereira et al. [50], compared the various studies related to Industry 4.0 analyzing the main technological developments, the most important innovation, trends and challenges and the consequences of Industry 4.0 on the economic, industrial and social aspects. Thoben et al. [65] have concentrated their studies on Industry 4.0 trying to know how intelligent production can increase company's logistics.

2. Tools of industry 4.0

Nowadays, the high competition induces companies to update their production systems to a smarter level than the previous. This allowed them to make more flexible, smart and fast their production systems and to be ready to face the challenges of dynamic global market [56,77]. The approach to the technologies of Industry 4.0 allows companies to achieve sustainable aims having a great indoor work environment, improving employees' moral, reducing production times and making high personalized products, with high quality and able to satisfy the needs and requirements of customers [34]. The technologies of the Industry 4.0 are basic for the companies to achieve sustainable aims from an ecological, social and economic point of view [43,64]. Germany was the first nation which introduced the concept of Industry 4.0 and by a study of the Boston Consulting Group (2015), it will be able to increase manufacturing sector of 90/150 billion euros, the productivity of 5/8%, GDP of the 1% and the occupation of 6% [28]. Yet, to achieve these aims is necessary to implement the various technologies of Industry 4.0, which are basic for the business success.

First of all, we have to consider the **IoT** (Internet of Things), which is considered as a key technology of the Industry 4.0 because it allows to have a real-time analysis of the entire supply chain [5,6,24,77] and performance [30]. An important factor which is strongly correlated to the IoT is the OPC – UA (Open Platform Communications – Unified Architecture).

The second tool is **"Big Data"**. This tool is a large data processing technique [36]. Through Big Data we can put in relation a big quantity of heterogeneous data with the purpose to discover the links between different phenomena and predict future ones.

Cloud computing is identified as the provision of services from a supplier to the end customer through use of internet network. These services are made available by the end customer in fast and cheap times through use of automated procedures [66]. Van der Meulen et Pettey [70] are not agree regarding this vision of cloud computing, which is considered from them like a simply technological evolution of internet network.

Even the **CPS** (cyber-physical system) are very important, they allow to acquire and control useful information for the automation and process virtualization, for the impacts on the production systems and to know how many workers are needed to use the concepts of Industry 4.0 [36].

The **"robotic"** is another important tool of Industry 4.0. The attention to the robotic is increased a lot in the last years thanks to the capacity of the robots to replace human work, not just the repetitive one but even in the most complex activities [25]. The communication among the machines is an important element for the Industry 4.0 because the exchange of information among the various machines allows to analyze the production system in real time.

The last two tools of Industry 4.0 are the **"technology"** and the **"process"**. Technology is useful to analyze the contributions of the individual technologies of sector 4.0 [12,23,49,59-62]; and the process is useful to study the security of the various business processes [41].

With these tools of the Industry 4.0 above, there are other tools which can be considered as "evolutions" of "basic" tools. As mentioned above IoT is the main tool of Industry 4.0 but a strongly correlated factor with the IoT is the **OPC - UA** (Open Platform Communications – Unified Architecture), which is considered as the best known communication of the fourth industrial revolution [13]. This technology allows exchange information and data transfer and it is becoming the standard platform for the communication among the machines (M2M), in order to allow the self-organization of the production process [31,54]. OPC – UA can be considered as another tool of the Industry 4.0 part of the IoT field. OPC – UA is an added factor, a key element useful for the transition to industry 4.0. A correlated tool of the CPS is the **CPPS** – Cyber Physical Production System) [47]. Even IoT has got an evolution called **IIoT** (Industrial Internet of Things), which is higher than the traditional IoT for its flexibility, quality of the service, reliability and real-time management [40]. The evolution of Big Data is **IBD** (Industrial Big data), it has got an efficiency and ability to manage a large amount of information better than traditional Big data. The main feature of IBD is featured by the multiple data processing techniques which allow to foresee future situations regarding production and to improve the efficiency of the decision-making process.

3. The relationship between tools industry 4.0 and lean production

Notwithstanding the tools of Industry 4.0 are very useful for the companies, they need to integrate the tools with the Lean Production. This will be useful to allow companies to improve SOP, acronym of Standard Operating Procedures [34]. The integration between tools of Industry 4.0 and Lean Production will not only accelerate the development of lean systems in manufacturing companies, but it will also reduce the perceived risk deriving from the high implementation costs of I4.0 tools [39]. Thus, integration between I4.0 tools and LP offers lots of advantages for the companies with a reduction of cost in areas where it could be difficult to put on this integration. Furthermore, this integration takes the name of Lean Automation (LA), which aims to have a greater variability and shorter information flows to meet future market demands [39]. The same authors think that tools of Industry 4.0 play an important role in Lean production, but in literature missing the studies that develop this topic from a literature review point of view [10]. The aim of the study is to give a complete overview about the tools of the Industry 4.0. The research question of study is the following:

