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Industry 4.0 and Industry 5.0 from the Lean Perspective

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Purpose: Despite the significant attention that Industry 4.0 (I4.0) has gained in the last decade, little importance has been given to shop-floor workers' role in effectively implementing these new technologies in production systems. Nowadays, several authors discuss the need to bring workers back to the centre of the decision-making about implementing the latest technologies in what is being called Industry 5.0 (I5.0). A key factor of using these new concepts is that they must make sense, and the new information generated by these technologies must have a precise use; otherwise, it will be considered waste. The Lean approach is already the best approach to identifying and eliminating waste from production systems. Not only that, but it allows decisions about process improvement to be human-centric. Thus, this article aims to present the main aspects and evolution of I4.0 and I5.0 over time, using the Lean approach as the analysis lenses.

Study design/methodology/approach: To identify the main aspects of I4.0 and I5.0, we develop a consistent literature review using the Systematic Search Flow (SSF).

Findings: As a result, it was possible to identify the evolution from I4.0 to I5.0; in I4.0, the main focus was on developing new technologies and combining them with classic Lean tools (e.g. Kanban 4.0, Poka-Yoke 4.0) and implement Cyber-Physical Systems. In I5.0, the focus is to use these new technologies together with shop floor workers to continuously improve production processes. Not only that, but in I5.0, the protagonist becomes (or returns to become) the shop floor workers to lead the improvements, as is in the Toyota Kata approach.

Originality/value: This work presents a new way of interpreting the progression of concepts from I4.0 to I5.0. In addition, the focus on workers for problem-solving is returning to the centre of the discussion. Together with the technologies of I4.0, this represents a new area for future research.

Keywords: Lean, Toyota Kata, Industry 4.0, Industry 5.0, Literature Review

Introduction

Industry 4.0 was labelled during the German 2011 Hannover Fair Event as the fourth industrial revolution (Kagermann et al., 2013). It can be defined as integrating machines and devices with sensors and related software to predict, control and plan better business (Martin et al., 2015). Furthermore, industry 4.0 technologies are considered a strategy to increase product quality and make manufacturing processes more efficient (Tortorella et al., 2018).

Adopting the new technologies and concepts only makes sense if the production system is already optimized and working without waste. Using Lean Production is a common practice in several industries to reduce waste. Thus, the combination between Lean and I4.0 has already been extensively discussed in the literature, especially combining new technologies with the traditional tools of the Lean approach.

The technological developments proliferate so fast that Industry 5.0 is already becoming part of the business landscape (Atwell, 2017). One of the points of view of I5.0 is "human-robot co-working". In this vision, robots and humans will work together whenever and wherever possible. Humans will focus on tasks requiring creativity, and robots will do the rest (Demir, Döven, and Sezen, 2019).

To better understand how these concepts evolve, this article aims to identify and present the main aspects and differences between Industry 4.0 and Industry 5.0 from the perspective of the Lean approach. To achieve the intended goals, we conduct a Systematic Literature Research (SLR) search of frameworks that describe the implementation process of the new digitalization technologies on production systems and how these are related to employees on the shop floor.

Literature Review

Lean first appeared in the late 1980s in a Massachusetts Institute of Technology (MIT) research project on the global auto industry. The survey revealed that Toyota had developed a new business management model in several dimensions, including manufacturing, product development, and relationships with customers and suppliers. The Lean approach appears in the manufacturing environment but started to be used in several other areas, mainly after the book publication "Lean Thinking" by Wolmak and Jones (1998). The authors defined the five fundamental principles of the Lean approach; (1) identify value, (2) map the value stream, (3) create flow, (4) establish pull, and (5) seek perfection. From identifying the value from the customer's perspective, we seek to eliminate waste so that the value flows lean. However, the lean approach is not just a set of tools. When investigating how Toyota maintains its continuous improvement standards, Rother (2009) presented an investigated approach within the company, which he called Toyota Kata. Kata has been described as a "way of doing" as a repeated pattern that develops skills and a new mindset for continuous improvement.

Industry 4.0 was introduced by Germany during the Hannover Fair Event in 2011 and symbolized the beginning of the fourth industrial revolution (Lee, 2013). Generically, Industry 4.0 includes a set of technologies based on the concepts and interactions between the Cyber-Physical System (Khaitan; Mccauley, 2015) and the Internet of Things (IoT) (Atzori et al., 2010). Resources are converted into intelligent objects to feel, act and modify their configuration within an intelligent environment (Zhong et al., 2017). The main objective of I4.0 is to meet customers' individual needs, which affects several industry areas, ranging from order management, research and development, and user experience to recycling products at their end of the life cycle (Neugebauer et al., 2016).

