Acta Montanistica Slovaca
ISSN 1335-1788
actamont.tuke.sk

An empirical study about the relationship between lean management and industry 4.0

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How to cite this article:
Oláh, J., Sztrapkovics, B., Puskás, E. and Martins, V. (2022). An empirical study about the relationship between lean management and industry 4.0. *Acta Montanistica Slovaca*, Volume 27 (4), 916-928

DOI:
https://doi.org/10.46544/AMS.v27i4.07

Abstract
Lean Management and its tools have been widely used for years. Lean Management aims at streamlining the flow of value while continually seeking to reduce the resources required to produce a given set of products. Although the adoption of Lean is not a new concept, few organizations fully understand the philosophy behind its practices and principles. The relationship between Industry 4.0 and Lean Management has been increasingly evidenced in operations management research. To create a better understanding, the main point of interest for this work is to investigate the link and integration between Industry 4.0 and Lean Management, as well as examine its implications on performance and the environmental factors influencing these relationships in some companies especially focusing on the mining industry. Based on the literature review, a questionnaire was created about Lean Management and Industry 4.0, which was applied in some companies in Brazil and Hungary, most of them from the mining industry. The aim of this paper is to evaluate the application of combining both methodologies, Lean Management and Industry 4.0. The unique contribution of the paper is to see the common areas of Lean and Industry 4.0 where there are research and knowledge, but the application level at the companies is low.

Keywords
lean management, Industry 4.0, integration, empirical study, questionnaire, mining industry

1. Introduction

Implementing automation equipment increases product quality while making manufacturing processes more efficient. This trend is especially true when considering the transformation many industries are undergoing due to Industry 4.0 (Landscheidt & Kans, 2016), (Lasi, Fettke, Feld, & Hoffmann, 2014). To improve their operations, companies have been adopting new strategies and tools. Lean Management and its tools have been widely used over the years. Lean Management aims at streamlining the flow of value while continually seeking to reduce the resources required to produce a given set of products. It was conceived as an evolutional detachment from the principles of traditional mass-production manufacturing (Neges, Koch, König, & Abramovici, 2017)

The relationship between Industry 4.0 and Lean Management has been increasingly evidenced in operations management research. Over the past few years, researchers and practitioners have started to investigate how both approaches, when implemented together within companies, can raise operational and financial performance levels to a different pattern (Kolberg & Zühlke, 2015) (Tortorella & Fettermann, 2018). In fact, in most cases, the integrated application of Lean Management and Industry 4.0 is the most effective way to achieve the next level of operational excellence. The impacts of Industry 4.0, as much as Lean Management, on productivity, cost reduction, control over the production process, and product customization point to a profound transformation in the plants. To create a better understanding, the main point of interest for this work is to investigate the link and integration between Industry 4.0 and Lean Manufacturing and examine its implications on performance and the environmental factors influencing these relationships. Therefore, the first step is to develop a conceptual framework that explains the primary constructs and their relationships. This work aims to analyze Lean Management tools and Industry 4.0 techniques used and integration through an interview with some companies in Brazil and Hungary.

The first part of this article will provide a brief description and an overview of Lean Management and Industry 4.0. The second part describes how the combination of both methodologies can be done. The following part shows the material and methods used to collect data to create this paper, and in the last part, we analyze the results and the conclusions of this work.

2. Brief literature review

2.1. Lean management – a brief description

The value of Lean Management helps manufacturers reduce operational complexity, eliminate waste and activities which add no value to the process and drive productivity improvements by empowering workers on the shop floor to make necessary and continuous improvements. Lean provides a basis for operational excellence by standardizing processes and creating a culture of continuous improvement by monitoring, proactively maintaining equipment, and empowering employees. One of the Lean Management aims is to eliminate waste. It is divided into shopfloor wastes (MUDA) into seven categories: overproduction, wait, transportation, over-processing, movement, defective products, and stocks (Liker, 2005). In addition to Muda, two more terms are often used to describe practices that generate waste in production systems (Liker, 2005). MURA refers to inconsistencies or instabilities in production, and MURI is caused by an overload of equipment or operators due to Muda and Mura (Ohno, 1988).

