Lean Robotics: A Multivocal Literature Review

Adis Jasarevic and Ricardo Colomo-Palacios

[1] Østfold University College, BRA veien. 4, 1757 Halden, Norway
{adisj,ricardo.colomo-palacios}@hiof.no

Abstract. Lean, as a business approach, has gained popularity in several functional areas. One of these applications is Lean Robotics that focus on the utilization of Lean aspects to improve robotic deployment. This study aims to be the first to conduct a Multivocal review on what Lean Robotics is, its main components, its benefits, and challenges and how it evolved. It was found that Lean Robotics is defined differently by some sources, and that its components can be understood both theoretically and practically. The benefits of Lean Robotics are found to resonate from the prioritization of human and machine collaboration, and the use of various Lean tools via continuous improvement. However, some challenges of Lean Robotics like cost and fear might arise if organizations are uneducated in what Lean Robotics offers regarding its knowledge.

Keywords: Multivocal Literature Review, Lean Robotics, Robot, Machine, Performance, Applications

1 Introduction

The Lean concept was coined by the Japanese automotive company Toyota after the second world war. This concept has been gaining considerable interest from various organizations worldwide [1]. Businesses in areas like manufacturing, service and other sectoral domains have been trying to assimilate and operationalize the Lean concept in order to gain success [2]. However, adopting said concept has not consistently been a steady or straightforward journey, because of various barriers known to arise during the implementation stages of Lean. [3] Most of these barriers are mainly linked to human and organizational errors, such as the improper transmittal of knowledge, attitude or behavior when implementing Lean. [4] Tackling said errors has therefore put stress on the necessity to reconsider the way Lean is actually understood in terms of its practical and theoretical aspects. For instance, Pettersen [5] asserts that organizations that missionize to fully understand Lean, requires to first acknowledge it dimensionally at two levels, such as 1) understanding it practically as a set of operational tools that support users with discrete improvement efforts, and 2) understanding it strategically as a set of philosophical principles of continuous improvement efforts. Both levels are suggested to be hard to formulate into a single definition that classifies one clear understanding of Lean [5]. Nevertheless, the main focus of Lean is still centralized around the improvement efforts from both levels of understanding. These efforts are understood as the systematic identification and elimination of all sources of waste, variabilities and inflexibilities that might jeopardize the cost, quality and delivery of an organization [6]. Because of the two-folded understanding of Lean, a plethora many specific definitions have arisen and entered the management lexicon over the years [7]. Whilst these definitions might be interpreted to contain aspects that tilt towards one understanding of Lean or the other, the distinction between them might reside with their applications or industries [7]. Some examples of this distinction may include extensions, such as *"Lean IT"*, *"Lean startup",* or *"Lean UX"* [8][9][10]**.** These said extensions are some of the evidence that suggest that Lean has expanded over a long period of time from what was primely confined to automotive industries decades ago. Most of these extensions mentioned have been researched and evaluated for their benefits and challenges within their confined application. However, there still exists other extensions that have not shared enough research. This is reflected by the low number of academic papers available. One such extension is the application of Lean Robotics.

Lean Robotics is a novel term that has arisen, but its concept seems still in its infancy. This concept employs the knowledge of Lean and tries to align it with the field of robotics in order to improve the deployment of robots [11]. Robotics by itself is an engineering discipline [12] , a science that involves the utilization of robots for automating different tasks within various settings. Such robots can be industrial robots that can be programmed with functions *to move* objects in the physical world to perform tasks [12]. Traditionally, robotics was viewed *as the utilization of machines performing a mechanized task or series of tasks automatically to multiply the impact of human effort* [13]. However, as advancements in science progressed, this view of robotics began to be surrounded by ethical rules that protect and prioritizes humans. This is reflected by the laws that arose over the years after the term robot came into existence. Whilst these laws originated because of the potential fear of robots harming humans, it is important to note that this harm might both be physically and psychologically caused [13]. Introducing robots into work environments by increasing automation can have detrimental effects on the workers [14]. In lean, the best degree of automation is deployed in a manner where both humans and robots can collaborate. This is emphasized by the Lean pillar known as *Jidoka*, which means *automation with a human touch* [15]. Considering this pillar, Lean and robotics might complement each other if robotics considers human efforts before robotics.