- *RQ1 What are the tools of Industry 4.0 implemented in lean production?*

- *RQ2 What are the tools of Industry 4.0 able to contribute to the success of the companies improving their productivity and flexibility?*

4. Methodology

To answer to these questions, this document shows a Systematic Literature Review (SLR) about Industry 4.0. The SLR is identified as "means to identify, evaluate and interpret all available research relating to a particular research question, thematic area or phenomenon of interest" [37]. The SLR is a quali-quantitative rating focused on a specific topic [8]. At the first, it is necessary to ask yourself questions, which are the final goal that we want to achieve at the end of the study [16]. At the second, we must collect materials and do a descriptive analysis by following specific guidelines [44]. Yet, the majority of the authors [57] prefer to follow Mayring’s method (2004), because it allows to analyze in depth the collected materials through specific structural dimensions by topic and analytical categories. Furthermore, this approach allows to classify even a large number of documents and to study in depth the topic we are talking about. This particular method [44] allows to divide SLR process basing on these steps: Formulation of research question; Collecting of materials; Descriptive analysis; Selecting of categories and Material evaluation.

5. Collection of materials

The majority of the materials used for the SLR regarding Industry 4.0 have been collected through Scopus, which is one of the most complete scientific and reliable database [1,29]. The keywords used for the research have been “Industry 4.0” and “Lean production” and only English articles have been selected because, inside the database, english british language, is not only the most used language but it is also the one recognized as an international academic language [26]. The search criterion used was “Title, Abstract, Keywords of the author”. From this first research 52 articles have been selected, which have been filtered using these words: Engineering, Business, Management and Accounting, Computer Science, Decision Sciences, Economics, Econometrics and Finance.

At the end of this first selection, 16 articles have been considered as consistent with the research activity to be carried out. In a second moment have been collected documents from Web Of Science, which is another database, and even in this case we used the same previous keywords. We considered 47 articles, which have been filtered using the following words: Engineering manufacturing OR Engineering industrial OR Economics OR Management OR Engineering Multidisciplinary OR Operations research management science OR Automation control systems OR Computer science information systems OR Social sciences interdisciplinary OR Business. Thus, 15 articles have been considered consistent with the research activity to be carried out and finally we have cancelled 6 duplicates from the 31 remaining for a total of 25 articles analyzed.

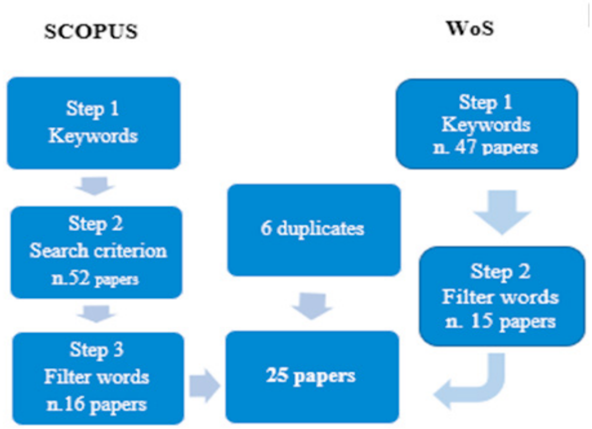

Fig. 1. Identification of relevant articles process. Authors' elaboration

6. Results

These 25 articles analyzed for our study have been divided according to research methodologies as shown in the Fig. 2. The most used are Case Studies and other types of unspecified articles (32%), also the Surveys (24%) are numerous.

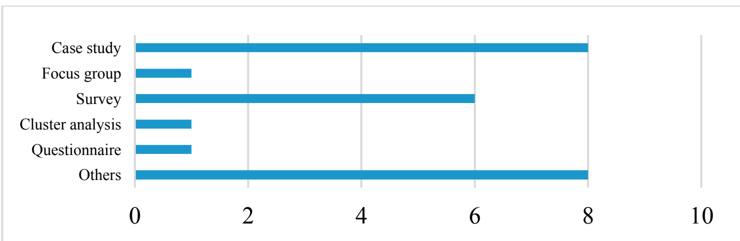

Fig. 2. *Research methodologies employed. Source: Authors' elaboration*

Furthermore, in the table 1 we have reported a list of selected journals. The majority part of the considered magazines has got like mean topic the Industry 4.0 and the Lean Production. The "International Journal of Production research" is the magazine with the highest number of articles (28%), followed from the "Journal of manufactoring technology management" and from the "IFAC – PapersOnLine" (8%).