According to Ohno, overall, Lean is based on five principles: Value, which is from the customer's point of view; Value Stream, which Identifies which process steps add value to the product or service provided and reduce or eliminate non-adding steps; Continuous Flow that meets customer needs quickly, with less time to process orders and low inventory (produce without interruption); Pull Production that means working according to customer demand, not creating excessive stocks and Strive for perfection means seeking for continuous improvement of processes, people, products, etc., aiming always adding value to the customer (Ohno, 1988). The Lean Management methodology is a famous production management methodology globally and is widely used in other sectors (Papalexi, Bamford, & Dehe, 2016), (Villareal, Garza-Reyes, Kumar, & Lim, 2017). With a focus on continuous improvement to solve problems and eliminate waste in the production process. Lean House model contains some of the Lean tools used to increase productivity (Dhandapani, Potter, & Naim, 2004). Among the Lean tools can be found: 5S, Andon, Heijunka, Hoshin Kanri, Jidoka, JIT – Just in Time, Just in Sequence (JIS), Kaizen, Kanban, Milk Run, Mizusumashi, PDCA, Poka Yoke, Smart Goals, SMED – Single Minute Exchange of Die, Spaghetti Chart, Takt time and standard work, TPM, TQM, Value Stream Mapping (VSM) and Visual management (Dennis, 2002).

2.2 Industry 4.0: an overview

Joining digital manufacturing creates competitiveness and reduces waste. The progress of technology enables mining industries to be more efficient, agile, and reliable. According to Schmidt, Industry 4.0 is the name for intelligent tools that can make manufacturers more flexible, efficient, and profitable. Industry 4.0 emerges from the overlap of various technological developments involving products and processes (Schmidt et al., 2015).

The main goal of Industry 4.0 is to exploit the potential resulting from extensive internet use, the integration of technical processes and business processes, digital mapping, and real-world virtualization, as well as the opportunity to create intelligent products. Further, Industry 4.0 adoption may impact other key aspects of an organizational structure, such as human resources development and customer relationship management (Schumacher, Erol, & Sihn, 2016). One of the major goals of Industry 4.0 is integrating at all levels, shop floor, systems and manufacturing software, other industries, and even integration with customers and suppliers, promoting better flow information and creation of value dynamics networks. Promotes connection of terminals, cloud, industrial networks and physical resources are some of the objectives of Industry 4.0 (Liker, 2005).

Industry 4.0 creates impacts in many areas and sectors, being composed of four disruptions:

- computational power and connectivity
- the emergence of market intelligence analysis
- new forms of human-machine interaction
- and improvements in transfer from the digital to the physical world, such as robotics advanced and 3D printing

There are many academic and industrial results (Srinivasan & Prasad Ganesh, 2017). Industry 4.0 also significantly influences the production environment with changes radical in the execution of operations. In contrast to the forecast-based production planning conventional, industry 4.0 permit and planning in production plans in real time, together with the dynamic optimization (Silva, Oliveira, Silva S. F., Salgado, & Mello, 2007). There is no consensus on the main technologies elements of Industry 4.0. However, it is described all the elements of technologies that were found in the articles and papers: Advanced Robotics and 3D Printing, Augmented and virtual reality, Big data and analytics, Cloud, Cyber Security and Cyber Physical Systems (CPS), Horizontal and vertical system integration, Internet of Things (IoT), Machine learning and artificial intelligence, RFID and Simulation.

2.3 Combining industry 4.0 and lean tools

Lean Automation picks up the idea of combining automation technology with Lean Production. The term occurred in the mid-1990s, shortly after the peak of Computer Integrated Manufacturing (CIM) (Leyh, Martin, & Schäffer, 2017) (Sanders, Elangeswaran, & Wulfsberg, 2016). In Industry 4.0, new solutions are available for combining automation technology with Lean Production, which is described below. A combination of Industry 4.0 practices with Lean concepts can be said that there is an increasingly effective pursuit of improvement. Since Lean principles produce more goods with fewer costs, automation and integration of technology processes are increasingly contributing to this purpose. Industry 4.0 can be integrated into Lean Management and, beyond that, improve Lean Management by increased integration of information and communication technology. This benefit accelerates the shift of Industry 4.0 from science to reality.