Industry 5.0 recognizes the power of industry to achieve societal goals beyond jobs and growth, become a resilient provider of prosperity by making production respect the boundaries of our planet, and place the well-being of the industry worker at the centre of the production process (Xu et al., 2021). This way, bringing workers back to the factory's shop floor will enable the creation of robots, in which repetitive work will be under the responsibility of the machines, and decision-making will be taken by employees.

The concepts of the Lean approach, Industry 4.0, and Industry 5.0, are increasingly being discussed together as they have several similarities and common goals. Thus, several authors discuss its main aspects. Therefore, these topics will be explored in more detail in the discussion section of this article.

Systematic Literature Research

Method

The current study's objective is to systematically analyze the available literature about Lean, Industry 4.0, and Industry 5.0 from the Lean perspective. The research question that drives this work is: How have concepts evolved from I4.0 to I5.0 in recent years, and how are these new paradigms connected to the Lean approach? To answer this question, we conducted an extensive literature review and followed the Systematic Search Flow (SSF) method from Ferenhof and Fernandes (2016), complemented by the approach for reviewing papers described by Webster and Watson (2002). We search leading journals and conference proceedings using the keywords that the online databases Scopus, Web of Knowledge, EBSCO, Engineering Village, ProQuest, and Google Scholar offer. The query string used was (("Lean" OR "Value Stream Management" OR "Toyota Kata") AND ("Industry* 4.0" OR "Industry* 5.0" OR "Smart Factory" OR "Cyber-Physical Systems")). The research was also complemented with exploratory research.

The query search was conducted on November 04, 2021. In total, 189 articles related to the research topic were found. After applying the filter criteria described by the SSF method and analyzing the articles, 36 works were fully aligned with the research topic and were examined in detail. Table 1 contains a summary of all analyzed works.

Table 1 – Summary of analyzed works

Authors (year)	Title	Journal / Event
Kolberg; Zuhlke (2015)	Lean automation enabled by Industry 4.0 Technologies	15th IFAC Symposium on Information Control Problems in Manufacturing
Sanders; Elangeswaran; Wulfsberg (2016)	Industry 4.0 implies Lean manufacturing: Research activities in industry 4.0 function as enablers for Lean manufacturing.	Journal of Industrial Engineering and Management
Tamás; Illés (2016)	Process improvement trends for manufacturing systems in industry 4.0	Academic Journal of Manufacturing Engineering
Davies; Coole; Smith (2017)	Review of socio-technical considerations to ensure successful implementation of Industry 4.0	27th International Conference on Flexible Automation and Intelligent Manufacturing
Dombrowski; Richter; Krenkel (2017)	Interdependencies of Industrie 4.0 & Lean Production Systems: A Use Cases Analysis.	Procedia Manufacturing
Kolberg; Knobloch; Zuhlke (2017)	Towards a Lean automation interface for workstations.	International Journal of Production Research
Leyh; Martin; Schaffer (2017)	Industry 4.0 and Lean Production-A matching relationship? An analysis of selected Industry 4.0 models.	Proceedings of the 2017 Federated Conference on Computer Science and Information Systems
Mrugalska; Wyrwicka (2017)	Towards Lean Production in Industry 4.0.	Procedia Engineering
Wagner; Herrmann; Thiede (2017)	Industry 4.0 Impacts on Lean Production Systems	50st CIRP Conference on Manufacturing Systems
Stehling; Schmiedinger; Kohlegger (2017)	Why Robots do not matter! Using Digital Twin and Augmented Learning for Continuous Improvement in the context of manufacturing	I-Know Conference
Bauer et al. (2018)	Integration of Industrie 4.0 in Lean Manufacturing Learning Factories	8th International CIRP Conference on Learning Factories
Hartmann et al. (2018)	Value stream method 4.0: Holistic method to analyze and design value streams in the digital age.	6th CIRP Global Web Conference
Lugert; Völker; Winkler (2018)	Dynamization of Value Stream Management by technical and managerial approach.	51st CIRP Conference on Manufacturing Systems