Table 1. List of selected journals

Journal	n	%	Journal	n	%
International Journal of Production Research	7	28%	Journal of Open Innovation: Technology, Market, and Complexity	1	4%
Journal of manufactoring technology management	2	8%	Production and Manufacturing Research	1	4%
IFAC-PapersOnLine	2	8%	Tehnicki Vjesnik	1	4%
International Journal of Operations and Production Management	1	4%	Production planning & control	1	4%
IEEE Engineering Management Review	1	4%	Production and manufactoring research-an open access journal	1	4%
Supply chain management	1	4%	International journal of advanced manufactoring technology	1	4%
Total quality management and business excellence	1	4%	Management and production engineering review	1	4%
FME Transactions	1	4%	Journal of ambient intelligence and humanized computing	1	4%
Total				**25**	**100%**

Source: Authors' elaboration

Table 2 shows the number of the authors for each article. In the majority part of the articles (44%) there are 3 authors who have collaborated to make the article.

Table 2. Numbers of authors per articles

Authors	1	2	3	4	≥5	**Tot**
n	3	3	11	4	4	**25**
%	12%	12%	44%	16%	16%	**100%**

Source: Authors' elaboration

Figure 3 shows the geographical origin of first authors, Brazil and Italy are the countries with the largest number of papers (6 in Brazil, 5 in Italy). The number of articles from Brazil are the 24% of the total. Yet, if we consider the authors' continent of origin, it can see that Europe is the first continent with 14 articles (56% of the total) as it is shown in the Figure 4. However, here aren't any articles from Northern America and Oceania.

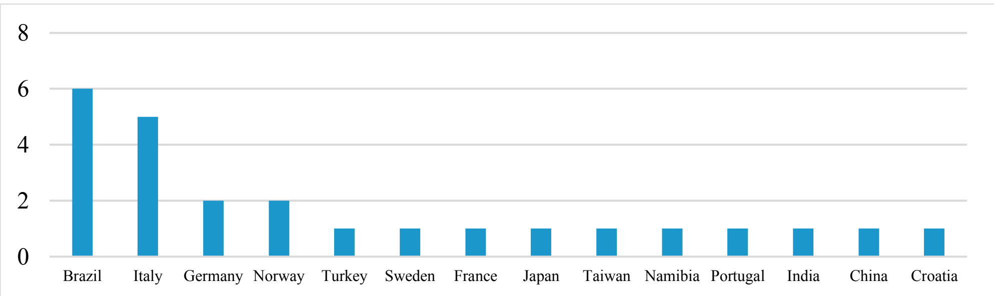

Fig. 3. *Number of papers per country of the first author. Source: Authors' elaboration*

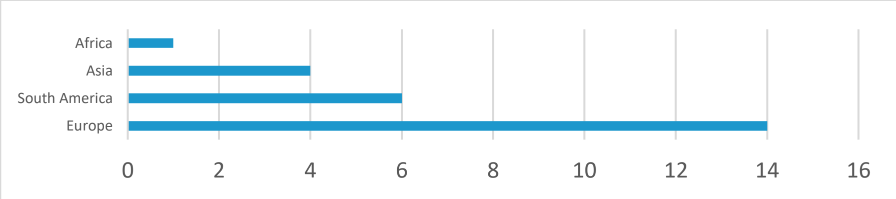

Fig. 4. *Continents of the first author. Source: Authors' elaboration*

Finally, table 3 shows what tools of Industry 4.0 have been mentioned by the authors in their papers and if they talked about Lean Production inside them.

Table 3. Authors' who talked about I4.0 tools and/or lean production in their papers