Industry 4.0 and Lean Management can aid, as the technologies of Industry 4.0 can support the elimination of barriers to Lean Management implementation. The production environments that already have the culture of Lean Management are more likely to be modelled and controlled by an Industry 4.0 platform (Buer, Strandhagen, & Chan, 2018). The literature on Industry 4.0 and Lean is unclear about the direction of such a relationship. Additionally, it argues about the necessity of studying the impacts of this relationship on companies' performance and the influence of external factors on the relationship between both approaches. It is important to understand that they are different things. Industry 4.0 is a new historic step in the industrial revolution that is underway. Lean Management is a management technique that can be applied or not, regardless of whether it is a smart factory or a traditional assembly line from the 3rd industrial revolution.

As Industry 4.0 also includes sustainability concepts, efficiency and continuous productivity and quality improvement, Lean Management is likely to become even more critical. The two concepts are complementary, and although some changes occur about how to use Lean tools and adaptations are made, Industry 4.0 will give Lean Management a big boost. Although this relationship has motivated some studies and practical experimentation, much still needs to be evaluated to comprehend its extent (Leyh, Martin, & Schäffer, 2017). Based on a set of mathematical modelling tools, Lean Manufacturing helps the industry's processes to be better managed so that it is possible to see the critical points, such as excess or lack of stock, errors in transportation or the sizing of production, also that it is possible to meet the exact demands of the customer and generate maximum value. By combining the concepts of Lean Management with the practices of Industry 4.0, there is a more effective search for improvement. After all, Lean focuses on avoiding waste - doing more with less. In this sense, the integration of these processes and automation contributes to this purpose.

3. Purpose

The interview is a data collection method that allows the researcher to relate directly to the studied group. Interviews can be structured, consisting of defined questions, or semi-structured, allowing greater freedom for the researcher. It, like any database, becomes more efficient when the universe of responses obtained becomes larger

(Dencker, 2000). Thus, based on the assumption that scientific research is defined as an activity aimed at clarifying problem situations or discoveries, it is essential to define the paths and forms that will be followed in this study. Therefore, some aspects need to be considered, which concerns the nature of the applied research, the problem approach (whether quantitative or qualitative), the exploratory and explanatory and technical procedures based on the literature review and the companies' experiences.

It was a semi-structured interview, and we chose this because we could analyze the results and gather the opinions of the companies. In this interview method also, the participants had the chance to clarify the meaning of terms and tools. The main parts of the interview were the following: the first part was about the companies' data (how many employees, size, operation sectors), the second was about the Lean tools and Industry 4.0 acquaintance and usage, the third part was about the feasibility of the techniques implementation and the possibilities integration. An empirical and analytical literature review of Lean Management and Industry 4.0 tools and techniques was realized to develop a consistent work. Hence, a questionnaire was created based on these methodologies and then sent to some companies and researchers. We sent the questionnaire via e-mail to the interviewees. The aim is to select the participant companies to involve as many sectors in this questionnaire as possible, but we focused especially on the mining industry. The prominent uniqueness of this research is to include companies from Brazil and Hungary, so the differences and similarities between Lean and Industry 4.0 applications can be analyzed. The data about the interview can be seen in Table 1. Three Hungarian and seven Brazilian companies (four of them from the mining industry) participated in the interviews, which were conducted in April 2020. The questionnaires were answered by different officials from different sectors of activity, such as the mining industry, IT, communication, steel and metallurgy, oil and petroleum and wood products.

Tab. 1. Details of the interview
Source: Authors' own creation, 2022

#	Country	Participant position	Date	Interview mode
1	Brazil	Account Manager	04/April/2020	written
2	Brazil	Programmer	04/April/2020	oral
3	Brazil	CEO	05/April/2020	oral
4	Brazil	Human Resource manager	05/April/2020	oral
5	Brazil	CEO	14/April/2020	written
6	Brazil	Communication manager	15/April/2020	written
7	Brazil	General manager	17/April/2020	written
8	Hungary	Finance manager	20/April/2020	oral
9	Hungary	Operational manager	23/April/2020	written
10	Hungary	Operational manager	23/April/2020	written

This study has several limitations that call for further research and interviews. This paper is an initial attempt to examine the applications and existing practices in different countries empirically. We limited our study to specific sectors like the mining industry and to two countries. It would be interesting to examine how these tools are applied in other countries and other now not included sectors. Although we selected cases deliberately to achieve a heterogeneous sample, we cannot conclude that the findings are transferable to all firms without adjustment.

4. Results

From the applied questionnaire, it was obtained that most companies, 60% have knowledge of Lean Manufacturing and use one or more tools, some of them 30% know about it but do not use and a few companies 10% do not know what the Lean tools are. This can be explained by the fact that this methodology is already used in many industries which seek to optimize results and reduce waste.

