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Impact of Poka Yoke methodology in the manufacturing industry: A Systematic Literature Review (2019-2024)

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Abstract*– This paper presents a systematic review of the impact of the Poka Yoke (PY) methodology in the manufacturing industry, focusing on how these practices can influence the prevention of errors, decrease defects, ensure higher quality processes, and foster a culture of continuous improvement. This research focuses on analyzing and synthesizing the existing literature to determine its contribution to quality and operational efficiency in the manufacturing sector. This study uses reliable databases such as Scopus and ScienceDirect, applying the PICO and PRISMA approaches to structure the search and selection of relevant articles published between 2019 and 2024. The results highlight the significant reduction of errors and defects, improvements in risk management and quality, as well as the optimization of delivery times and production processes. In addition, the methodologies that best fit with PY are identified, such as 5S, SMED, TPM and VSM, which also contribute to continuous improvement and production efficiency. Likewise, the bibliometric analysis carried out reveals a growing interest in the PY methodology, with a notable increase in the number of publications in recent years, especially in countries such as India and Peru. This study provides a comprehensive and up-to-date view of the contribution of the PY methodology in the manufacturing industry, highlighting its positive impact on improving quality and operational efficiency.

Keywords: Poka Yoke, manufacturing industry, Continuous improvement, Quality, Operational efficiency.

I. Introduction

In the field of industrial production, reducing waste and minimizing errors in the production chain is a priority for modern companies. Among the various methodologies applied, Poka Yoke (PY) stands out as an effective tool for preventing errors and optimizing manufacturing processes [1]. Its implementation makes it possible to reduce waste, ensure the correct sequence of operations and, consequently, improve the competitiveness of organizations [2].

The use of PY not only promotes the production of high-quality goods and services but also fosters a culture of continuous improvement by involving employees in identifying and solving problems [3]. However, although its impact is recognized, systematic reviews on its effectiveness are limited and lack standardized approaches that assess its applicability in the manufacturing sector.

Recent studies have explored the state-of-the-art analysis of lean construction and PY [4], aspects such as the relationship between PY and Industry 4.0[5], proposals for more comprehensive definitions [6] and key factors for the successful implementation of PY [7]. However, these papers present methodological limitations by not using robust approaches such as PICO, PRISMA, or bibliometric analyses. This underlines the need for a new systematic review that synthesizes and critically evaluates the available evidence.

Therefore, this article aims to comprehensively analyze the recent literature on the Poka Yoke methodology and its impact on the manufacturing industry. Through a qualitative approach and tools such as PICO and PRISMA, this review seeks to answer the question: How does the Poka Yoke methodology contribute to the improvement of quality and operational efficiency in manufacturing?

II. METHODOLOGY

This study employs a qualitative analytical approach, using recognized methodologies such as PICO and PRISMA. In addition, a bibliometric analysis was conducted to comprehensively synthesize and analyze information on the Poka Yoke (PY) methodology in the manufacturing industry.

The research was conducted in two reliable academic databases, Scopus and ScienceDirect, selected for their broad coverage of indexed articles. The time frame covered from 2019 to 2024, to ensure the inclusion of recent studies. Clear inclusion and exclusion criteria were established, detailed in Table 2, to select studies that were relevant, complete, and applicable to the research topic.

A. PICO

PICO (Problem, Intervention, Comparison, and Outcome) was used to structure and focus the literature search. This methodology allowed the formulation of specific research questions [8]. To limit according to the research, the elements P (problem), I (intervention) and O (outcome) were specifically used to formulate the general question and its parts.

General question:

- GQ: How does the Poka-Yoke methodology contribute in the manufacturing industry?

Specific question:

- EQ1: What is the impact of PY application in the manufacturing sector?
- EQ2: What is the contribution of PY within quality control?
- EQ3: Which methodologies work in a complementary way with PY?

To obtain the keywords and formulate the search equation, the following PICO table is developed.