Authors	I4.0 tools	LP	Authors	I4.0 tools	LP
Agostini L., Filippini R.	Iot, Big Data, Cloud computing, CPS, Robotic, Technology and process		Li, L. R.	Iot, Big Data, Cloud computing, CPS, Robotic, Technology and process	X
Ante G., Facchini F., Mossa G., Digiesi S.	Robotic, Technology and process	X	Lu, Y.	IoT, Big Data, CPS	
Ben-Daya, M., Hassini, E., & Bahroun, Z.	IoT		Monostori, L., Kádár, B., Bauernhansl, T., Kondoh, S., Kumara, S., Reinhart, G., ... & Ueda, K.	CPS	
Bevilacqua, M., Ciarapica, F. E., & Antomarioni, S.		X	Nascimento, D. L. M., Alencastro, V., Quelhas, O. L. G., Caiado, R. G. G., Garza-Reyes, J. A., Rocha-Lona, L., & Tortorella, G.	Iot, Big Data, Cloud computing, CPS, Robotic, Technology and process	
Buer, S. V., Fragapane, G. I., & Strandhagen, J. O.	Iot, Big Data		Pereira, A. C., Dinis-Carvalho, J., Alves, A. C., & Arezes, P.	Iot, Big Data, Cloud computing, CPS, Robotic, Technology and process	X
Buer, S. V., Strandhagen, J. O., & Chan, F. T.	Iot, Big Data, Cloud computing, CPS, Robotic, Technology and process	X	Rosin, F., Forget, P., Lamouri, S., & Pellerin, R.	Iot, Big Data, Cloud computing, CPS, Robotic, Technology and process	X
Busert T., Fay A.	Iot, Big Data, Cloud computing, CPS, Robotic, Technology and process	X	Rossini, M., Costa, F., Tortorella, G. L., & Portioli-Staudacher, A.	Iot, Big Data, Cloud computing, CPS, Robotic, Technology and process	X
Chiarini, A., Belvedere, V., & Grando, A.	Iot, Big Data, Cloud computing, CPS, Robotic, Technology and process		Scholer, M., & Müller, I. R.	Robotic, Technology and process	
Dalenogare, L. S., Benitez, G. B., Ayala, N. F., & Frank, A. G.	Technology and process		Sony, M.	IoT, Cloud computing, CPS	X
De Vin, L. J., Jacobsson, L., & Odhe, J.		X	Thoben, K. D., Wiesner, S., & Wuest, T.	IoT, Big Data, CPS	
Falcone D, Silvestri A, Bona G, et al.	Robotic, Technology and process		Tortorella, G. L., & Fettermann, D.	Iot, Big Data, Cloud computing, CPS, Robotic, Technology and process	X
Falcone D, Silvestri A, Forcina A, Pacitto A	Robotic, Technology and process		Tortorella, G.L., Giglio R, Van Dun D.H.	Iot, Big Data, Cloud computing, CPS, Robotic, Technology and process	X
Fettermann, D. C., Cavalcante, C. G. S., Almeida, T. D. D., & Tortorella, G. L.	IoT, Cloud computing, CPS, Technology and process		Tortorella G.L., Miorando R., Mac Cawley A.F.,	Iot, Big Data, Cloud computing, CPS, Robotic, Technology and process	
Kabadurmus, O., & Durmusoglu, M. B.		X	Tortorella G.L., Rossini M., Costa F., Portioli Staudacher A., Sawhney R,	Iot, Big Data, Cloud computing, CPS, Robotic, Technology and process	X
Kagermann, H., Lukas, W. D., & Wahlster, W	CPS, Techonoly and process		Veza, I., Mladineo, M., & Gjeldum, N.	IoT, Robotic, Technology and process	X
Kamble, S., Gunasekaran, A., & Dhone, N. C.	Iot, Big Data, Cloud computing, CPS, Robotic, Technology and process	X	Wittenberg C.	CPS, Technology and process	
Kipper, L. M., Furstenau, L. B., Hoppe, D., Frozza, R., & Iepsen, S.	IoT, Big Data, CPS		Yin, Y., Stecke, K. E., & Li, D.	Iot, Big Data	
Kolberg, D., Knobloch, J., & Zühlke, D.	CPS	X	Zhang, K., Qu, T., Zhou, D., Thürer, M., Liu, Y., Nie, D., ... & Huang, G. Q.	IoT, Technology and process	X
Kolberg, D., Zühlke, D.	Robotic, Technology and process	X			

Source: Authors' elaboration

As it can see from the previous table, not all the authors reported in the references have been reported inside the table because not all of them talk about the I4.0 tools and Lean Production in their papers. For this reason, it has been decided to not introduce them inside the table 3 although their papers have been used to write this paper. Furthermore, not all the authors reported talk both I4.0 tools and the lean production. A few authors consider all the tools of Industry 4.0; some of them consider just a few tools and 19 of them have talked about lean production integrated with I4.0 tools. However, in the majority part of the cases, it can see that IoT, Big Data, Robotic and technology and process are the most mentioned tools by the authors. Finally, it is possible to see that some authors think that lots of I4.0 tools, starting from IoT and arriving to technology and process, could be implemented with lean production.

7. Discussion

The fourth industrial revolution and all its tools are an important turning point for the companies, which will be able to increase their productivity and flexibility. However, the companies ask to themselves which tools should be used to achieve their aims and if Industry 4.0 is the right solution to undertake. As it possible to see from the Tab. 3, lots of authors think that I4.0 tools could be integrated with Lean Production even if not all the authors see eye to eye. Indeed, some of them have only talked about I4.0 tools without considering lean production, so it possible to say that not all of them are on the same page. In this perspective, some authors [55] suggeste that the integration among workers (human factor) and the robotic could improve business productivity and process efficiency. Thus, it is making a scenary where, over the use of the various tools of the Industry 4.0, the human factor endorses the main character for the implementation of Industry 4.0 inside the companies.