Figure 1 shows the most known and used tools used in the interviewed companies. They are disposed of from left to right in ascending order. It can be observed that some tools are known, but they are not used, and other ones are still unknown, such as RFID and Advanced Robotics. As it can be observed, the cloud is more common, maybe due to the use of applications for storage, such as Dropbox, Google Drive and others. RFID is a surprise that none of the interviewed companies uses it. According to the major articles and papers read, it was totally unexpected because RFID and IoT are the most used Industry 4.0 tools, with Big Data as the most used one. In our opinion, it is mainly used in logistics, the mining industry and high-valued product manufacturing, and none of the participants is included in these groups. These results are based on our sample and the structured questionnaire that was applied to the companies. We are planning further analyses from other perspectives and samples to improve the conclusions and get a more comprehensive picture.

Kaizen's predominance in companies familiar with and using the tools can be observed in Figure 2 of the questions answered a. This may indicate that the standardization of production processes has gradually come to managers' attention, not only because of the quality requirements required by consumers but also through optimizing the workforce and inputs. In the sequence, 5S appears, perhaps representing an aspect that causes surprise, given that such a tool, "a priori", could be considered the most usual for application in business routine, considering its less complexity compared with other tools. It can be justified not only by the benefits it introduces but also by the likely greater acceptance by company employees. Three others are relatively highlighted (JIT, Visual Management, and Kanban), although they represent the acquaintance of a small number of companies, for example, companies from the mining industry, do not apply these tools. Others have not yet reached priority for implementation by managers.

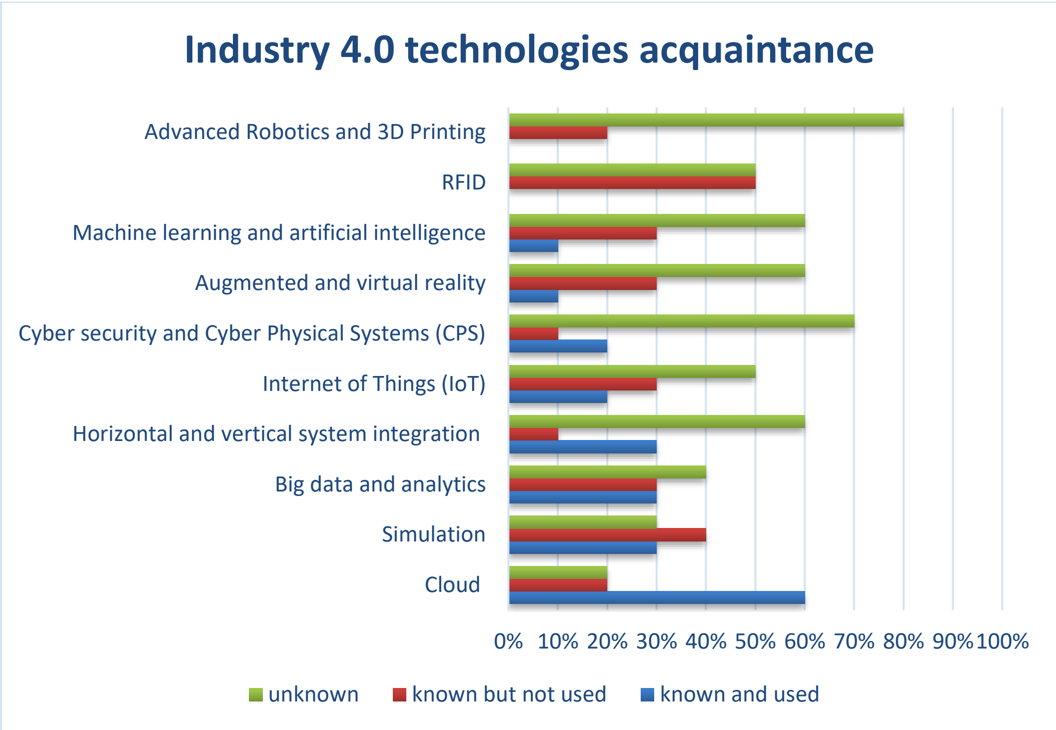

Fig. 1. Industry 4.0 techniques acquaintance
Source: Authors' own creation, based on data from the questionnaire, 2022

