
Support for the Implementation of the Lean Concept by Industry 4.0 Tools – Experts' Opinion

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Abstract:

Purpose: The goal of the article is to identify the possibilities of supporting the implementation of the Lean Management concept by selected Industry 4.0 tools.

Design/Methodology/Approach: The theoretical part describes the concept of Lean Management and Industry 4.0. in the context of their joint use. The research part collected the opinions of experts with knowledge and experience in the implementation of Lean Management and knowledge of Industry 4.0 tools.

Findings: The obtained research results show the opinions of experts on the joint use of selected Industry 4.0 tools and the Lean Management concept in the elimination of waste.

Practical Implications: The research results provide knowledge for management practice in the selection of appropriate Industry 4.0 tools for further elimination of waste in companies applying Lean Management.

Originality/Value: Continuous process improvement requires the use of many concepts and tools. The article presents the opinions of experts in the field of supporting the implementation of the Lean concept by Industry 4.0 tools, which is a voice in the discussion on the possibility of effective integration of both concepts.

Keywords: Industry 4.0, Lean Management, Lean Production.

JEL Classification: M2, M11.

Paper Type: Research article.

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1. Introduction

The industrial revolution 4.0 is understood as an intelligent combination of machines and processes in industry using information and communication technologies. It made it possible to automate repetitive activities, such as planning the sequence of work at the stages of the production line, and their optimization is carried out by dedicated systems collecting and processing the received data. This publication presents the opinions of experts on the use of Industry 4.0 tools in companies applying the Lean concept. The article consists of a theoretical and practical part carried out based on survey research.

The term Industry 4.0 is often referred to as the fourth industrial revolution (Kagermann, Wahlster, Helbig, Hellinger, Stumpf, and Kobsda, 2013; Bauer, Baur, Camplone, George, et al. 2015; Hermann, Pentek, and Otto, 2015). At the European level, the slogans "Factory of the future", "Industrial Internet" in the USA and "Internet +" in China were proposed (Mrugalska and Wyrwicka, 2017). The Industry 4.0 concept describes the growing digitization of the entire value chain and the resulting connection of people, objects and systems through real-time data exchange (Spath, Ganschar, Gerlach, Hämmerle, Krause, and Schlund, 2013; Dorst, Glohr, Hahn, Knafla, Loewen, Rosen, et al., 2015). Certainly, the Industry 4.0 concept creates many new opportunities, but at the same time many challenges resulting from automation and digitization (Łupicka and Grzybowska, 2017).

It can be said that Industry 4.0 is a term that refers to modernly organized production and logistics, including mutual data exchange, digitization, and cloud computing. Along with the development of the concept, the questions inevitably arise: Does the implementation in the enterprise of the components of the Industry 4.0 concept allow to gain a competitive advantage. Is it possible to: further increase the efficiency of implemented processes, including the elimination of waste? For many, Industry 4.0 is the opportunity to use new IT systems, for others, the introduction of robots.

We can use similar questions in the context of the Lean concept, which is certainly focused on the customer, and at the same time improving the processes carried out in the enterprise. Lean focuses on continuous improvement, mainly through the elimination of various forms of waste. Lean Manufacturing can be described as a multi-faceted approach to production, encompassing a variety of industrial practices that are aimed at identifying the processes of adding value from the customer's perspective and ending the flow of these processes because of attracting customers by the organization (Shah and Ward, 2007; Womack, Jones, and Roos, 1990). Lean can also be defined as improving the value-added process by reducing waste and defects. According to the Lean perspective, the best way to increase profitability is to reduce waste, which is directly related to cost reduction.

When looking for a relationship between Industry 4.0 and the Lean concept, it is worth knowing that the principles of creating LM value focus on reducing internal waste and increasing value for the customer. While the principles of I4.0 do not take these factors into account, it is clear that I4.0 seeks to create value by increasing operational efficiency, reducing production costs, ensuring quality and creating new business models.

Both LM and I4.0 ensure continuous improvement of processes and products to satisfy customers (Osti, 2020). The best way to integrate these two concepts is to introduce them under the CPPS (Cyber-Physical Production) platform, which indicates that the organization should respect the well-adopted Lean principles in the physical world and follow the value stream, involving available Industry 4.0 technologies (Golczew 2019).