For instance, the use of CPS technologies presupposes a high degree of preparation by the staff [73]. Thus, the man should have a highly innovative mentality to improve the business productivity [49]. Even other authors express their theory that man, in the future, in spite of several machines inside the factories, will still have a decisive role [27]. Thus, companies mustn't forget the element that maybe is at the base of all, not only of the Industry 4.0, but even of the company itself, without which this couldn't get any positive results: the man.

Industry 4.0 can't be supported by innovation technologies without support of human factor [15]. For this reason, Industry 4.0 is not a synonymous of elimination of human factor from the companies [4] but is an opportunity for the man to identify new forms of work inside the companies. Other studies [74] highlight as a company can't get good results if the "internal customer" (employee) doesn't work in a good job environment or if he hears that his position could be threatened by innovation technology. Workers should be able to adapt their skills and qualities to the innovation technology, because they are the authors of the innovation: which is not from machine but from the man.

The results show that there are lots of tools (IoT, Big data, CPS…) and their following integrations (IIoT, Industrial Big Data, CPPS…) that are all useful for the introduction of Industry 4.0 inside the companies. All these tools listed in the section 2 have the purpose to increase business productivity improving companies' performance and trying to get more positive results than the competitors. Obviously, each company must decide what tools will be used to achieve their aims; what from these tools will be used to have success and what among them will be put in second place. However, at the base of the Industry 4.0 there are IoT and Big Data, without which company couldn't even start the process of the fourth industrial revolution. These tools those that can be identified as the "basic tools" of Industry 4.0.

Finally, approaching to the fourth industrial revolution will allow to the companies to have lots of advantages, such as greater flexibility and competitiveness of the production system with high control of the system, which it will depend on the ability to measure, monitor and evaluate productivity and industrial sustainability parameters and services [42]. The companies, to join the fourth industrial revolution will have to use the tools previous mentioned, betting on those tools that will allow them to get greater positive results. Yet, the most important tool on which they must continue to rely is man, the human factor will be a fundamental tool for businesses, the source of guaranteed success.

8. Conclusion

In this research only 25 articles have been analyzed: a too small number to reach exact conclusions. This paper is only a guideline of the main tools of I4.0. The research must be further integrated not only by using the same keywords as I4.0, LP or tools of I4.0. It will necessary to extend the range of the keywords as to have a greater number of articles to analyze. This will be useful to delve into the topic. Furthermore, another next step is to consider even papers from Northern America, Africa and Oceania because, as already shown in figure 4, too many papers from Europe have been analyzed. For this reason, it could be useful to balance the geographical origin of the papers. IoT and Big Data seem to be the most used I4.0 tools that companies should use inside themselves to get higher results than the competitors. The results achieved show that I4.0 tools could be integrated with lean production in such a way that companies are able to improve their productivity and flexibility. Yet, there are some authors who say that human factor can be considered as the most important part for companies to integrate I4.0 tools with lean production.

References

[1] Aghaei Chadegani, A., Salehi, H., Yunus, M., Farhadi, H., Fooladi, M., Farhadi, M., & Ale Ebrahim, N. (2013). A comparison between two main academic literature collections: Web of Science and Scopus databases. Asian social science, 9(5), 18-26.

[2] Agostini, L., & Filippini, R. (2019). Organizational and managerial challenges in the path toward Industry 4.0. European Journal of Innovation Management.

[3] Ante, G., Facchini, F., Mossa, G., & Digiesi, S. (2018). Developing a key performance indicators tree for lean and smart production systems. IFAC-PapersOnLine, 51(11), 13-18.

[4] Bauer, M. D., & Mertens, T. M. (2018). Information in the yield curve about future recessions. FRBSF Economic Letter, 20, 1-5.

[5] Belfiore G, Falcone D, Silvestri L (2018) Assembly line balancing techniques: Literature review of deterministic and stochastic methodologies. In: 17th International Conference on Modeling and Applied Simulation, MAS 2018. pp 185–190.

[6] Ben-Daya, M., Hassini, E., & Bahroun, Z. (2019). Internet of things and supply chain management: a literature review. International Journal of Production Research, 57(15-16), 4719-4742.

[7] Bevilacqua, M., Ciarapica, F. E., & Antomarioni, S. (2019). Lean principles for organizing items in an automated storage and retrieval system: an association rule mining–based approach. Management and Production Engineering Review, 10(1), 29-36.

[8] Brewerton, P. M., & Millward, L. J. (2001). Organizational research methods: A guide for students and researchers. Sage.

[9] Buer, S. V., Fragapane, G. I., & Strandhagen, J. O. (2018). The Data-Driven Process Improvement Cycle: Using Digitalization for Continuous Improvement. IFAC-PapersOnLine, 51(11), 1035-1040.