Among the companies that know, but do not apply, the tools, it is evident that could be a delay in such adoption due to a lack of knowledge and the unavailability of funds to invest. Besides that, most companies cannot see successful projects in lean and industry 4.0 applications; therefore, they cannot imagine the benefit of these projects. According to the interviews, the main problem of the participant was that the ROI of the Lean and Industry 4.0 investigation is currently unknown to them. While the need to implement Lean Management and Industry 4.0 is clear to many manufacturers, they are unsure how to combine both methodologies for maximum benefit. The interview showed which tools the companies have been using to integrate these two techniques. The combined tools they most use in their companies were: Big Data and Kaizen, Big Data and 5S, Simulation, and Poka-Yoke.

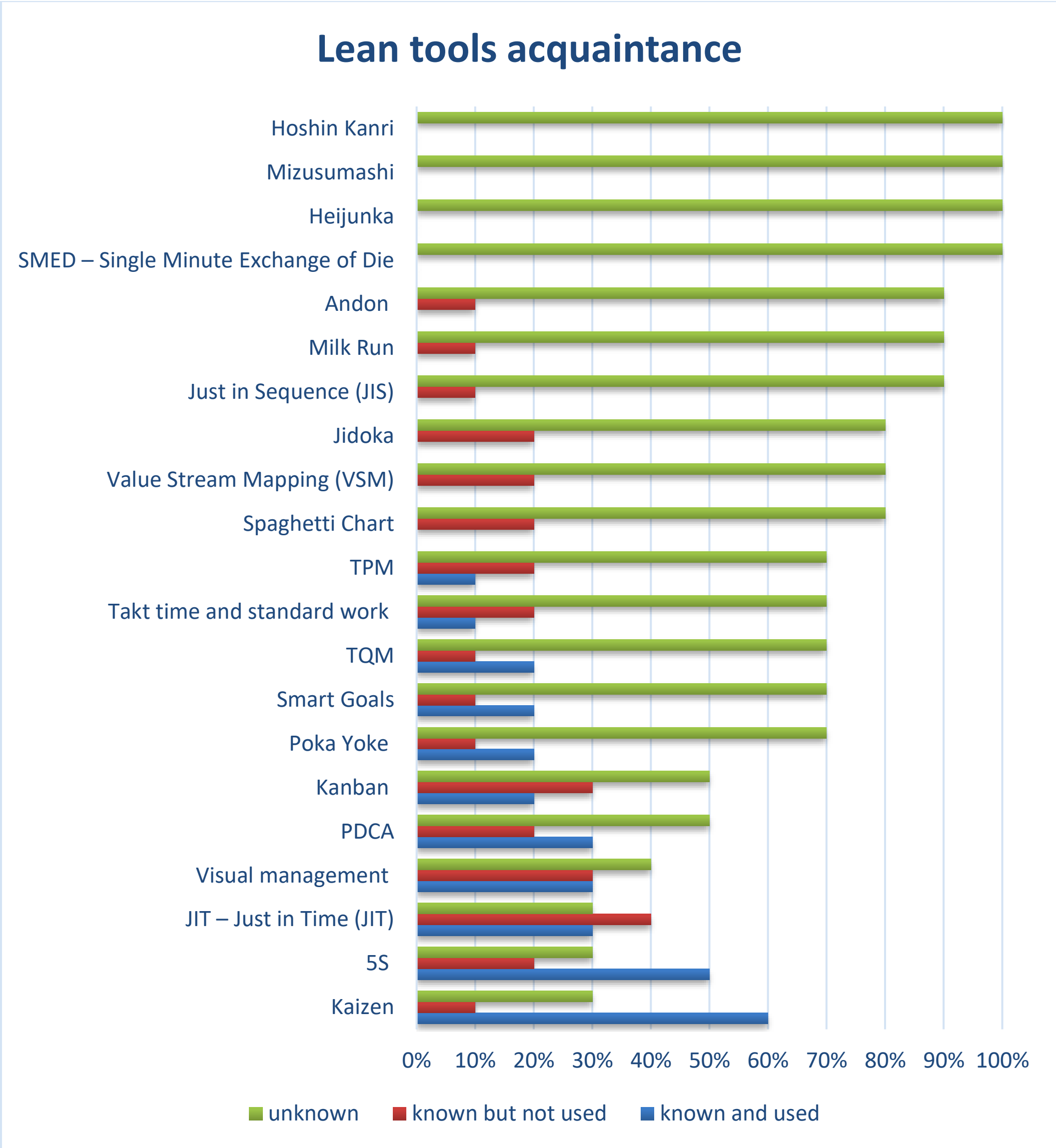

Fig. 2. Lean tools acquaintance and usage
Source: Authors' own creation, based on data from the questionnaire, 2022