Mayr et al. (2018)	Lean 4.0-A conceptual conjunction of Lean management and Industry 4.0	Procedia CIRP
Prinz; Kreggenfeld; Kuhlenkötter (2018)	Lean meets Industrie 4.0 - A practical approach to interlink the method world and cyber-physical world	8th International CIRP Conference on Learning Factories
Sony (2018)	Industry 4.0 and Lean management: a proposed integration model and research propositions.	Production and Manufacturing Research
Wagner; Herrmann; Thiede (2018)	Identifying target-oriented Industrie 4.0 potentials in Lean automotive electronics value streams	50st CIRP Conference on Manufacturing Systems
Uriarte; Ng; Moris (2018)	Supporting the lean journey with simulation and optimization in the context of Industry 4.0	Procedia Manufacturing
Veres et al. (2018)	Industry 4.0 Implementation Model: Taking Steps Towards Digitization	Performance Management or Management Performance
Kolla; Minufekr; Plapper (2019)	Deriving essential components of lean and industry 4.0 assessment model for manufacturing SMEs	52nd CIRP Conference on Manufacturing Systems
Trebuňa; Edl; Pekarcikova (2019)	Digital Value Stream Mapping Using the Tecnomatix Plant Simulation Software	International Journal of Simulation Modelling
Pereira et al. (2019)	How Industry 4.0 Can Enhance Lean Practices	FME Transactions
Villalba-Diez et al. (2019)	Characterization of industry 4.0 lean management problem-solving behavioural patterns using EEG sensors and deep learning	Sensors
Özdemir; Hekim (2018)	birth of Industry 5.0: Making Sense of Big Data with Artificial Intelligence, "the Internet of Things," and Next-Generation Technology Policy	OMICS A Journal of Integrative Biology
Pathak et al. (2019)	Fifth Revolution: Applied AI & Human Intelligence with Cyber-Physical Systems	International Journal of Engineering and Advanced Technology
Demir; Döven; Sezen (2019)	Industry 5.0 and Human-Robot Co-working	Procedia Computer Science
Mihardjo et al. (2019)	Boosting the Firm Transformation in Industry 5.0: Experience-Agility Innovation Model	International Journal of Recent Technology and Engineering
Welfare et al. (2019)	Consider the Human Work Experience When Integrating Robotics in the Workplace	4th ACM/IEEE International Conference on Human-Robot Interaction
Nahavandi (2019)	Industry 5.0—A Human-Centric Solution	Sustainability
Doyle-Kent; Kopacek (2019)	Industry 5.0: Is the Manufacturing Industry on the Cusp of a New Revolution?	Proceedings of the International Symposium for Production Research
Paschek; Mocan; Draghici (2019)	Industry 5.0 – The expected impact on the next industrial revolution	Thriving on Future Education, Industry, Business and Society and TIIM International Conference
Longo; Padovano; Umbrello (2020)	Value-Oriented and Ethical Technology Engineering in Industry 5.0: A Human-Centric Perspective for the Design of the Factory of the Future	Applied Sciences
Aslam et al. (2020)	Innovation in the Era of IoT and Industry 5.0: Absolute Innovation Management (AIM) Framework	Information
Bednar; Welch (2020)	Socio-Technical Perspectives on Smart Working: Creating Meaningful and Sustainable Systems	Inf Syst Front

Xu et al. (2021)	Industry 4.0 and Industry 5.0—Inception, conception, and perception	Journal of Manufacturing Systems
Chin (2021)	Influence of Emotional Intelligence on the Workforce for Industry 5.0	Journal of Human Resources Management Research

Discussion

When analyzing the studies referring to Industry 4.0, Industry 5.0, and the Lean approach, it was possible to verify how these concepts have been worked on in theory and practice. Several aspects could be observed in the integration between the concepts, the continuous improvement of processes, I4.0, and the rise of I5.0. Such aspects will be discussed in sequence.

From the article's analysis, it is evident that I4.0 contributes to an organization's activities, focusing on optimizing and improving the efficiency of processes. Furthermore, industry 4.0 aims to acquire and present data and information about the production environment to assist employees' decision-making. The motivation to integrate the technologies of I4.0 with the Lean approach is diverse, but it can be summed up by Bauer et al. (2018, p149), which states that "the automation of inefficient processes will continue to make the process inefficient". Thus, integrating sensors and Cyber-Physical Systems into a production system with no complete knowledge of its value flows can make the process even more confusing. Similarly, Hartmann et al. (2018) say that the new data generated through the new technologies must have a defined utility. Otherwise, it can be considered waste.

Dombrowski et al. (2017), Prinz, Kreggenfeld, and Kuhlenkötter (2018), and Wagner, Herrmann, and Thiede (2018), suggest a progressive order in which the Lean approach is first implemented and is responsible for optimizing and organizing the manufacturing environment. Then, after quite an optimization, I4.0 can be used to connect and digitalize the processes. On the other hand, Mayr (2018) states that the Lean and I4.0 approaches can iteratively influence each other. Thus, the progress does not have to be purely sequential. Kolberg and Zuhlke (2015), Kolberg, Knobloch, and Zuhlke (2017), and Wagner, Herrmann, and Thiede (2018) carried out case studies to analyze the effects of using the two approaches together. The main benefits found were: real-time worker communication at the workstation and the Cyber-Physical Systems, real-time error recognition, and the consequent elimination of waste from processes.