Thus, Lean Manufacturing is a prerequisite for the successful implementation of Industry 4.0 solutions, as decision makers require LM competencies to recognize customer value and avoid waste. Standardized, transparent and repeatable processes play an important role in implementing I4.0 solutions. LM focuses on reducing process variability and complexity, which increases the efficiency and economic use of I4.0 tools (Mayr, Weigelt, Kuhl, Grimm, Erll, Potzel, and Franke 2018). High-tech I4.0 tools help stabilize Lean processes and increase the ability to improve the flexibility of Lean production systems. I4.0 can improve LM by removing LM constraints. I4.0 helps in dealing with fluctuating market demand with increased flexibility to cope with increasing complexity (Mayr *et al.*, 2018.). Dombrowski, Richter, and Krenkel (2017) state that the Lean Production system builds the basis for Industry 4.0 and the processes determine the application of the I4.0 technological solution.

In the article, the authors answered the following questions: Can Industry 4.0 tools support the improvement of value streams in organizations that have implemented the Lean concept and its selected tools? The answer to the research question was based on the result of the opinion poll of a group of experts with many years of experience in implementing Lean and knowledge of Industry 4.0 tools.

2. Research Methodology

The concepts of Industry 4.0 and Lean presented above should be used in most modern enterprises, which must move with the times in order to be competitive and stay on the market. The authors' experience shows that the Lean concept is widely used in enterprises. In contrast, Industry 4.0 is present to a limited extent. Therefore, there is a need to conduct research among experts in the field of knowledge about Industry 4.0 and Lean and their solutions in their activities. The study was conducted using a questionnaire sent by e-mail in order to obtain a set of data suitable for further quantitative analysis.

The main aim of the research was to answer the following questions:

- What are the determinants of the need to implement Industry 4.0?
- Is the use of Lean tools important when implementing industry 4.0?
- What industry 4.0 tools can support the elimination of waste?
- and What are the possibilities of cooperation between selected Industry 4.0 tools and the Lean concept?

The subjects of the research are selected experts who have knowledge of the Lean concept. Defining the material and time scope of the research is as follows:

- entity – an expert with experience in implementing Lean and knowledge of Industry 4.0 tools,

- sample unit – enterprises with implemented Lean concept,
- spatial scope – the whole country (Poland),
- time – July and August 2021.

80 experts were invited to participate in the study. From the invited group of managers who declared their willingness to participate in the study based on meeting the criterion of knowledge and experience, 15 were selected. The study was conducted in the form of an indirect interview with the use of questionnaires. Responses to the questionnaire were provided mainly by managers 53% (8 people). The remaining respondents were the CEOs 27% (4) and plant / production managers 20% (3). 66.7% of them were companies with foreign capital, 26.7% only with Polish capital and 6.6% with mixed capital.

To obtain information on the knowledge of Lean experts, their work experience was analyzed and several control questions concerning Lean tools and principles were asked. Well, 1/3 of experts stated their work experience over 15 years and the same percentage indicated 11-15 years. On the other hand, for 6-10 years, answers were given by 26.7% of the respondents, and 6.7%, i.e., one respondent, indicated an internship from 1 to 5 years. None of the experts had experience under a year.

To obtain the characteristics of the surveyed enterprises, their criterion was made. The criteria for the division were the size of the enterprise, the prevailing nature of production and the creation of production to order or warehouse (Table 1).

Table 1. Research objects characteristics (15 companies)

Characteristics	Number of respondents
Enterprise size:	
1-9 employees	1
10-49 employees	1
50-250 employees	5
250 or more employees	8
Predominant nature of production:	
short series production	10
mass or large-scale production	3
services of a unique individual character	2
repetitive services	0
unit production	0
Does the company implement:	
production to stock (ready products are handed over for distribution)	6
production to order (according to customer specifications, after receiving the order)	13

Source: Own work.

Did medium-sized enterprises account for 1/3 of the surveyed companies, and large enterprises – over a half. Apart from that, out of 15 surveyed representatives were manufacturing companies. 13. The remaining companies are consulting companies (2) employing several or a dozen or so people.