In this paper, an extensive deep dive of the topic Lean Robotics, its definition, main components, evolution, and its benefits and challenges will be studied in order to get a better understanding of said topic. To the best of our knowledge there is not a previous literature review carried out on Lean Robotics. The remaining sections of this paper are as follows: Second, the literature review process will be described. Third, the findings of the literature review will be discussed. Last and foremost, the literature review will be concluded.

2 Methodology

2.1 Multivocal literature review

For obtaining relevant knowledge regarding the topic of Lean Robotics, this paper will carry out a Multivocal Literature Review (MLR) approach. This approach was chosen, due to its extendibility of reaching publications that are within and outside of academia. For instance, in [16] authors show that this approach can be extended upon the respected systematic literature review approach (SLR) to include both grey and formal literature. Grey literature can be classified in blog posts, videos, and whitepapers, whilst formal literature can be classified in journals and conference papers. This is perfect for topics that lacks necessary formal evidences [16].

2.2 Research questions

Because of the novelty of Lean Robotics, the objective is to understand what Lean Robotics is (its meaning and definition), its main components, its benefits, and challenges, and how it evolved. In doing so, four research questions were formulated to guide the search process. See Table 1.

TABLE I. RESEARCH QUESTIONS

RQ1	How is Lean robotics defined?
RQ2	What are the main components of Lean Robotics?
RQ3	What are the benefits/challenges of Lean Robotics?
RQ4	How did Lean Robotics evolve?

2.3 Review protocol

The review protocol can be viewed as a strategic process on how a review of the literature can be executed [16]. In this paper, a model was constructed in order to plan out and descript the review process. This model includes the quantity of publications fetched and extracted from the chosen databases, the main search string employed to conduct the search, and the selection criteria for identifying the correct data. The parameters chosen within the model is justified in the following sections. See Table 2 for a view of the model.

2.4 Data source

To find publications about Lean Robotics, the databases Google and Google scholar were selected as the main sources of data for formal and grey literature. Both Google and Google scholar are excellent and well-known data sources, due to their vast library of various publications on topics across the board. This is perfect for novel topics that require an exhaustive literature review because these databases fetch data that are included within other databases. Another reason for the choice is that Google utilizes a world-class algorithm that automatically filter out data that are not relevant during the search. For info about how Google works and how it performs in regard to other search engines, please refer to its documentation and the benchmarking study tested [17][18].

TABLE II. REVIEW PROCESS

Databases	**Publications**	**Extractions**
Google	270	17
Google Scholar	63	15
Search string (search strategy)		
(“Lean robotics” OR “Lean robotization”) AND (definition OR benefits OR barriers OR challenges) AND (robot OR machine)		
Selection criteria		
• Publications that specifically mention or discuss the utilization of Lean Robotics. • Publications that discuss the effects of Lean Robotics.	• Publications that are inaccessible. • Publications that use other languages. • Publications that are similar (Duplicates).	

2.5 Search strategy

As seen below, most of the terms used within the search string is based on the research questions found in Table 1.

- (“Lean robotics” OR “Lean robotization”) AND (definition OR benefits OR barriers OR challenges) AND (robot OR machine)

In making sure that relevant publications are reached, the term *“Lean Robotization”* was included within the search string. This is because *“robotization”* by itself means *automation of a system or process* using *robotic devices* [19]. However, separating the term “*Lean”* from “*robotics”* or robotization will give irrelevant results. This is because Lean by itself means many things depending on its context. For instance, Lean can mean fit or to cast weight to a position [20]. Other terms that are included within the search string are *“machine”* and *“robot”*. This is to make sure that the search reaches publications that utilizes the term *“machine”* and not necessarily *“robot”* within a Lean context, and wise versa. “*Machine*” is a broad term and can be applied to “robot” [21]. Nevertheless, adding both terms together with the operator “OR” in between will help reach publications that talk about robotics in Lean contexts without including *“Lean robotics”.* The other terms, such as *“barriers”* and *“challenges”* can have the same meaning. However, *“barriers”* was utilized as an extra, due to it often being mentioned in Lean studies [22].