Of the studies analyzed, eight discussed using the Value Stream Mapping approach in conjunction with I4.0. For Davies, Coole, and Smith (2017), Tamás and Illés (2016), and Kolla, Minufekr, and Plapper (2019), the use of sensors on the shop floor generates performance data and metrics transmitted in real-time Cyber-Physical Systems. This information can be combined with the VSM approach and used to optimize the production systems. Sony (2018), Hartmann et al. (2018), Lugert, Völker, and Winkler (2018) also presented the use of the VSM in conjunction with the technologies of I4.0. According to the authors, its use allows a comprehensive visualization of socio-technical systems, including technologies, organizations, and people. Considering that the new technologies implementation of I4.0 can be expensive, Trebuňa, Edl, and Pekarcikova (2019) carried out a case study in which the information was collected manually in the value stream, analyzed, and then digitalized. The authors argue that it is possible to make significant gains when performing the data feed manually, but the real gain is combining the VSM with sensors that collect data from the production process in real-time.

Excessive automation may not be beneficial in the continuous improvement process since, currently, machines and equipment cannot suggest improvements independently. As shown by Bauer et al. (2018), in 2004, Toyota announced that it would replace robots with people since the lack of understanding of the processes makes continuous improvement no longer exist.

Likewise, authors like Davies, Coole, and Smith (2017) state that workers at the operational level will no longer be passive agents but elevated to "intelligent workers". Thus, they will suggest improvements much more effectively from the use of data in real-time, transmitted by sensors and Cyber-Physical Systems. Kolberg and Zuhlke (2015), Leyh, Martin, and Schaffer (2017) highlight that the human factor must be better described in the existing models for integrating the two approaches since employees will continue to participate in processes on the shop floor actively. A point to highlight is that few authors discuss the sustainability of the improvements made. Most of the articles presented application cases that last only a few months, and it is impossible to monitor changes for a more extended period. Little research also focuses on changing employee behaviours to create a continuous improvement routine.

Regarding the Toyota Kata approach, Stehling, Schmiedinger, and Kohlegger (2017) developed a model that uses the Digital Twin concept to support employees in the workplace. The Toyota Kata approach was aligned with some of the proposed model's elements and used to characterize the Current Condition, the Target Condition and list the organization's Obstacles. However, the authors did not discuss the use of the approach as a continuous improvement routine so that the workers are continually looking for a system with better conditions based on the application of the scientific method for solving problems. Tamás and Illés (2016) also presented the Toyota kata approach as a possibility for the continuous improvement of processes. Although the work presents the concepts of I4.0, the connection between the Toyota Kata approach and I4.0 has not been made. According to Uriarte, Ng, Moris (2018), the Toyota Kata approach can benefit from using the I4.0 technologies since the Current Condition, and Target Condition characterization can be performed more efficiently and quickly using the new technologies. Besides, process improvement can be simulated in the Cyber-Physical Systems before being implemented in the existing production system, optimizing the Coaching Kata's performance.

Among the articles analyzed, the model developed by Veres et al. (2018) is the most concise concerning the Toyota Kaya approach's fundamental concepts. The authors developed a model for implementing I4.0 by combining the Kaizen events with the Toyota Kata approach. In addition, a bibliographic review was carried out to identify the main steps that should be taken toward I4.0. However, the Toyota Kata approach is only used to introduce the concepts of continuous improvement through the PDCA cycles, and the authors did not define the implementation of I4.0 technologies as the organization's challenge. Also, the Value Stream Mapping tool was not discussed to characterize how the production system behaves and the possibility of simulating optimized future states when combined with I4.0 technologies. Finally, the study does not present a case study demonstrating the Toyota Kata approach's behaviour when implementing the I4.0 Technologies.

We are at a watershed in smart working progress, in which we contemplate moving forward into a digital age from I4.0 to I5.0 (Bednar and Welch, 2020). While I4.0 has been concerned with creating smart factories' through the application of robotics and virtualization in production systems, I5.0 is more concerned with synergistic relationships between such systems and people, including socio-democratic and ethical considerations (Özdemir and Hekim 2018). In this sense, I4.0 creates the foundation for the Smart Factory, and I5.0 is the era of a 'Social Smart Factory', where every single cooperative building block of a Cyber-Physical Production Systems will be able to communicate with the human component through enterprise social network (Longo, Padovano and Umbrello, 2020). McDonnell (2018) sets out a vision for an I5.0 manufacturing environment in which humans and AI artefacts interact continuously to manage processes effectively. She highlights how digital assistants (similar to the now-familiar Amazon Alexa) will support monitoring and managing complex systems in dialogue with human managers, using AI to give expert advice to optimize production.