In order to get acquainted with the characteristics of the production of the surveyed enterprises, the questionnaire included questions concerning: the level of automation of the company, production profile, assortment diversity, methods of organization used, and the IT system used in the enterprise. To confirm the knowledge of experts, questions were asked about the knowledge of Lean principles and tools. Positive responses were obtained, which confirmed the accuracy of the selection of experts for the study (Table 2 and Table 3).

In the survey, respondents were asked to answer the question: "Which of the following Lean principles do you know?" The researchers' aim was to obtain information about the knowledge of the Lean concept used in the market.

Table 2. Knowledge of the above-mentioned principles by the 15 experts participating in the study

Principle	Knowledge level %			
	I know and apply,	I know and I am aware that this is the Lean principle	I know but I did not know that it is the Lean principle	I do not know
determination of value for the customer	53	40	7	0
identifying the value stream and all activities in the value stream	60	33	7	0
continuous flow	60	27	13	0
pull system	53	33	7	7
striving for excellence – continuous improvement of processes	80	13	7	0

Source: Own work.

The results of the survey show a very good knowledge of the principle of striving for excellence. It is worth emphasizing that over 50% of respondents know and apply all of the above-mentioned rules.

In management practice, there are many Lean tools used to eliminate waste. The following are noteworthy: VSM – value stream mapping, 5S – 5 steps / activities, SMED – Single Minute Exchange of Die, TPM – Total Productive Maintenance, kanban – visible description (sheet of paper), standardized work – standardized work, Show – Yoke – mistaka proofing, kaizen – change for the better. In the survey, respondents were asked to answer a question about the knowledge of the above-mentioned tools. The researchers' aim was to obtain information about the knowledge and application of Lean tools.

Table 3. Knowledge of the above-mentioned tools by the 15 experts participating in the study

Tools	Knowledge level %		
	I know and I use it	I know but I do not use it	I do not know
VSM	87	13	0
5S	93	7	0
SMED	67	33	0
TPM	73	27	0
kanban	73	27	0
Standardized operation	87	13	0
Poka-Yoke	53	47	0
kaizen	73	27	0

Source: Own work.

The results of the survey show very good knowledge of all the above-mentioned tools. Most often, respondents use 5S over 90% and value stream mapping and standardized work 87%. 73% of experts know and use TPM, kanban and kaizen. They also know what SMED and Poka-Yoke are. Knowledge of these tools was a necessary condition for participation in the study. It can be concluded that the knowledge of the most modern tools for the improvement and elimination of waste is satisfactory. It should be emphasized that the knowledge of the above-mentioned methods is related to their application. Therefore, experts were asked to identify the methods that they use in the day-to-day operations of enterprises.

It is worth noting that all experts indicated that the area of production is the most susceptible to the implementation of the Lean concept. They also agreed that applying Lean brings benefits in each enterprise.

Another series of questions confirmed the knowledge of Industry 4.0 by the invited group of experts? The questions concerned: knowledge of the concept of Industry 4.0 and the use of Industry 4.0 tools in the company. Experts indicated that the following tools are most often used in enterprises:

- robotics and automation of logistics processes,
- big data,
- cloud computing,
- 3D printing,
- wireless sensor network (eg RFID).

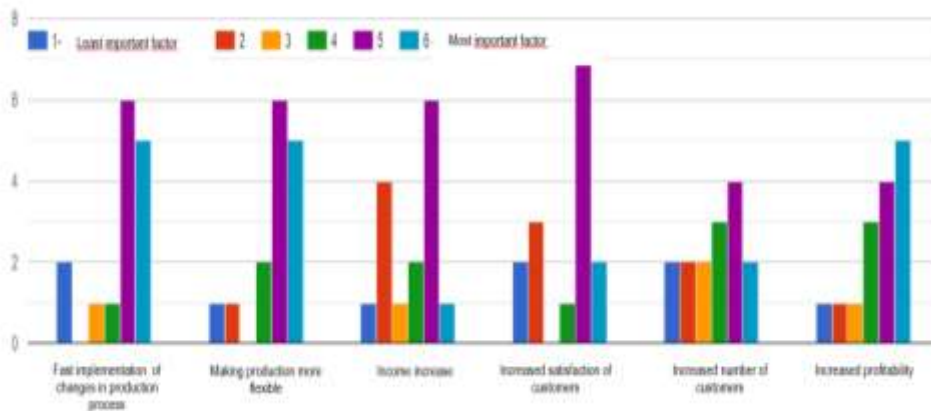
In addition, 87% of experts indicated that the use of Industry 4.0 tools brings significant benefits for the company. For the authors of the article, the above characteristics of the experts' responses confirm that the managers qualified for the study may constitute a source of knowledge on the topic under study and the basis for answering the formulated research question.