As the Lean philosophy aims to eliminate all waste in the value chain - from the customer's order to the delivery of the product -the basis of Industry 4.0 is fundamental for greater efficiency throughout the production chain, with connectivity between machines and processes systems integration and data analysis. Therefore, the objective is always to increase production capacity, reduce costs, deliver high-quality products, and generate more value for the customer. This is what the union between Lean and Industry 4.0 seeks. We made a highly detailed literature review to analyze which lean tools were combined in practical application with Industry 4.0 pillars. The examined tools and pillars were based on the interview. In the past few years, academic researchers combining Industry 4.0 with lean management have been one of the most favoured topics. We found 72 different publications which introduce or analyze the combined application of the listed lean tools and industry 4.0 pillars. Table 2 in the first column contains the lean tools. In the second, we listed the industry 4.0 pillars which were linked with the tools. The last column contains the references according to the combination of the tool and pillar.

Tab. 2. Integration possibilities of the tools
Source: Authors' own creation, 2022

Tools Integration	Industry 4.0	References
Kaizen	***Big Data AI Integration Simulation***	(Varian, 2014), (Benotsmane, Dudás, & Kovács, 2018), (Sony, 2018), (Tamás & Illés, 2016), (Baril, Gascon, Miller, & Coté, 2016)
5S	***Virtual Reality***	(Wang, Wu, Chi, & Li, 2020)
JIT	***IoT Big Data Integration RFID, CPS, Simulation***	(Xu & Chen, Improving Just-in-Time Manufacturing Operations by Using Internet of Things Based Solutions, 2016), (Yao, Alkan, Ahmad, & Harrison, 2020), (Qu, Chen, Wang, Duxian, & Luo, 2015), (Xu & Chen, An Internet of Things based framework to enhance just-in-time manufacturing, 2017), (Karpathiotakis, Alagiannis, Heinis, Branco, & Ailamaki, 2015), (Wang J. , Zhang, Shi, Duan, & Liu, 2018) (Wagner, Herrmann, & Thiede, 2017) (Hofmann & Rüsch, 2017)
SMED	***Big Data RFID Integration***	(Andrew, Daming, & Dragan, 2006) (Joanna & Robert, 2010) (Mayr, Weigelt, Kühl, Grimm, & Erll, 2018)
Spaghetti Chart	***Virtual reality Simulation RFID RFID, Cloud, Big Data***	(Bortolini, Faccio, Galizia, Gamberi, & Pilati, 2020), (Michalos, Karvouniari, Dimitropoulos, Togias, & Makris, 2018) (Cantini, De Carlo, & Tucci, 2020) (Zhong, Huang, & Lan, 2015)
Visual management	***Cloud IoT***	(Steenkamp, Hagedorn-Hansen, & Oosthuizen, 2017) (Murata, 2019)
VSM	***Big Data Simulation, RFID IoT Simulation AI***	(Urnauer, Gräff, Tauchert, & Metternich, 2020) (Huang, Kim, Sadri, Dowey, & Dagusch, 2019) (Balaji, Venkumar, Sabitha, & Amuthaguka, 2020) (Atieh, Kaylani, Almuhtady, & Al-Tamimi, 2015) (Abo-Hamad, Crowe, & Arisha, 2012) (Huang, Kim, Sadri, Dowey, & Dagusch, 2019)
Kanban	***CPS RFID, Integration, Simulation IoT, Cloud AI***	(Bauernhansl, Hompel, & Vogel-Heuser, 2014) (Hofmann & Rüsch, 2017) (Köchel & Nieländer, 2002), (Simic, és mtsai., 2020) (Matsuo, Kurita, & Barolli, 2019), (Thürer, és mtsai., 2019) (Lee, 2007)
Poka Yoke	***RFID AI RFID Cloud Big Data, Virtual reality Simulation***	(Rammelmeier, Galka, & Günthner, 2012) (Mayr, Weigelt, Kühl, Grimm, & Erll, 2018) (Rubio-Romero, Parfo-Ferreira, & Arquillos, 2019) (Kumar, Vaishya, & Parag, 2018) (Widjajanto, Jaqin, & Purba, 2020) (Pötters, Scmitt, & Leyendecker, 2018)
Takt time	***Big Data Robotics Simulation, virtual reality AI RFID, IoT***	(Wang & Zhang, 2016), (Tan, Wing, Cai, & Wang, 2020) (Miller-Abdelrazeq, Stiehm, Haberstroh, & Hees, 2018), (Mosallaeipour, Nejad, Shavarani, & Nazerian, 2018) (Bortolini, Faccio, Galizia, Gamberi, & Pilati, 2020), (Ojstersek, Palcic, & Buchmeister, 2019) (Gelmereanu, Morar, & Bogdan, 2014) (Aydos & Ferreira, 2016)
Heijunka	***Simulation Big Data***	(Mayr, Weigelt, Kühl, Grimm, & Erll, 2018) (Żywicki, Rewers1, & Bożek, 2017)