[10] Buer, S. V., Strandhagen, J. O., & Chan, F. T. (2018). The link between Industry 4.0 and lean manufacturing: mapping current research and establishing a research agenda. International Journal of Production Research, 56(8), 2924-2940.

[11] Busert T., Fay A. (2019). Extended Value Stream Mapping Method for Information Based Improvement of Production Logistics Processes. IEEE Engineering Management Review Vol.47: pp. 119-127.

[12] Caravella, S., & Menghini, M. (2018). Race against the Machine. Gli effetti della quarta rivoluzione industriale sulle professioni e sul mercato del lavoro. L'industria, 39(1), 43-68.

[13] Cavalieri, S., Salafia, M. G., & Scroppo, M. S. (2019). Integrating OPC UA with web technologies to enhance interoperability. Computer Standards & Interfaces, 61, 45-64.

[14] Chiarini, A., Belvedere, V., & Grando, A. (2020). Industry 4.0 strategies and technological developments. An exploratory research from Italian manufacturing companies. Production Planning & Control, 1-14.

[15] Dalenogare, L. S., Benitez, G. B., Ayala, N. F., & Frank, A. G. (2018). The expected contribution of Industry 4.0 technologies for industrial performance. International Journal of Production Economics, 204, 383-394.

[16] Denyer, D., & Tranfield, D. (2009). Producing a systematic review.

[17] De Vin, L. J., Jacobsson, L., & Odhe, J. (2019). Simulator-assisted lean production training. Production & Manufacturing Research, 7(1), 433-447.

[18] Di Bona G, Duraccio V, Silvestri A, Forcina A (2014) Productive line reengineering through simulation techniques. In: Proceedings of the IASTED International Conference on Modelling, Identification and Control. pp 291–296

[19] Di Bona G, Duraccio V, Silvestri A, Forcina A (2014) Validation and application of a safety allocation technique (integrated hazard method) to an aerospace prototype. In: Proceedings of the IASTED international conference on modelling, identification, and control, MIC. pp 284–290

[20] Di Bona G, Forcina A, Falcone D, Silvestri L (2020) Critical Risks Method (CRM): A New Safety Allocation Approach for a Critical Infrastructure. Sustainability 1–19. https://doi.org/10.3390/su12124949

[21] Falcone D, Silvestri A, Bona G, et al (2010) Study and modelling of very flexible lines through simulation

[22] Falcone D, Silvestri A, Forcina A, Pacitto A (2011) Modeling and simulation of an assembly line: a new approach for assignment and optimization of activities of operators. In: MAS (The International Conference on Modeling and Applied Simulation), Rome. pp 12–14.

[23] Fettermann, D. C., Cavalcante, C. G. S., Almeida, T. D. D., & Tortorella, G. L. (2018). How does Industry 4.0 contribute to operations management?. Journal of Industrial and Production Engineering, 35(4), 255-268.

[24] Forcina A, Silvestri L, Di Bona G, Silvestri A (2020) Reliability allocation methods: A systematic literature review. Qual Reliab Eng Int.

[25] Freddi, D. (2018). Digitalisation and employment in manufacturing. AI & SOCIETY, 33(3), 393-403.

[26] Genc, B., & Bada, E. (2010). English as a world language in academic writing.

[27] Gershwin, S. B. (2018). The future of manufacturing systems engineering. International Journal of Production Research, 56(1-2), 224-237.

[28] Gu, J. C., Ling, Z. H., Zhu, X., & Liu, Q. (2019). Dually interactive matching network for personalized response selection in retrieval-based chatbots. arXiv preprint arXiv:1908.05859.

[29] Guz, A. N., & Rushchitsky, J. J. (2009). Scopus: A system for the evaluation of scientific journals. International Applied Mechanics, 45(4), 351.

[30] Hwang, J. Y., Myung, S. T., & Sun, Y. K. (2017). Sodium-ion batteries: present and future. Chemical Society Reviews, 46(12), 3529-3614.

[31] José Álvares, A., Oliveira, L. E. S. D., & Ferreira, J. C. E. (2018). Development of a Cyber-Physical framework for monitoring and teleoperation of a CNC lathe based on MTconnect and OPC protocols. International Journal of Computer Integrated Manufacturing, 31(11), 1049-1066.

[32] Kabadurmus, O., & Durmusoglu, M. B. (2019). Design of pull production control systems using axiomatic design principles. Journal of Manufacturing Technology Management.

[33] Kagermann, H., Lukas, W. D., & Wahlster, W. (2011). Industrie 4.0: Mit dem Internet der Dinge auf dem Weg zur 4. industriellen Revolution. VDI nachrichten, 13(1).