3. Research Results

100% of experts expressed the opinion that the use of Lean tools has a significant impact on the implementation of Industry 4.0. The tools are a good basis for improving the production system, i.e., for its further development. Experts confirm that with the implementation of Industry 4.0 tools, the methodology of using Lean tools does not change, but only the methods of information transfer, automation, and digitization increase.

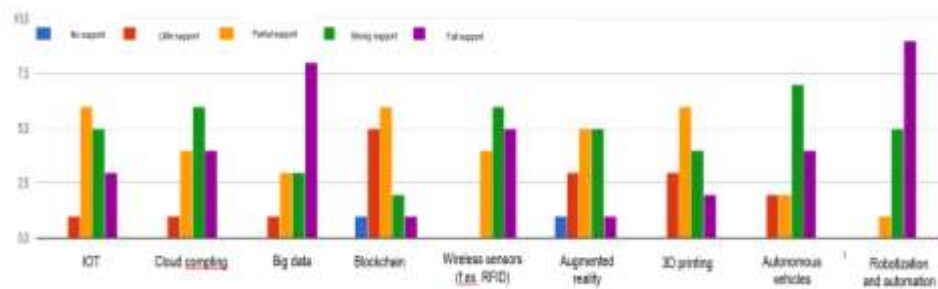
When asked about the determinants of the implementation of Industry 4.0 solutions, the experts indicated (Figure 1) that the most important (indications 5 and 6 in the adopted scale) include, quick introduction of changes in the production process, making production more flexible and increasing customer satisfaction. These are determinants resulting from the need to respond faster to customer orders and are important both in the scope of standard products and products manufactured and modified to order. In the opinion of managers, an important determinant is also the desire to increase profitability.

Figure 1. Determinants of implementation of Industry 4.0 in a company



Source: Own study.

Figure 2. Industry 4.0 supporting waste minimization in a company



Source: Own study.

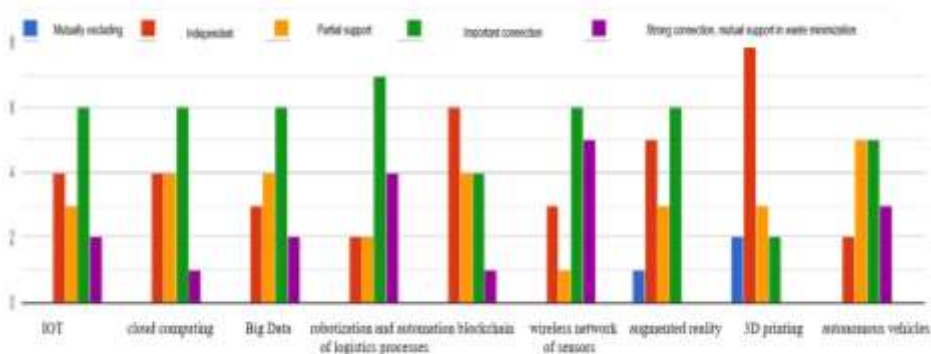
100% of experts expressed the opinion that the use of Lean tools has a significant impact on the implementation of Industry 4.0. The tools are a good basis for improving the production system, i.e., for its further development. Experts confirm that with the implementation of Industry 4.0 tools, the methodology of using Lean tools does not change, but the methods of transmission change. The domain of Lean is the desire to eliminate waste. Therefore, the next question was about what Industry 4.0 tools can support the elimination of waste. Experts indicated that the most important tools (Figure 2) include: big data, as well as robotization and automation of logistics processes (including autonomous vehicles).