TABLE I
PICO METHODOLOGY

P	Problem	High number of defects and errors	Failure, waste, manufacturing
I	Intervention	Methodology to reduce errors	Poka-Yoke, Poka-Yugo
O	Outcome	Fewer errors and malfunctions	Effectiveness, efficiency, “waste management”, "lest waste"

The search was performed with the following equations, with a slight variation because each search engine has different algorithms to run the equation, the keywords were tested and the equation that yielded the highest number of articles that are delimited to the research topic was chosen.

SCOPUS: (“poka-yoke” OR “Poka-yugo”) AND (“manufacturing industry” OR “industrial sector”).

SCIENCEDIRECT: (“poka-yoke” OR “Poka-yugo”) AND (“Waste management” OR “Mistake”) AND (“manufacturing industry” OR “industrial sector”).

The initial results (144 in Scopus and 112 in ScienceDirect) were analyzed qualitatively, limiting the selection to published articles of any language accessible in full text and with data relevant to the topic. The search result was delimited from January 2019 to May 15, 2024, with a total of 256 articles.

Inclusion and exclusion criteria are defined in order to be able to analyze only the most relevant articles for this research and that are closely related to our research topic. Each criterion is key for an adequate selection of scientific articles.

TABLE II
INCLUSION AND EXCLUSION CRITERIA

INCLUSION CRITERIA	EXCLUSION CRITERIA
CI1. Studies related to the manufacturing industry.	CE1. No literature reviews.
CI2. Studies present quantitative measurable results.	CE2. Theoretical analysis studies.
CI3. Implementation of the PY	CE3. Focused on other industries.
	CE4. Non-relevant studies of the impact of the PY.

B. PRISMA

The PRISMA methodology, helps us to narrow down and specify the largest number of articles of interest, considering the criteria, based on the searches performed in Scopus and ScienceDirect.

In order to continue with the review, all articles of interest were downloaded and organized in Excel, where the screening phase continued, initially from the total number of articles downloaded, 2 duplicate articles were discarded. Likewise, considering the title and abstract, there were articles that did not meet inclusion criteria one and three, 134 of them not being considered, as well as inclusion criterion 2 regarding quantitative measurable results, where 59 of them did not meet this criterion. In addition, 38 records were excluded due to the exclusion criteria. Finally, 22 studies were excluded, and their results were subsequently evaluated. The entire PRISMA process can be reviewed in Fig. 1.

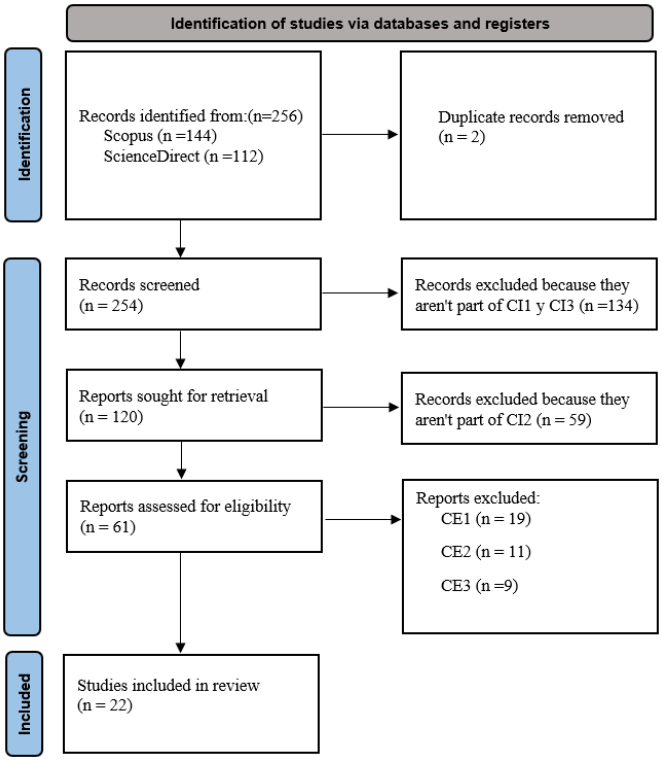

Fig. 1 PRISMA flowchart for the selection of scientific articles.