	AI ***Simulation***	(Hou, Katayama, & Hwang, 2015) (Korytkowski, Korytkowski, & Rymaszewski, 2013)
JIS	***Big Data*** ***RFID***	(Bányai & Juhász, 2) (Mayr, Weigelt, Kühl, Grimm, & Erll, 2018)
Jidoka	***Robotics*** ***IoT*** ***RFID***	(Romero, Gaiardelli, Powell, Wuest, & Thürer, 2019) (Rosin, Forget , Lamouri, & Pellerin, 2020) (Pagliosa, Tortorella, & Ferreira, 2019) (Kolberg & Zühlke, 2015)
Mizusumashi	***Simulation*** ***RFID*** ***IoT***	(Kundu, Rossini, & Portioli-Staudacher, 2019) (Su, Hu, Zhang, & Ma, 2009) (Thürer, és mtsai., 2019)
Smart Goals	***Big Data*** ***RFID*** ***Simulation***	(George, Haas, & Pentland, 2014) (Stevens, Goemaere, Strycker, & Nauwelaers, 2012) (Rath, Mangaraj, & Mishra, 2012)
Hoshin Kanri	***Simulation*** ***Big Data*** ***CPS***	(Uriarte, Ng, Moris, & Jägstam, 2017) (Liedtke, 2017) (Sony, 2018)
PDCA	***Big Data***	(Koh & Choi, 2016)
TPM	***Simulation*** ***Big Data***	(Oleghe & Salonitis, 2019) (Dubey, Gunasekaran, Childe, Wamba, & Papadopoulos, 2015)
Milk Run	***IoT*** ***Simulation,*** ***Big Data*** ***AI*** ***RFID*** ***Simulation***	(Qu, Chen, Wang, Duxian, & Luo, 2015) (Simic, és mtsai., 2020) (Bocewicz, Banaszak, Rudnik, & Smutnicki, 2020), (Aragao, Novaes, & Luna, 2019) (Gotthardt, Hulla, Eder, & Karre, 2019) (Kluska & Pawlewski, 2018)
Andon	***CPS*** ***IoT***	(Mohamad, Rahman, Ito, & Rahman, 2019) (Mohamad, Rahman, Ito, & Rahman, 2019)
TQM	***CPS*** ***Big Data*** ***RFID***	(Chiarini, 2020) (Dubey, Gunasekaran, Childe, Wamba, & Papadopoulos, 2015) (Chiarini, 2020)

Tab. 3 summarizes the company interviews and our research results about which tools can be combined from lean and industry 4.0. Some of the participants had just heard about these combinations. Others worked before in other companies, and they learned about this connection. On the green, there are the integrations mentioned by both researchers and companies. Highlighted in light blue are the possible integrations described by research, and in orange are the possibilities mentioned by the companies. Note that it is surprising that the companies did not mention some combinations due to their lack of knowledge about these possibilities. There are also some mentioned possibilities made by the companies that are unknown to the authors. Therefore, it is a knowledge exchange. Table 3 should be understood as a conceptual, initial framework and is open to adding upcoming Industry 4.0 pillars or known lean tools.