In addition, it was indicated that in the fight against waste, artificial intelligence may be used to optimize processes as well as further automation and robotization of production processes. The next questions concerned the possible support of specific actions and tools known from Lean by Industry 4.0 tools in the elimination of waste. The aim of the question was to determine whether in the process of waste elimination, individual tools:

- 1 – are mutually exclusive (one or the other is used, not both),
- 2 – are independent (no interaction),
- 3 – they support each other to a small extent (no significant synergy as a result of their use),
- 4 – show a significant relationship (they allow to achieve better results than using one of them),
- 5 – show a high relationship (they are compatible in functioning, complement each other, allow for a significant improvement in results).

In the case of value stream mapping (VSM), a significant relationship between tools was indicated (Figure 3), robotics and automation of logistic processes (elimination of selected forms of waste) and wireless sensor network (collection of information about machine downtime).

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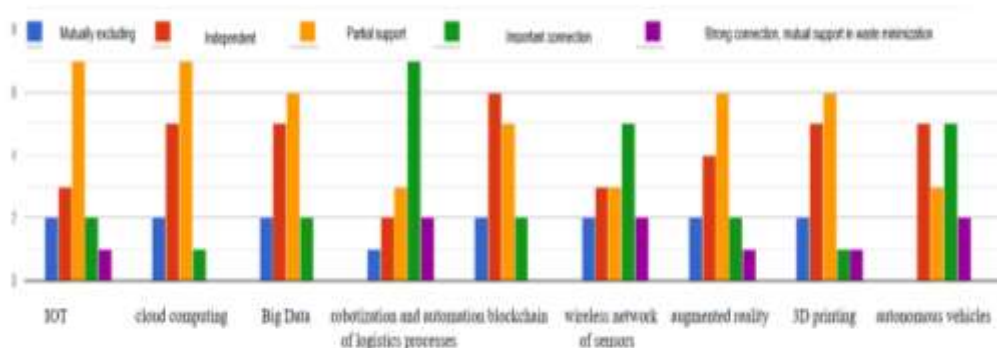
Source: Own study.

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 - 4 – show a significant relationship (they allow to achieve better results than using one of them),
 - 5 – show high correlation (they are compatible in operation, complement each other, allow for significant relations)
- Assessment of the relationships of Industry 4.0 tools in the value stream mapping process - in the opinion of experts

In the case of using the 5S tool in the elimination of waste, experts indicated (Figure 4) significant relationships with robotization and process automation. The overwhelming number of responses suggests no significant relationships with other tools or minimal support.

Figure 4. Assessment of the relationships between Industry 4.0 tools and the 5S tool in the elimination of waste – in the opinion of experts



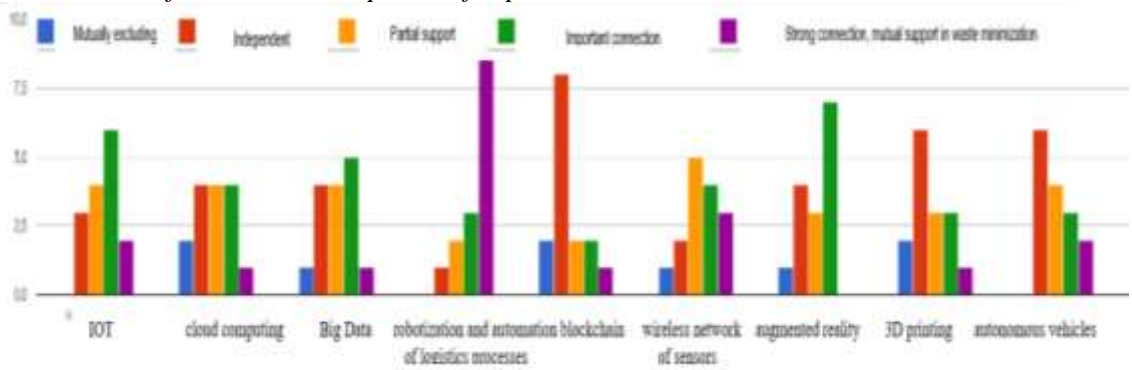
Source: Own study.

For the SMED tool, managers identified (Figure 5) the relationship with robotization and process automation (changeover automation) and augmented reality (operator support in the process of manual changeovers).