The PRISMA methodology also identified key areas where more research is needed and possible gaps in existing literature. It also helped to find 22 articles that met the inclusion and exclusion criteria of the SME in the manufacturing industry within the Scopus and ScienceDirect search engines.

On the other hand, during the search process, a bibliometric analysis was carried out, a methodology used in several systematic reviews [9].

This analysis was performed using the Visualization of Science Viewer (VOSviewer) tool and graphs that compact the large amount of data provided by the search engines; only the results from Scopus were considered for this analysis since most of the final articles are from this search engine. Data such as the number of articles per year, countries where most articles were published, most cited authors, most used keywords and documents by subject area are analyzed. Finally, Mendeley was used to manage citations and references throughout the review. According to [10], Mendeley is a reference manager widely used by students, professors and the research community.

III. RESULTS

This study is divided into two main sections. The first section provides a distribution of articles, represented by tables and figures, which addresses the three main questions previously formulated in the systematic review. The second section presents a bibliometric analysis based on parameters previously established in the methodology, complemented by an analysis performed using the VOSviewer tool.

A. *First section*

1) Impact of PY methodology to improve the manufacturing sector: After reviewing the articles, the impact of the Poka Yoke methodology on companies to improve in the manufacturing sector was identified, as shown in Table 3.

TABLE III
IMPACT OF THE PY METHODOLOGY IN THE MANUFACTURING INDUSTRY

Author(s)	What is the impact of PY application in the manufacturing sector?
[11]; [12]; [13]; [2]; [14]	Reduction of waste, scrap and defects
[15]	Avoiding defects can arise due to human error during handling
[16]	Risk management and quality improvement
[14]	Reduce lead times and optimize the production process

Poka Yoke in the manufacturing sector. One of the main benefits is the reduction of waste, scrap and defects, as pointed out by [11], [12], [13], [2] and [14]. Furthermore, [15]warn that defects may arise due to human errors during handling. [16] highlight risk management and quality improvement, while [14] emphasizes the reduction of lead times and optimization of the production process.

II) PY contribution to quality control: Table 4 highlights the different contributions of PY in the field of quality control. Among the main benefits are improved efficiency and waste reduction, as pointed out by [17] and [18]

TABLE IV
CONTRIBUTION TO QUALITY CONTROL

Author(s)	What is the contribution of PY to quality control?
[17]; [18]	Efficiency Improvement and Waste Reduction
[19]; [13]; [20]	Product Quality and Customer Satisfaction
[17]; [21]; [2]	Loss Reduction and Process Improvement
[22]; [20]	Nonconformity Control System

In addition, improvements in product quality and customer satisfaction are observed, as reported by [19] and [20]. Significant reductions in losses and process improvements are also identified, as reported by [17], [21] and [2]. Finally, the implementation of nonconformity control systems is highlighted, according to [22] and [20]

III) Methodologies that work and complement the PY: Articles were considered to identify the tools used to improve production processes, as shown in table V.

TABLE V
METHODOLOGIES THAT WORK WITH PY

Author(s)	Which methodologies work in a complementary way with PY?
[11];[12]; [23];[15];[14]; [24]	5S
[14]	Kanban
[18]; [23]	SMED
[15]	TPM
[18]	VSM

Table 5 shows the most frequently used methodologies with PY. The use of 5S is highlighted, as well as SMED for continuous improvement and optimization of time reduction. VSM and TMP are also mentioned as tools for error prevention.

B. *Second section*

1) Articles published per year: To address the research topic, a period of historical analysis was established to demonstrate the PY research trend in the Scopus database. The results reveal an upward trend in the number of articles published, reflecting a growing interest in the topic over time.