2.6 Search results

The process conducted for finding relevant publications was operationalized in three steps. The first step was reading the abstracts and keywords for relevancy in accordance with the selection criteria. The second step was extracting the relevant publications.

The third step was analyzing the publications and placing them into their classification corpus. See Table 3 in the third section for a view of the corpus.

2.7 Selection criteria

As Table 3 below displays, the selection criteria inclusion and exclusion were applied to filter out irrelevant publications that could clutter up the search results. The term *"inclusion"* [23] means basically the action of including something in, whereas the term *"exclusion"* means the opposite of said action. In this paper, it was opted to include anything related to automation in the context of Lean Robotics. Any other form of automation in Lean that is not Lean Robotics is therefore excluded. This exclusion is also applied with publications that are inaccessible, are similar in nature (e.g., duplicates), or are written in languages other than English.

TABLE III. REVIEW PROCESS

Selection criteria	
Inclusion	**Exclusion**
• Publications that specifically mention or discuss the utilization of Lean Robotics. • Publications that discuss the effects of Lean Robotics.	• Publications that are inaccessible. • Publications that use other languages. • Publications that are similar (Duplicates).

3 Findings

As Table 2 from **2.3** displayed, 333 publications were fetched in totality from both databases. Google had 207 publications more than Google scholar using the same search string. Nevertheless, after filtration was applied in accordance with the selection criteria, the total amount of results got reduced to 32 publications respectively. These results were later on categorized and placed into a classification corpus. See Table 4 for a view of the corpus.

TABLE IV. CLASSIFICATION CORPUS

Discusses Lean Robotics	Mentions Lean Robotics
23	10

As Table 4 displays, 23 publications discuss the topic of Lean Robotics, whereas 10 publications mention the topic of Lean Robotics. In the following subsections, the findings will be discussed in accordance with the posed research questions.

3.1 How is Lean Robotics defined?

Defining Lean Robotics can be a complex task to conduct, due to Lean not having a clear definition itself. Nevertheless, this does not mean that some publications have not opted to define it. For instance, most of the publications extracted from the databases exhibits indications that Lean Robotics is either defined as a "*methodology"* for efficiently incorporating robots in factory environments, [24][25][26][27][28][29][30] a *"project"* that investigates robotics with Lean, [31][32][33] a *"framework"* that help efficiently integrate robots [34][35]**,** or as *"automation"* that help on-going problem-solving [36]**.** Most of these definitions signify that Lean Robotics is defined differently by some of the extracted publications. However, this does not mean that some definitions do not share a similar understanding of Lean Robotics. For instance, the most significant definition utilized was *methodology*. This definition shares a common source of knowledge as the ones that defined it as a *framework*. According to [11]**,** Lean Robotics *is a method for efficiently deploying robotic cells in factories.* This said source also utilizes the terms method, methodology, guide, way, and framework throughout its publication interchangeable, despite them having different meanings in theory. The other publications that define Lean Robotics as a *project* or as *automation* do not share a common source of knowledge. The ones that define Lean Robotics as a *project* are of an investigative nature, in which the authors specifically refer Lean Robotics as the name of the research endeavor. This means that a conceptual definition of Lean Robotics was not necessarily implied here, but rather the naming of the research project itself that was partaken by the researchers. The one publication that defines Lean Robotics as *automation*, implies a more general definition of understanding. In this definition, the author suggests that Lean Robotics is *automation which supports an ongoing and distributed problem-solving activity with strong emphasis on the knowledge and competence of the company's human resources*. The *automation* definition stresses the challenge of continuously improving robotic automation at a holistic level in order to maintain the innovative capacity of the workforce. This said definition also falls more in line with the Lean concept itself, in which the main focus is to centralize and propel the continuous improvement efforts conducted by each of the individuals in an organization. The only difference here is that the *automation* definition of Lean Robotics specifically refers to the continuous improvement efforts as being activities operationalized for robotic automation. However, looking back at the *methodology* definition, it seems to suggest a more limited understanding of Lean Robotics as opposed to the suggested *automation* definition. This is because the *methodology* definition only applies to the deployment of robots in factory domains. The *automation definition* does not mention any specific type of application domain, but rather provides an indication that Lean Robotics can be interpreted at different levels in terms of continuous improvement, innovation, and robotic automation. Nevertheless, this does not mean that the *methodology* definition applied to Lean Robotics is wrong in contrast to the *automation* definition. Perhaps, the vital question to ask here is what the consensus conforms about the main components of Lean Robotics and if these components contain any knowledge that compliment or contradict Lean as a concept.