In the case of the TPM concept, experts pointed to a significant relationship between the elimination of waste and robotization and process automation (Figure 6). They also indicated the importance of such tools as: wireless sensor network (support for machine diagnosis and repair) and the Internet of Things.

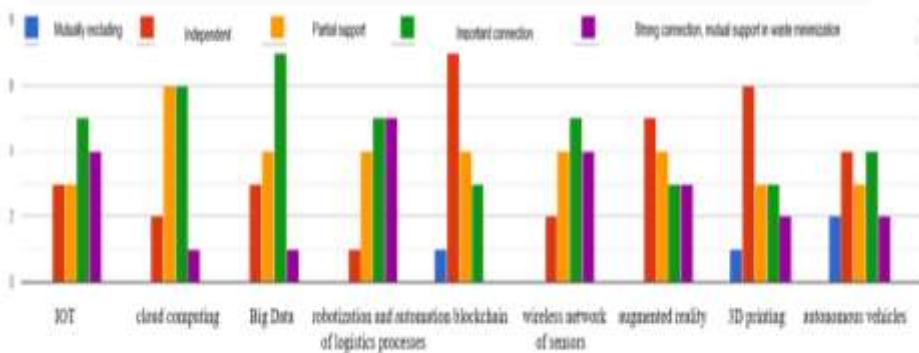
In the case of the Kanban tool, the respondents did not indicate potentially significant support from the analyzed tools (Figure 7).

Figure 5. Assessment of relations between Industry 4.0 tools and the SMED tool in the elimination of waste – in the opinion of experts



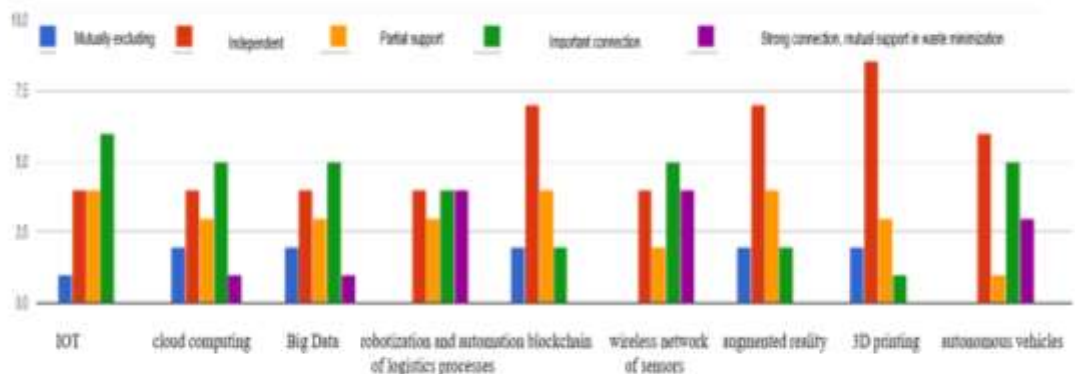
Source: Own study.

Figure 6. Assessment of the relationships between Industry 4.0 tools and the TPM concept in the elimination of waste – in the opinion of experts



Source: Own study.

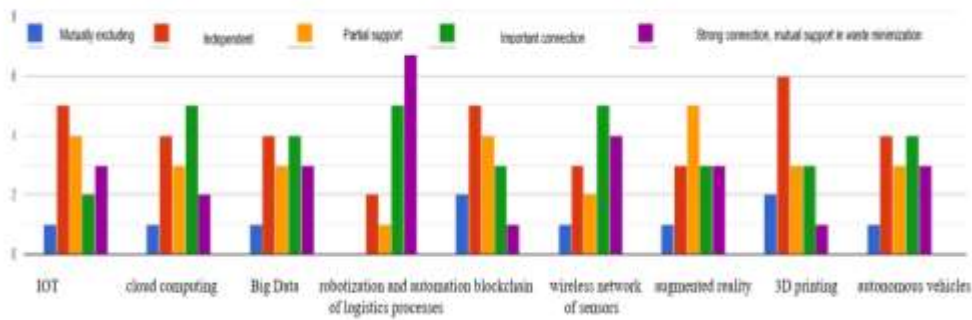
Figure 7. Assessment of the relationships between Industry 4.0 tools and the Kanban tool in the elimination of waste – in the opinion of experts



Source: Own study.