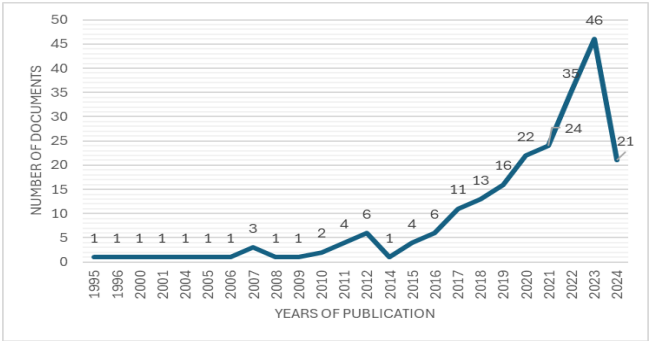

Fig. 2 Number of articles published by year

Figure 2 shows that in 2012 and 2016, 6 research projects were reported throughout the year, but it was in 2017 that a higher growth regarding annual publications on PY methodology began, reaching the highest peak in 2023 with 46 publications. This visualization clearly shows the evolution of scientific production on PY, highlighting a remarkable growth in recent years.

II) Location of published articles: Articles from different countries were identified, according to Scopus, India is, until 2024, the country with the most published research over the years, followed by Peru with 22 and Malaysia with 16

publications. The following graph shows the countries with the most publications and their location.

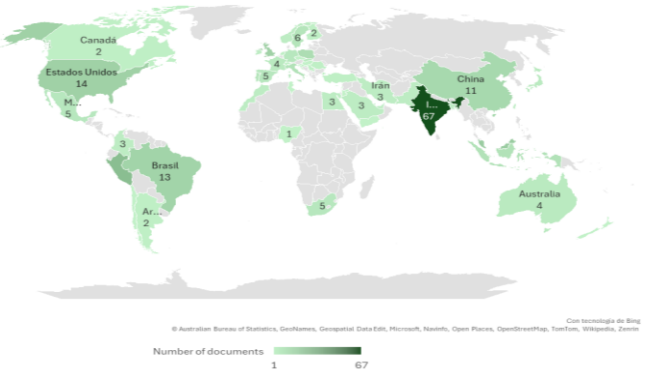

Fig. 3 Scientific production by country

Fig. 3 presents a map showing the number of articles published by country with a more contrasting shade, the countries with the highest number of articles. India stands out as the country with the highest number of published research papers, reflecting intense academic activity in this field. Peru and Malaysia also show a significant scientific production, with 22 and 16 publications respectively. The graph clearly illustrates the geographical distribution of publications, highlighting the concentration of studies in these regions.

III) Authors with most cited articles: Over time, numerous authors have investigated the Poka Yoke methodology, with a notable participation of Asian researchers. For the analysis of this research, we identified the most cited authors in the Scopus database who have contributed significantly to the field of Lean tools, especially from the PY approach.

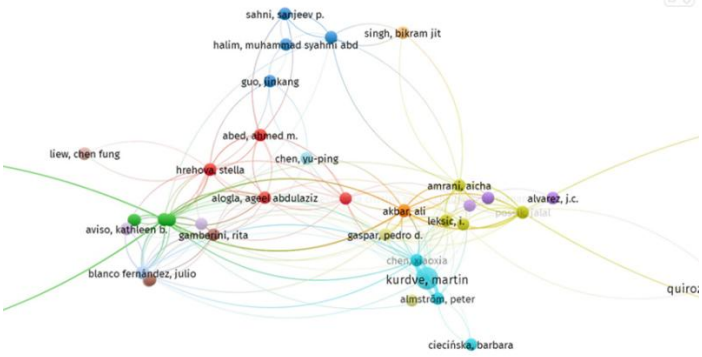

Fig. 4 The most cited authors

Fig. 4 shows a greater number of publications by the most cited authors in the field of Poka Yoke methodology. Asian researchers stand out in the graph issued by VOSviewer, reflecting their intense academic activity and contribution to the development and application of this methodology. The diagram shows the authors with the most published articles and their influence in the field, providing a clear view of the leaders in this area of study.