Similarly, Nahavandi (2019) states that by bringing back human workers to the factory floors, the Fifth Industrial Revolution will pair humans and machines to utilize human brainpower and creativity to increase process efficiency by combining workflows with intelligent systems. Thus, while the primary concern in I4.0 is automation, I5.0 will be a synergy between humans and autonomous machines. In the same way, for Chin (2021), I5.0 will bend back towards serving humanity. At workplaces, this industrial revolution will shed more excellent light on human intelligence than ever.

The structures of industries and markets have been transformed, and new products (goods and services), which never before contemplated, have come into being. This industrial transformation wave has enabled mass customization of products so that a customer's exact personal requirements for a product can be met at little or no additional cost to the producer (Bednar and Welch, 2020). In this sense, I5.0 provides customers with more customized products and services than ever before, which can only be possible with the increased engagement of humans in designing products and services (Ozkeser, 2018). According to Atwel, C. (2017), more and more manufacturers are increasing the human component to customize products and increase efficiency on the production line. One example is Toronto's Paradigm Electronics, which manufactures high-end loudspeakers. The company uses Universal Robots' UR10 robotic arm to polish the speaker cabs to a high-lustre sheen, but it takes considerable time to do so. By adding a human counterpart, however, it increased its production efficiency by 50%. This is not to say robots will eventually be phased out of the production cycle. On the contrary: I5.0 will enhance machine and human roles in the manufacturing industry, leaving the monotonous, repetitive tasks to the mechanical and opening up the creative side to the biological. It is a natural evolution within the intelligent manufacturing industry, and robotics producers have already developed collaborative robots that are safe to use around human workers to prevent injuries in the workplace.

A contradiction arises in the Lean approach's context and its combination with I4.0 and I5.0. Let us consider organizations that already work with the Lean approach and have thought of continuous improvement. It should be natural that the search for more efficient processes would incorporate these new concepts with human-centred problem solving into the production environment. Thus, SLR identified that one of the items that harm the implementation of these new technologies is the lack of knowledge about fundamental concepts of the Lean approach, such as scientific thinking to solve problems and the focus on continuous improvement with the participation of employees to guarantee the sustainability of these improvements over time.

Table 2 presents the articles analyzed on the SLR and the relationships of I4.0, I5.0, and the Lean approach.

Table 2 – Evolution of concepts from I4.0 to I5.0 with the Lean perspective.

		Concepts									
Authors		VSM	Toyota Kata	CPS	IoT (sensors)	Problem-solving strategies	Smart Workers	Human-centred	Human-Robot collaboration	Personalization of products	Value-oriented
Industry 4.0	Kolberg; Zuhlke (2015)			●	●						
	Sanders; Elangeswaran; Wulfsberg (2016)				●						
	Tamás; Illés (2016)	●	●	●	●						
	Davies; Coole; Smith (2017)	●		●			●				

	Dombrowski; Richter; Krenkel (2017)			●	●						
	Kolberg; Knobloch; Zuhlke (2017)			●	●						
	Leyh; Martin; Schaffer (2017)			●	●						
	Mrugalska; Wyrwicka (2017)			●	●						
	Wagner; Herrmann; Thiede (2017)			●							
	Stehling; Schmiedinger; Kohlegger (2017)		●	●	●	●	●				
	Bauer et al. (2018)							●			
	Hartmann et al. (2018)	●		●	●						
	Lugert; Völker; Winkler (2018)	●						●			
	Mayr et al. (2018)			●	●						
	Prinz; Kreggenfeld; Kuhlenkötter (2018)			●	●	●					
	Sony (2018)	●		●							
	Wagner; Herrmann; Thiede (2018)	●		●							
	Uriarte; Ng; Moris (2018)		●	●	●						
	Veres et al. (2018)		●	●	●	●					
	Kolla; Minufekr; Plapper (2019)	●			●						
	Trebuňa; Edl; Pekarcikova (2019)	●		●							
	Pereira et al. (2019)			●	●		●		●		
	Villalba-Diez et al. (2019)		●			●					
Industry 5.0	Özdemir; Hekim (2018)			●	●				●		
	Pathak et al. (2019)			●			●	●	●	●	
	Demir; Döven; Sezen (2019)						●	●	●		
	Mihardjo et al. (2019)							●		●	
	Welfare et al. (2019)					●	●	●	●		
	Nahavandi (2019)							●	●		
	Doyle-Kent; Kopacek (2019)					●		●		●	●
	Paschek; Mocan; Draghici (2019)							●		●	
	Longo; Padovano; Umbrello (2020)						●	●			
	Aslam et al. (2020)					●		●			
	Bednar; Welch (2020)							●	●	●	
	Xu et al. (2021)							●		●	●
	Chin (2021)							●			