[34] Kamble, S. S., Gunasekaran, A., & Gawankar, S. A. (2018). Sustainable Industry 4.0 framework: A systematic literature review identifying the current trends and future perspectives. *Process Safety and Environmental Protection*, *117*, 408-425.

[35] Kamble, S., Gunasekaran, A., & Dhone, N. C. (2020). Industry 4.0 and lean manufacturing practices for sustainable organisational performance in Indian manufacturing companies. International Journal of Production Research, 58(5), 1319-1337.

[36] Kipper, L. M., Furstenau, L. B., Hoppe, D., Frozza, R., & Iepsen, S. (2020). Scopus scientific mapping production in industry 4.0 (2011–2018): a bibliometric analysis. International Journal of Production Research, 58(6), 1605-1627.

[37] Kitcharoen, K. (2004). The importance-performance analysis of service quality in administrative departments of private universities in Thailand. ABAC journal, 24(3).

[38] Kolberg, D., Knobloch, J., & Zühlke, D. (2017). Towards a lean automation interface for workstations. International journal of production research, 55(10), 2845-2856.

[39] Kolberg, D., Zühlke, D. (2015). Lean automation enabled by Industry 4.0 Technologies.

[40] Li, L. R. (2019). Lean Smart Manufacturing in Taiwan—Focusing on the Bicycle Industry. Journal of Open Innovation: Technology, Market, and Complexity, 5(4), 79.

[41] Liboni, L. B., Cezarino, L. O., Jabbour, C. J. C., Oliveira, B. G., & Stefanelli, N. O. (2019). Smart industry and the pathways to HRM 4.0: implications for SCM. Supply Chain Management: An International Journal.

[42] Lu, Y. (2017). Industry 4.0: A survey on technologies, applications and open research issues. Journal of industrial information integration, 6, 1-10.

[43] Luthra, S., & Mangla, S. K. (2018). Evaluating challenges to Industry 4.0 initiatives for supply chain sustainability in emerging economies. Process Safety and Environmental Protection, 117, 168-179.

[44] Mayiring, P. (2004). Qualitative content analysis. A companion to qualitative research, 1 (2004), 159-176.

[45] Merli, R., Preziosi, M., Acampora, A., Lucchetti, M. C., & Petrucci, E. (2020). Recycled fibers in reinforced concrete: A systematic literature review. Journal of Cleaner Production, 248, 119207.

[46] Merli, R., Preziosi, M., & Acampora, A. (2018). How do scholars approach the circular economy? A systematic literature review. Journal of Cleaner Production, 178, 703-722.

[47] Monostori, L., Kádár, B., Bauernhansl, T., Kondoh, S., Kumara, S., Reinhart, G., ... & Ueda, K. (2016). Cyber-physical systems in manufacturing. Cirp Annals, 65(2), 621-641.

[48] Nascimento, D. L. M., Alencastro, V., Quelhas, O. L. G., Caiado, R. G. G., Garza-Reyes, J. A., Rocha-Lona, L., & Tortorella, G. (2019). Exploring Industry 4.0 technologies to enable circular economy practices in a manufacturing context. Journal of Manufacturing Technology Management.

[49] Palazzeschi, L., Bucci, O., & Di Fabio, A. (2018). Correlati di personalità del High Entrepreneurship, Leadership, Professionalism Questionnaire (HELP): uno studio esplorativo. [Personality correlates of High Entrepreneurship, Leadership, Professionalism Questionnaire (HELP): an exploratory study]. Counseling. Giornale Italiano di Ricerca e Applicazioni, 11(10.14605).

[50] Pereira, A. C., Dinis-Carvalho, J., Alves, A. C., & Arezes, P. (2019). How Industry 4.0 can enhance Lean practices. FME Transactions, 47(4), 810-822.

[51] Pettey, C., & van der Meulen, R. (2018). Gartner Says Global Artificial Intelligence Business Value to Reach $1.2 Trillion in 2018. Retrieved August, 4, 2018.

[52] Rosin, F., Forget, P., Lamouri, S., & Pellerin, R. (2020). Impacts of Industry 4.0 technologies on Lean principles. International Journal of Production Research, 58(6), 1644-1661.

[53] Rossini, M., Costa, F., Tortorella, G. L., & Portioli-Staudacher, A. (2019). The interrelation between Industry 4.0 and lean production: an empirical study on European manufacturers. The International Journal of Advanced Manufacturing Technology, 102(9-12), 3963-3976.

[54] Schleipen, M., Lüder, A., Sauer, O., Flatt, H., & Jasperneite, J. (2015). Requirements and concept for plug-and-work. at-Automatisierungstechnik, 63(10), 801-820.

[55] Scholer, M., & Müller, I. R. (2017). Modular configuration and control concept for the implementation of human-robot-cooperation in the automotive assembly line. IFAC-PapersOnLine, 50(1), 5694-5699.