3.2 What are the main components of Lean Robotics?

The main components of Lean Robotics are discussed by some of the extracted publications, some more detailly than others. For instance, most of these publications [27][28][29] explain the main components as being principles, such as 1) putting people before robots, 2) focusing on the robotic cell output, 3) eliminating waste, and 4) leveraging the skills. Each of these publications refers to a common source [11] when explaining said principles. The source stresses that the first principle exhibits that the robotic cells must be safe and usable for all humans. This said principle touches on aspects of risk avoidance, continuous improvement, and the centrality of humans. The second principle is stressed as the importance of serving the internal customer so that value is generated. With this principle, the internal customer can be any robotic station that comes after the first station deployed. By serving the internal customer (the robotic station) with the proper resources at the right time will help create flow in the production. The third principle is stressed as minimizing any form of waste during the production flow. With this principle, the waste might be anything that bottlenecks the whole robotic cell station to adequately carry out the operation. Typically, in Lean, there are seven forms of waste, but the one that is often left out by Lean studies is the "*Underutilization of human potential"*. In Lean Robotics, this waste is prioritized as one of the most important ones. [11] The final principle is stressed as leveraging the skills from the early robotic deployments and taking small steps towards perfection. This principle guides the robotic users to improve upon previous skills continuously through learning. This principle is similar to the last principle exhibited in Lean, which is about continuously improving, (e.g., kaizen in Lean) so that a certain state of perfection might be obtained [37]**.** The difference between Lean and Lean Robotics here, is that the latter orients its improvement efforts solely on robotics. Operationalizing said principles in practice is stressed to be carried out via three steps. The first step is to design the robotic cell by planning out the potential requirements and resources. The second step is to integrate the robotic cell into action by assemble and installation. This step also includes the necessary preparation of the robotic cell and training of the deployment staff. The third step is the operation of the robotic cell by monitoring and improving its performance. In this step, the Lean aspect *"Gemba"* might come into play, in which means "*the real workplace"* where value is created. This aspect encourages the user to continuously monitor the workplace to identify problems and improvements [37]. Looking at these components of Lean Robotics, they can be understood both theoretically and practically. For instance, at a theoretical level, some might understand these components only as mere principles of Lean Robotics, whereas at a practical level, these components might be understood only as mere activities in operationalizing the principles. Just like the barriers companies face with Lean [3] during the implementation stages, Lean Robotics might encounter the same barriers if the transfer of knowledge is not sufficiently communicated. This stresses the importance of formally evaluating Lean Robotics as a full concept and exploring its potential in organizations that utilize Robotics.