As it can be seen, it is evident that in the last six years, the discussion of these new concepts migrated from using Cyber-Physical Systems and IoT to human-centred production with competent workers, human-robot collaboration, and the personalization of products. Xu et al. (2021) summarize the differences between I4.0 and I5.0 with the following statement "Industry 4.0 is considered technology-oriented, while Industry 5.0 is value-oriented". Also, it can be noted that using the VSM and Toyota Kata approach is not being discussed on the I5.0 frameworks. Wich presents an excellent opportunity to be explored in future work.

Conclusion and areas for future research

This article aimed to identify and present the main aspects and differences between Industry 4.0 and Industry 5.0 from the perspective of the Lean approach through an SLR. From the results, it became evident that new technologies are evolving faster and faster. Still, there is no reason to believe this will change in the coming years, especially considering that the costs of new technologies are decreasing, and the resources are becoming more affordable.

In the last ten years, the concept of I4.0 has been essential to make it possible to develop these new technologies, such as CPS, IoT, smart factories, etc. However, organizations need to be aware that new data generated by sensors must have a destination. Otherwise, it can be classified as waste and should be eliminated. Wich is one of the many reasons for integrating the concepts of I4.0 with the Lean approach, as described by several authors.

Over time, it was possible to realize that continuous improvement is only possible with the active participation of employees. In this way, I4.0 technologies can be used to interconnect processes while I5.0 brings employees back to the centre of the discussion. In addition, the Lean approach should serve as a basis for reducing waste and use the scientific thinking decoded by the Toyota Kata approach to achieve process improvement. Thus, there is no reason to suspect that one paradigm replaces the other but that they have common goals and not only can but should be used together. In doing so, companies will ensure that process improvement will come from the people who actively participate in the production process, i.e., shop floor workers.

We highlight that there are still gaps to be filled, such as using VSM in conjunction with I4.0 technologies, I5.0 concepts and the Toyota Kata approach to implementing improvements in production processes with the use of scientific thinking by employees. It is expected that the Toyota Kata approach centralizes decision-making on employees to have the autonomy to suggest the improvements that best suit the process. Thus, optimizing production processes and continuous improvement will be guided by employees, who will be able to use robots or other technologies to help their routine.

Companies that will use the concepts of I5.0 must be aware that changes do not happen overnight. The centralization of decisions among shop floor workers is an important step to be taken, but they must be assisted by managers, who will monitor and participate in the implementation of improvements. Finally, it must be clear that the data generated using new technologies must have a clear use, otherwise, they will be considered waste.

References

Aslam, F.; Aimin, W.; Li, M.; Ur Rehman, K. (2020). Innovation in the Era of IoT and Industry 5.0: Absolute Innovation Management (AIM) Framework. *Information, 11*, 124. https://doi.org/10.3390/info11020124

Atwell, C. (2017). Yes, Industry 5.0 is already on the horizon. *Machine Design*, Retrieved from https://search.proquest.com/trade-journals/yes-industry-5-0-is-already-on-horizon/docview/1938056866/se-2?accountid=26642 (accessed on November 04, 2021)

Atzori, L.; Iera, A.; Morabito, G.; (2010). The internet of things: a survey. *Computer Networks, 54*, 2787-2805.

Bauer, H.; Brandl, F.; Lock, C.; Reinhart, G. (2018). Integration of Industrie 4.0 in Lean Manufacturing Learning *Factories. 8th International CIRP Conference on Learning Factories, 23*, 147-152.

Bednar, P.M., Welch, C. Socio-Technical Perspectives on Smart Working: Creating Meaningful and Sustainable Systems. (2020). *Inf Syst Front 22*, 281–298. https://doi.org/10.1007/s10796-019-09921-1

Chin, S. T. S. (2021) "Influence of Emotional Intelligence on the Workforce for Industry 5.0". *Journal of Human Resources Management Research*. DOI: 10.5171/2021.882278

Davies, R.; Coole, T.; Smith, A. (2017). Review of socio-technical considerations to ensure successful implementation of Industry 4.0. *27th International Conference on Flexible Automation and Intelligent Manufacturing*, *11,* 1288-1296.

Demir, K. A.; Döven, G.; Sezen, B. (2019). Industry 5.0 and Human-Robot Co-working. *Procedia Computer* Science, 158, 688-695.