[56] Shen, W., & Norrie, D. H. (1999). Agent-based systems for intelligent manufacturing: a state-of-the-art survey. Knowledge and information systems, 1(2), 129-156.

[57] Shukla, M., & Jharkharia, S. (2013). Agri-fresh produce supply chain management: a state-of-the-art literature review. International Journal of Operations & Production Management.

[58] Sidharth, M., Ispir, N., & Agrawal, P. N. (2015). GBS operators of Bernstein–Schurer–Kantorovich type based on q-integers. Applied Mathematics and Computation, 269, 558-568.

[59] Silvestri L, Falcone D, Belfiore G (2018) Guidelines for reliability allocation methods. In: The International conference on modelling and applied simulation, MAS 2018, pp. 191-198

[60] Silvestri L, Forcina A, Arcese G, Bella G (2020) Recycling technologies of nickel–metal hydride batteries: an LCA based analysis. J Clean Prod 123083. https://doi.org/https://doi.org/10.1016/j.jclepro.2020.123083

[61] Silvestri L, Forcina A, Arcese G, Bella G (2019) Environmental Analysis Based on Life Cycle Assessment: An Empirical Investigation on the Conventional and Hybrid Powertrain. In: Conference on Sustainable Mobility. SAE International

[62] Silvestri L, Forcina A, Silvestri C, Ioppolo G (2020) Life cycle assessment of sanitaryware production: A case study in Italy. J Clean Prod 251:119708. https://doi.org/https://doi.org/10.1016/j.jclepro.2019.119708

[63] Sony, M. (2018). Industry 4.0 and lean management: a proposed integration model and research propositions. Production & Manufacturing Research, 6(1), 416-432.

[64] Stock, T., & Seliger, G. (2016). Opportunities of sustainable manufacturing in industry 4.0. Procedia Cirp, 40, 536-541.

[65] Thoben, K. D., Wiesner, S., & Wuest, T. (2017). "Industrie 4.0" and smart manufacturing-a review of research issues and application examples. International journal of automation technology, 11(1), 4-16.

[66] Tortorella, G. L., & Fettermann, D. (2018). Implementation of Industry 4.0 and lean production in Brazilian manufacturing companies. International Journal of Production Research, 56(8), 2975-2987.

[67] Tortorella, G.L., Giglio R, Van Dun D.H. (2019). Industry 4.0 adoption as a moderator of the impact of lean production practices on operational performance improvement. International Journal of Operations and Production Management Vol. 39 No. 6/7/8, pp. 860-886.

[68] Tortorella G.L., Miorando R., Mac Cawley A.F. (2019). The moderating effect of Industry 4.0 on the relationship between lean supply chain management and performance improvement. Supply Chain Management Vol. 24(2):301-314.

[69] Tortorella G.L., Rossini M., Costa F., Portioli Staudacher A., Sawhney R. (2019). A comparison on Industry 4.0 and Lean Production between manufacturers from emerging and developed economies. Total Quality Management & Business Excellence 1-22.

[70] Van der Meulen, R., Pettey, C. (2018). Gartner Says Global Artificial Intelligence Business Value to Reach $1.2 Trillion in 2018. *Retrieved August*, *4*, 2018.

[71] Veza, I., Mladineo, M., & Gjeldum, N. (2016). Izbor osnovnih Lean alata za razvoj Hrvatskog modela Inovativnog pametnog poduzeća. Tehnički vjesnik, 23(5), 1317-1324.

[72] Wilding, R., Wagner, B., Seuring, S., & Gold, S. (2012). Conducting content-analysis based literature reviews in supply chain management. Supply Chain Management: An International Journal.

[73] Wittenberg C. (2016). "Human-CPS Interaction-requirements and human-machine interaction methods for industry 4.0." IFAC-PapersOnLine 49.19 (2016): 420-425.

[74] Womack, K. L. (1996). Do brokerage analysts' recommendations have investment value?. The journal of finance, 51(1), 137-167.

[75] Yin, Y., Stecke, K. E., & Li, D. (2018). The evolution of production systems from Industry 2.0 through Industry 4.0. International Journal of Production Research, 56(1-2), 848-861.

[76] Zhang, K., Qu, T., Zhou, D., Thürer, M., Liu, Y., Nie, D., ... & Huang, G. Q. (2019). IoT-enabled dynamic lean control mechanism for typical production systems. Journal of Ambient Intelligence and Humanized Computing, 10(3), 1009-1023.

[77] Zhong, Z., Sanchez-Lopez, E., & Karin, M. (2016). Autophagy, inflammation, and immunity: a troika governing cancer and its treatment. Cell, 166(2), 288-298.