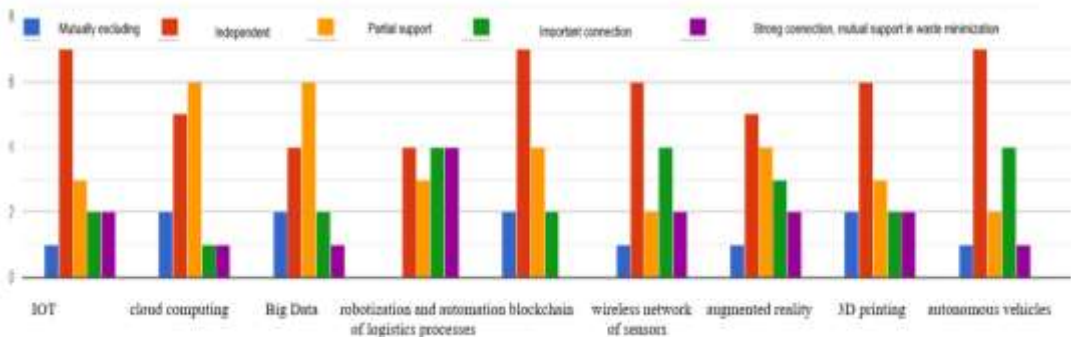
Experts unambiguously associate the high level of work standardization with robotics and process automation, and see it as further opportunities to reduce man-work (Figure 8). According to experts, the fight against waste in the case of using the Poka-yoke tool can be supported by robotics and process automation as well as a wireless network of sensors (detection of errors and quality defects) (Figure 9).

Figure 8. Assessment of relations between Industry 4.0 tools and the standardized work tool in the elimination of waste – in the opinion of experts



Source: Own study.

Figure 9. Assessment of the relationships between Industry 4.0 tools and the Poka-Yoke tool in the elimination of waste – in the opinion of experts



Source: Own study.

Kaizen as a tool for engaging employees in continuous process improvement is perceived by experts as not very susceptible to the support of modern Industry 4.0 tools (Figure 10). Potential support could come from such tools as, Big Data, Internet of Things and cloud computing (data collection and analysis tools).

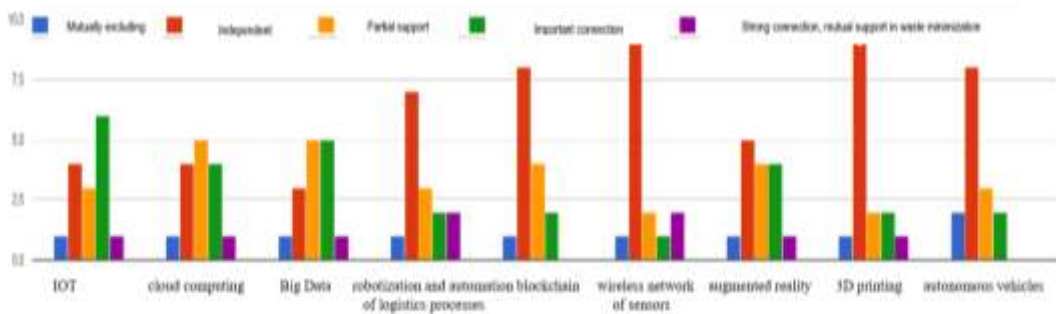
4. Conclusion

Continuous improvement of processes requires the use of many concepts and tools. The collected opinions of experts with knowledge and experience in the implementation of Lean Management and knowledge of Industry 4.0 tools allowed to identify the

possibilities of integrating both concepts. It is a challenge for a management practice that improves production systems by increasing their flexibility and reducing waste.

The research presents experts' opinions on supporting the implementation of the Lean concept by Industry 4.0 tools. in the selection of appropriate Industry 4.0 tools for the further elimination of waste in companies using Lean Management. The issue of integration is the direction of further research by the authors, including a detailed methodology for the use of individual tools.

Figure 10. Assessment of the relationships between Industry 4.0 tools and the Kaizen tool in the elimination of waste – in the opinion of experts



Source: Own study.

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