IV) Most used keywords: The most used keywords were identified within the articles, highlighting the entire lean environment and the highlights of the PY methodology.

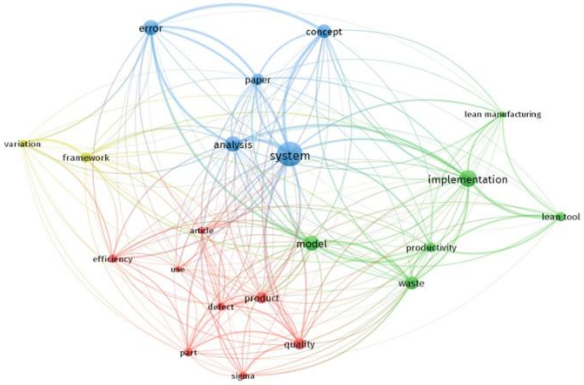

Fig. 5 The most used keywords

The keywords most frequently used in the studies reviewed are presented in Fig. 5. The categories of “lean” and “Poka Yoke” stand out, reflecting the prominence of these methodologies in the current literature. In addition, there is a high frequency of associated terms such as “system”, “productivity”, and “efficiency”, indicating a strong correlation between these practices and optimization objectives in manufacturing processes. The diagram also reveals a web of interconnections between these keywords, visually representing how these concepts are interrelated in manufacturing research.

V) Research by area of study: Figure 6 provides a detailed view of the distribution of research on the PY methodology according to different areas of study. This analysis allows us to identify the prevalence of PY in various fields, highlighting its relevance in engineering, business, computer science and decision sciences.

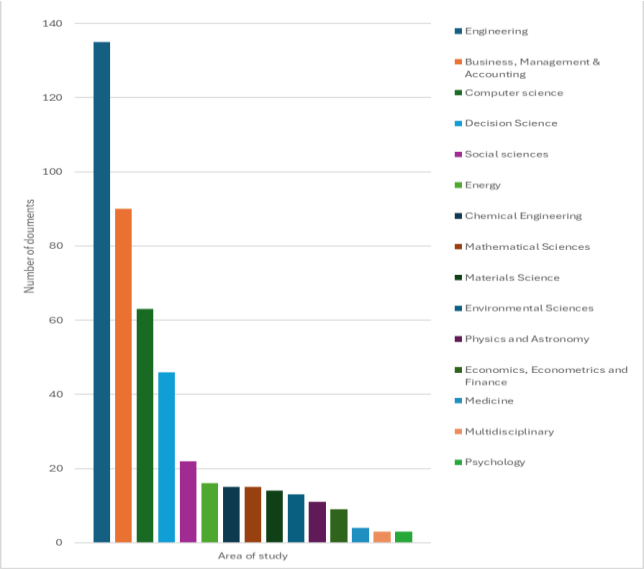

Fig. 6 Results by area of study

The graph reveals that the PY methodology has significant application in the engineering domain, but also excels in areas such as business, computer science and decision sciences. The graphical representation provides a clear view of how PY integrates into various fields, highlighting its versatility and applicability in multiple contexts.

IV. DISCUSSION

The Poka Yoke methodology, developed to avoid errors in production processes, has demonstrated a significant impact in the manufacturing sector. According to several studies included in Table 3, the implementation of PY has led to a considerable reduction in waste, defects and scrap. For example, research by [11]; [12]; [13] and [2] show that PY helps minimize human errors and product defects. Additionally, [14] highlights that PY not only improves product quality but also optimizes lead times and the efficiency of the production process. This evidence suggests that the PY methodology is a crucial methodology for improving competitiveness and quality in the manufacturing sector.