3.3 What are the benefits and challenges of Lean Robotics?

Some benefits of Lean Robotics have been discussed by some of the extracted publications. For instance, [24] mentions that Lean Robotics prioritizes the utilization of collaborative robots or cobots more than traditional robotics. Cobots are robots that directly work alongside human workers by sharing their workplace. These robots have exhibited great results as strategies within Lean settings that are prone to variable and hazardous contexts. For instance, this [38] publication exhibits that these robots integrated with Lean can reduce the production time, improve ergonomic conditions and the wellbeing of the workers. Other publications explains that cobots are enablers of prosperous automation in Lean [39] and that Lean as a concept in the digital age best can be sustained through human and machine mutual learning [15]. Other benefits of Lean Robotics identified is that it borrows most of the core philosophical aspects found in Lean. For instance, it borrows the aspects of putting humans at the centrum, continuous improvement and the continuous removal of any form of waste in the production setting [11]. All of these aspects of Lean have been evaluated and proven by the Japanese company Toyota and other studies to increase performance if implemented properly by an organization [40]. For instance, the first aspect of putting humans at the center has been configured in Lean Robotics as the first principle to mean *putting humans before robots*. The takeaway with this principle is that in no matter which circumstances, robotic cells must be safe and usable for all humans. This principle also touches upon the laws of robotics by Asimov, in which signify that humans should not be harmed by robots, whether the harm is physiologically or psychologically caused [11]**.** Another vital benefit of Lean Robotics is that it provides robotic deployers with the knowledge on how to operationalize the three steps of deployment via the lens of a variety of Lean tools. For instance, [11] provides a dynamic framework that guides and encourages the robotic deployers in what Lean tools to utilize in each of the steps of deployment. One example of this can be utilizing the Lean tool value-stream mapping in order break down processes and identify value-adding activities during the design of deployment. Another example can be utilizing the Lean tools called 5S and Poke Yoke for order and error-proofing. Most of the Lean tools has been well established to be versatile procedures that help organizations in creating standards that can be executed in workplace environments and maintained for continuous improvement efforts [40]. Some challenges of Lean Robotics might manifest from the perceptions and understanding people have of the concept. Since Lean Robotics contains terms like robotics, robots and automation, people might worry or fear that its main purpose is to take over or steal jobs. For instance, in [14] authors exhibit that fear of robots at work can partly be understood to reside from variables of self-interest and cultural differences. Managers in higher position in an organization might like and interest the idea of robotics, but the workforce downstream with cultural differences might fear and reject it. The publication further stresses that the level of education is amongst the strongest predictors of fear of robots at work. Another challenge of Lean Robotics is that some might perceive it as being costly to deploy. In [41], authors emphasize the need to deal with the cost associated with robotics, instead of fearing it. The publication exhibits that there are cost-effective solutions to robotics and that organizations require to move forward in how they think about automation in order to survive in the future. Both of these challenges are highly linked to the lack of knowledge on how people might perceive and understand the term robotics. It is therefore suggested that Lean Robotics as a concept is properly communicated in order to overcome said challenges.

3.4 How has Lean Robotics evolved?

As Table 5 below displays, the idea of integrating Lean with Robotics was not mentioned before the year of 1994. During this time, the idea was termed as *"Lean Robotization"* [42]. Afterwards, the term "*Lean Robotics"* entered the lexicon in year 2007 as a research project for Lean and Robotics [31]. However, it was not until the year 2017 that Lean Robotics was hyped as a method of efficiently deploying Robotics [11].

TABLE V. PUBLICATION TIMELINE

Year	Publications
1994 - 1997	3
2007 - 2011	5
2017 - 2019	8
2020 - 2022	12
Unknown	5

4 Conclusion

This paper describes a multivocal literature review operationalized on the topic of Lean Robotics. The paper also discusses the findings of said topic regarding its definition, main components, benefits/challenges, and evolution. The findings suggests that Lean Robotics is defined with different terms, but that the most prominent one utilized was that of a methodology. The components of Lean Robotics exhibit a two-leveled understanding in terms of theoretical principles and activities utilizing Lean tools. The benefit of Lean Robotics exhibit that it borrows proven aspects of Lean, such as continuous improvement (kaizen), waste removal and the centralization of humans. The challenges of Lean Robotics indicate that it might be perceived negatively, due to the terms robot or robotics. These terms have been discussed to affect people who are culturally different and afraid of the unknown. Other challenges of Lean Robotics might also be that people perceive it as highly costly to apply in an organization.

Future work will be concentrated on the inclusion of security and safety aspects in Lean Robotics.

Acknowledgements

This research was partially funded by "User-centered Security Framework for Social Robots in Public Space", project code 321324, funded by Norwegian Research Council.

References

1. Chiarini, A.: Chiarini, A. (2012). Lean Organization: from the Tools of the Toyota Production System to Lean Office: From the Tools of the Toyota Production System to Lean Office (Vol. 3). Springer. Springer; 2013th edition. 3, 180 (2012).