Dombrowski, U; Richter, T.; Krenkel, P. (2017). Interdependencies of Industrie 4.0 & Lean Production Systems: A Use Cases Analysis. *Procedia Manufacturing. Procedia Manufacturing, 11*, 1061–1068.

Doyle-Kent, M. Kopacek, P. (2020). Industry 5.0: Is the Manufacturing Industry on the Cusp of a New Revolution? *Proceedings of the International Symposium for Production Research 2019, 1,* 432 – 441.

Ferenhof, H. A.; Fernandes, R. F. (2016). Desmistificando a revisão de literatura como base para redação científica: Método SSF. *Revista ACB, 21*(3).

Hartmann, L.; Meudt, T.; Seifermann, S.; Metternich, J. (2018). Value stream method 4.0: Holistic method to analyse and design value streams in the digital age. *6th CIRP Global Web Conference*, 78, 249-254.

Khaitan, S. K.; Mccauley, J. D.; (2015). Cyber-Physical Systems Approach to Smart Electric Power Grid. *Springer-Verlag Berlin Heidelberg.*

Kagermann, H.; Helbig, J.; Hellinger, A.; Wahlster, W. (2013). Recommendations for implementing the strategic initiative INDUSTRIE 4.0: securing the future of German manufacturing industry. Final Report of the Industrie 4.0 Working Group. Forschungsunion.

Kolla, S.; Minufekr, M.; Plapper, P. (2019). Deriving essential components of lean and industry 4.0 assessment model for manufacturing SMEs. *52nd CIRP Conference on Manufacturing Systems, 81,* 753 – 758.

Kolberg, D.; Zuhlke, D. (2015). Lean Automation enabled by Industry 4.0 Technologies. *15th IFAC Symposium on Information Control Problems in Manufacturing, 28*, 1870-1875.

Kolberg, D.; Knobloch, J.; Zuhlke, D. (2017). Towards a Lean automation interface for workstations. *International Journal of Production Research, 55*, 2845-2856.

Lee, J. (2013). Industry 4.0 in Big Data Environment. *German Harting Magazine*, 8-10.

Leyh, C.; Martin, S.; Schaffer, T.; (2017). Industry 4.0 and Lean Production-A matching relationship? An analysis of selected Industry 4.0 models. *Proceedings of the 2017 Federated Conference on Computer Science and Information Systems,* 989-993..

Longo, F.; Padovano, A.; Umbrello, S. (2020). Value-Oriented and Ethical Technology Engineering in Industry 5.0: A Human-Centric Perspective for the Design of the Factory of the Future. *Appl. Sc, 10*, 4182.

Lugert, A.; Völker, K.; Winkler, H. (2018). Dynamization of Value Stream Management by technical and managerial approach. *51st CIRP Conference on Manufacturing Systems, 72*, 701-706.

Martin, R.; Lin, S.W.; Miller, B.; Durand, J.; Joshi, R.; Didier, P.; Chigani, A.; Torenbeek, R.; Duggal, D.; Bleakley, G.; et al. (2015). Industrial Internet Reference Architecture Technical Report; *Technical Report; Industrial Internet Consortium: Boston, MA, USA*. doi:10.13140/RG.2.2.18076.90249

Mayr, A.; Weigelt, M.; Kühl, A.; Grimm, S.; Erll, A.; Potzel, M.; Franke, J. (2018). Lean 4.0-A conceptual conjunction of Lean management and Industry 4.0. *Procedia CIRP, 72*, 622-628.

Mihardjo, L. W.; Sasmoko, S.; Alamsjah, F.; Djap, E. (2019). Boosting the Firm Transformation in Industry 5.0: Experience-Agility Innovation Model. *International Journal of Recent Technology and Engineering*, *8*(2S9).

Mrugalska, B; Wyrwicka, K. (2017). Towards Lean Production in Industry 4.0. *Procedia Engineering, 182*, 466–473.

Nahavandi, S. (2019). Industry 5.0—A Human-Centric Solution. *Sustainability, 11*, 4371

Neugebauer, R.; Hippmann, S.; Leis, M.; Landherr, M. (2016). Industrie 4.0 - Form the perspective of applied research, *49th CIRP conference on manufacturing systems*.