Tab. 3. Combination of the research and interview results
Source: Authors' own creation, 2022

Lean/ I4.0	IoT	Big data	Robo-tics	Virtual Reality	Cloud	AI	CPS	Integ-ration	RFID	Simu-lation
Kaizen		B				R		R		R
5S		C		R						
JIT	B	B	C		C		B	R	B	R
SMED		R						R	B	
Spaghetti		R		R	R				R	R
Visual man.	R				R					
VSM	R	B			C	R			B	B
Kanban	R	C			B	R	R	R	B	R
Poka Yoke	C	B	C	R	B	R	C		B	B
Takt time	R	R	R	R		R			R	R
Heijunka		R				R				R
JIS		R							R	

Jidoka	R		B						R	
Mizusumashi	R								R	R
Smart Goals		R							R	R
Hoshin Kanri		R					R			R
PDCA		R								
TPM		B								R
Milk Run	R	R				R			R	R
Andon	R						R			
TQM		R					R		R	

C: Companies answer **R:** Based on researches **B:** Both of them

Concentrating on the industry 4.0 pillars, we summarised how many lean tools were combined according to the publications and the interviews at each pillar. The result shown in Table 4, we can see that based on the publication, the most valuable tools are Big data, RFID, and Simulation. There is a huge difference between the interviews and the research results at some pillars. According to the answers, the main reason for these differences is the lack of knowledge at the companies. For instance, at simulation, most companies do not have an expert who can build and analyze the models.

Tab. 4. Combination of the research and interview results
Source: Authors' own creation, 2022

	IoT	***Big data***	Robo-tics	Virtual Reality	Cloud	AI	CPS	Integration	***RFID***	***Simu-lation***
Publications	9	***15***	2	4	4	7	5	4	***13***	***13***
Interviews	2	***7***	3	0	4	0	2	0	***5***	***2***
Both	10	***17***	4	4	6	7	6	4	***13***	***13***

It analyzed the sectors where the companies most use the tools. It can be noted in Table 5 that the average number of implemented tools is divided by sector. Note that the mining sector still needs to improve its users' techniques, and the IT sector is the most developed one from the methodologies application usage perspective.

Tab. 5. Average number of implemented techniques and tools
Source: Authors' own creation, 2022

Sectors	**The average number of implemented lean management tools**	**The average number of implemented Industry 4.0 tools**
Mining industry	1	0
IT	5	6
Communication	2	2
Steel metallurgy	2	1
Wood products	2	4
Chemicals	7	2
Oil/Petroleum	4	4

5. Conclusion

This questionnaire analyzed that small and medium-sized companies have more difficulty accessing information from Lean and Industry 4.0 tools. Comparing the literature review with the interviews, while in the research combining Industry 4.0 with lean tools is quite widespread, at the companies not so far (Wagner, Herrmann, & Thiede, 2017; Tortorella & Fettermann, 2018). The results show that most companies do not know about Industry 4.0. Although the philosophy may seem simple and obvious, experience has shown that few companies can successfully deploy the tools. It often requires a radical change in mentality, values, and discipline.

The unique contribution of the paper is to see the common areas of Lean and Industry 4.0 where there are research and knowledge, but the application level at the companies is low. At those combinations of lean tools and industry 4.0 pillars, where we found only research, but the companies did not apply them, we think that practical implementation at the operational level and the analysis of the results would be useful. On the other side, improving knowledge at the companies is essential to raise a higher penetration of some industry 4.0 pillars (Big Data, Simulation, AI) (Simic et al., 2020; Lee, 2007). e also found some research gaps at some combinations, where companies see the potential, but few publications and case studies can be found (Big data and 5S, Robotics and JIT, etc.).

In our opinion, our research gives significant value to those conducting practical research and decision-makers in this field. Given this observation, it is possible to understand what would be the main reasons for this "non-adoption", especially the lack of investments, through the other answers provided. This paper signs the most critical areas where further research and case studies should be created. Despite the long history and widespread of Lean and Industry 4.0, we experienced a lack of knowledge at most companies. Participants did not substantiate the claim that Industry 4.0 can help to eliminate the existing barriers to implementing lean management (Adam, Chola, & Jens, 2016). In contrast to previous research (Wagner, Herrmann, & Thiede, 2017), we compared the corporate practices with the research, which shows a significant difference.

In our view, further research is required because there are huge differences between the application at the companies and the literature review. Further interviews and examinations should be done to get a more exact picture of the companies' current implementation level of Lean and Industry 4.0.

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