2. Lawal, O.R., Elegunde, A.F.: Lean Management: A Review of Literature. EAI. 26, 25–33 (2020). https://doi.org/10.35219/eai15840409102.
3. R. Jadhav, J., S. Mantha, S., B. Rane, S.: Exploring barriers in lean implementation. International Journal of Lean Six Sigma. 5, 122–148 (2014). https://doi.org/10.1108/IJLSS-12-2012-0014.
4. Čiarnienė, R., Vienažindienė, M.: Lean Manufacturing Implementation: The main challenges and barriers. Management Theory and Studies for Rural Business and Infrastructure Development. 35, 43–49 (2013).
5. Pettersen, J.: Defining lean production: some conceptual and practical issues. The TQM Journal. 21, 127–142 (2009). https://doi.org/10.1108/17542730910938137.
6. Drew, J., McCallum, B., Roggenhofer, S.: Journey to lean: making operational change stick. Palgrave Macmillan, Houndmills, Basingstoke, Hampshire ; New York (2004).
7. Bhamu, J., Singh Sangwan, K.: Lean Manufacturing: literature review and research issues. International Journal of Operations & Production Management. 34, 876–940 (2014). https://doi.org/10.1108/IJOPM-08-2012-0315.
8. Bell, S., Orzen, M.A.: Lean IT: Enabling and Sustaining Your Lean Transformation. Productivity Press; 1st edition, NY 10016 (2010).
9. Bortolini, R.F., Nogueira Cortimiglia, M., Danilevicz, A. de M.F., Ghezzi, A.: Lean Startup: a comprehensive historical review. MD. 59, 1765–1783 (2021). https://doi.org/10.1108/MD-07-2017-0663.
10. Liikkanen, L.A., Kilpiö, H., Svan, L., Hiltunen, M.: Lean UX: the next generation of user-centered agile development? In: Proceedings of the 8th Nordic Conference on Human-Computer Interaction: Fun, Fast, Foundational. pp. 1095–1100. ACM, Helsinki Finland (2014). https://doi.org/10.1145/2639189.2670285.
11. Bouchard, S.: Lean Robotics: A Guide to Making Robots Work in Your Factory. Samuel Bouchard (2017).
12. Xie, M.: Fundamentals of robotics: linking perception to action. World Scientific Pub, River Edge, NJ (2003).
13. Carroll, K.: Robotics: Considerations for Practice. Nurs Sci Q. 34, 253–255 (2021). https://doi.org/10.1177/08943184211010451.
14. OUP accepted manuscript. Socio-Economic Review. (2017). https://doi.org/10.1093/ser/mwx005.
15. Romero, D., Gaiardelli, P., Powell, D., Wuest, T., Thürer, M.: Rethinking Jidoka Systems under Automation & Learning Perspectives in the Digital Lean Manufacturing World. IFAC-PapersOnLine. 52, 899–903 (2019). https://doi.org/10.1016/j.ifacol.2019.11.309.
16. Garousi, V., Felderer, M., Mäntylä, M.V.: Guidelines for including grey literature and conducting multivocal literature reviews in software engineering. Information and Software Technology. 106, 101–121 (2019). https://doi.org/10.1016/j.infsof.2018.09.006.
17. Google Search - Discover How Google Search Works, https://www.google.com/search/howsearchworks/, last accessed 2022/04/19.