Özdemir, V.; Hekim, N. (2018). Birth of Industry 5.0: Making Sense of Big Data with Artificial Intelligence, "the Internet of Things" and Next-Generation Technology Policy. *OMICS A Journal of Integrative Biology, 22*, 65 – 76. http://doi.org/10.1089/omi.2017.0194

Paschek, D.; Mocan, A.; Draghici, A.; (2019). "Industry 5.0 – The Expected Impact Of Next Industrial Revolution," *Thriving on Future Education, Industry, Business and Society; Proceedings of the MakeLearn and TIIM International Conference.*

Pathak, P.; Pal, P. R.; Shrivastava, M.; Ora, P. (2019). Fifth Revolution: Applied AI & Human Intelligence with Cyber-Physical Systems. *International Journal of Engineering and Advanced Technology, 8*, 23 – 27.

Pereira, A. C.; Carvalho, J. D.; Alves, A. C.; Arezes, P. (2019). How Industry 4.0 Can Enhance Lean Practices. *FME Transactions, 47*, 810 – 822.

Prinz, C.; Kreggenfeld, N.; Kuhlenkötter, B. (2018). Lean meets Industrie 4.0 - A practical approach to interlink the method world and cyber-physical world. *8th International CIRP Conference on Learning Factories, 23*, 21-23.

Rother M. (2009), "Toyota Kata: Managing People for Improvement, Adaptiveness and Superior Results", New York: McGraw-Hill

Sanders, A.; Elangeswaran, C.; Wulfsberg, J.; (2016). Industry 4.0 implies Lean manufacturing: Research activities in industry 4.0 function as enablers for Lean manufacturing. *Journal of Industrial Engineering and Management, 9*, 811-833.

Sony, M. (2018). Industry 4.0 and Lean management: a proposed integration model and research propositions. *Production and Manufacturing Research, 6*, 416-432.
Stehling, M.; Schmiedinger, T.; Kohlegger, M. (2017). Why Robots do not matter! Using Digital Twin and Augmented Learning for Continuous Improvement in the context of manufacturing. *I-Know Conference*.
Tamás, P.; Iilés, B. (2016). Process improvement trends for manufacturing systems in Industry 4.0. *Academic Journal of Manufacturing Engineering, 14*, 119 – 125.
Trebuňa, P.; Edl, M.; Pekarcikova, M. (2019). Digital Value Stream Mapping Using the Tecnomatix Plant Simulation Software. *International Journal of Simulation Modelling, 18*, 19 – 32.
Tortorella, G. L.; Fetterman, D. Giglio R.; Borges, G. A.; (2017). Implementation of industry 4.0 and Lean production in Brazilian manufacturing companies. *International Journal of Production Research, 1-13*.
Uriarte, A.; Ng, A.; Moris, M. U. (2018). Supporting the lean journey with simulation and optimization in the context of Industry 4.0. *Procedia Manufacturing, 25*, 586 – 593.
Veres, C.; Marian, L.; Moica, S.; Al-Akel, K.; Hosu, D. Industry 4.0 (2018). Implementation Model: Taking Steps Towards Digitization. *Performance Management or Management Performance, 503 – 510*.
Villalba-Diez, J.; Zheng, X.; Schmidt, D.; Molina, M. (2019). Characterization of industry 4.0 lean management problem-solving behavioral patterns using EEG sensors and deep learning. *Sensors, 19*.
Xu, X.; Lu, Y.; Vogel-Heuser, B.; Wang, L. (2021). Industry 4.0 and Industry 5.0—Inception, conception and perception. *Journal of Manufacturing Systems, 61*, 530-535. https://doi.org/10.1016/j.jmsy.2021.10.006.
Welfare, K. S.; Hallowell, M. R.; Shah, J. A.; Riek, L. D.; (2019). "Consider the Human Work Experience When Integrating Robotics in the Workplace," *14th ACM/IEEE International Conference on Human-Robot Interaction (HRI)*, 75-84, doi: 10.1109/HRI.2019.8673139.
Wagner, T.; Herrmann, C.; Thiede, S. (2017). Industry 4.0 Impacts on Lean Production Systems. *50th CIRP Conference on Manufacturing Systems, 63*, 125-131.
Wagner, T.; Herrmann, C.; Thiede, S. (2018). Identifying target-oriented Industrie 4.0 potentials in Lean automotive electronics value streams. *51st CIRP Conference on Manufacturing Systems, 72*, 1003-1008.
Webster, J. And Watson, Rt (2002), "Analyzing the past to prepare for the future: writing a literature review", *MIS Quarterly, 26*(2), 13-23.
Womack, J. P.; Jones, D. T. (1996). Lean thinking: banish waste and create wealth in your corporation. *New York, NY: Simon & Schuster*.
Zhong, R. Y.; Xu, X.; Klotz, E.; Newman, S. T.; (2017). Intelligent Manufacturing in the Context of Industry 4.0: A Review. *Engineering, 3*, 616-630.