18. Lewandowski, D.: The retrieval effectiveness of web search engines: considering results descriptions. Journal of Documentation. 64, 915–937 (2008). https://doi.org/10.1108/00220410810912451.
19. Definitions.net: Robotization, https://www.definitions.net/definition/Robotization, last accessed 2022/04/19.
20. Definitions.net: Lean, https://www.definitions.net/definition/lean, last accessed 2022/04/19.
21. Definitions.net: Machine, https://www.definitions.net/definition/machine, last accessed 2022/04/19.
22. Almeida Marodin, G., Saurin, T.A.: Managing barriers to lean production implementation: context matters. International Journal of Production Research. 53, 3947–3962 (2015). https://doi.org/10.1080/00207543.2014.980454.
23. Definitions.net: Inclusion, https://www.definitions.net/definition/inclusion, last accessed 2022/04/19.
24. Will Automation Help Improve Lean Manufacturing, https://lean-manufacturing-junction.com/2019/11/will-automation-help-improve-lean-manufacturing/, last accessed 2022/04/17.
25. Get Started With Your Collaborative Robot Project - The Right Way!, https://olympus-controls.com/2021/08/19/get-started-with-your-collaborative-robot-project-the-right-way/, last accessed 2022/04/17.
26. How Can Manufacturers Benefit From Lean Robotics?, https://lean-manufacturing-junction.com/2021/11/how-can-manufacturers-benefit-from-lean-robotics/, last accessed 2022/04/17.
27. RBR Staff: Cobots, Lean Robotics Will Help Automation Ease of Use, Says Robotiq CEO, https://www.roboticsbusinessreview.com/manufacturing/cobots-lean-robotics-help-with-ease-of-use-says-robotiq-ceo/, last accessed 2022/04/17.
28. Medium.com: A Lean Robotics Approach To Maximizing Automation Output, https://augmentus.tech/a-lean-robotics-approach-to-maximizing-automation-output/, last accessed 2022/04/17.
29. What Can 80 Engineers Do with 40 Robots in 24 Hours?, https://www.engineering.com/story/what-can-80-engineers-do-with-40-robots-in-24-hours, last accessed 2022/04/17.
30. “Lean Robotics” Method Empowers Manufacturers To Deploy Robots Faster Than Ever, https://www.manufacturing.net/operations/press-release/13195377/lean-robotics-method-empowers-manufacturers-to-deploy-robots-faster-than-ever, last accessed 2022/04/17.
31. Hedelind, M., Hellström, E.: Programming of reconfigurable robotic working cells programming. IFAC Proceedings Volumes. 40, 277–282 (2007). https://doi.org/10.3182/20070927-4-RO-3905.00047.
32. Hedelind, M., Jackson, M.: Industrial Robotics in the Lean Enterprise - A Case Study. The 6th International Conference on Manufacturing Research, Brunel University, UK (2008).
33. Mikael, H., Erik, H., Mats, J.: Robotics for SME´s – Investigating a Mobile, Flexible, and Reconfigurable Robot Solution. 6.

34. How to Decide If You Should Bother With Lean Robotics, https://robotswetrust.com/how-to-decide-if-you-should-bother-with-lean-robotics/, last accessed 2022/04/17.
35. Louw, L., Deacon, Q.: Teaching Industrie 4.0 technologies in a learning factory through problem-based learning: case study of a semi-automated robotic cell design. Procedia Manufacturing. 45, 265–270 (2020). https://doi.org/10.1016/j.promfg.2020.04.105.
36. Segelod, E.: Studies in industrial renewal: coping with changing contexts. Malardalen University, Vasterås (2011).
37. Wittenberg, G.: Kaizen—The many ways of getting better. Assembly Automation. 14, 12–17 (1994). https://doi.org/10.1108/EUM0000000004213.
38. Colim, A., Morgado, R., Carneiro, P., Costa, N., Faria, C., Sousa, N., Rocha, L.A., Arezes, P.: Lean Manufacturing and Ergonomics Integration: Defining Productivity and Wellbeing Indicators in a Human–Robot Workstation. Sustainability. 13, 1931 (2021). https://doi.org/10.3390/su13041931.
39. Malik, A.A., Bilberg, A.: Framework to Implement Collaborative Robots In Manual Assembly: A Lean Automation Approach. In: Katalinic, B. (ed.) DAAAM Proceedings. pp. 1151–1160. DAAAM International Vienna (2017). https://doi.org/10.2507/28th.daaam.proceedings.160.
40. Gupta, S., Jain, S.K.: A literature review of lean manufacturing. International Journal of Management Science and Engineering Management. 8, 241–249 (2013). https://doi.org/10.1080/17509653.2013.825074.
41. Fiaidhi, J., Mohammed, S., Mohammed, S., Fiaidhi, J.: The Robotization of Extreme Automation: The Balance Between Fear and Courage. IT Prof. 20, 87–93 (2018). https://doi.org/10.1109/MITP.2018.2876979.
42. Hollingum, J.: ABB focus on “lean robotization.” Industrial Robot: An International Journal. 21, 15–16 (1994). https://doi.org/10.1108/01439919410068140.