In contrast, other studies outside the present review put forward different perspectives on the implementation of PY in the manufacturing sector. For example,[25] argue that, although PY can reduce human errors, it does not address deeper systemic problems that may be present in production processes. Similarly, [26]emphasize that over-reliance on PY can lead to a decrease in workers' creativity and problem-solving skills because they rely too much on automated solutions to avoid errors. These views suggest that while PY is beneficial, it must be part of a broader process improvement strategy.

Regarding the contribution of PY in quality control, several studies reviewed in Table 4 highlight that the implementation of PY in quality systems leads to substantial improvements in efficiency and waste reduction, according to [17] and [18] show that PY improves operational efficiency, while[19], [13] and [20] point to improvements in product quality and customer satisfaction. Likewise, studies by [21] and [2] reveal that PY contributes to loss reduction and process improvement. Finally, the implementation of nonconformity control systems, as indicated by [22] and [20] is also part of an important advantage of using PY.

In contrast, other authors point out that the implementation of PY can be costly and requires significant upfront investment, which can be a barrier for small and medium-sized companies. In addition, they argue that the PY methodology may not be suitable for all types of production, especially in highly dynamic environments where design and process changes are frequent. This suggests that the implementation of PY should be carefully evaluated in the specific context of each company.

On the other hand, Table 5 mentions that the integration of PY with other methodologies has proven to be effective in improving production processes. According to[11], [12], [23] , [15], [14] and [24], the 5S methodology is one of the most frequently implemented in conjunction with PY for continuous improvement. [14] also highlights the usefulness of Kanban, while [18] and [23]mention SMED as an effective tool for time optimization together with PY. Likewise, other methodologies such as TPM and VSM are mentioned as compatible with PY, contributing to error prevention and efficiency improvement.

However, some researchers argue that combining PY with other methodologies does not always produce the expected results. Suggests that the integration of multiple methodologies can complicate processes and generate confusion among workers, which can lead to a decrease in operational efficiency. Furthermore, the overload of methodologies can result in excessive documentation and procedures, which can demotivate employees and reduce their commitment to continuous improvement. These views indicate that, although the combination of methodologies can be beneficial, it must be managed carefully to avoid unnecessary complications.

It should be noted that a system that incorporates the PY methodology continues to present challenges in terms of efficiency for the detection of specific errors, since it requires more advanced technological capabilities that allow greater precision in the identification of faults within the implemented system [13] . This need represents a major constraint for some managers, since the investment in more sophisticated resources is usually high and many of these do not yet have a consolidated flow in the market. However, despite these limitations, the PY methodology has proven to contribute significantly to safety [17], improve the quality of services and products, reduce the generation of waste that could negatively impact the environment, and optimize repetitive activities of high stress for operating personnel, among other benefits mentioned by the authors reviewed.

Concerning bibliometric indicators, there are no points of comparison with other reviews conducted in recent years with the PY methodology as the main theme, which is why, as a discussion, the figures presented above are analyzed.

Starting from Figure 2, which tells us about the number of articles published per year in the Scopus database, as reviewed in this figure, there is an increasing trend in the level of scientific publications per year related to the PY methodology, based on the figure it can be seen that approximately 74% of publications were made in the last 6 years, with the publications until July 2024 that is increasing, likewise, it can be evidenced that starting point of the trend in the growth of scientific research related to PY starts in 2016 with 6 publications made, as in 2012, but had a drop during 2014 and 2015, that between the 2 years only 5 scientific researches were published.

Similarly, Figure 3 shows the regions and countries where the largest number of publications were made regarding the PY methodology, where 35% corresponds to India, Peru and Malaysia, countries that seek to position themselves as reliable and economically sustainable industries, as well as 14% of published research between England, USA and Brazil, developed and highly competitive countries in industrialized production processes, in these countries the PY methodology focuses on sustainable development with a green industry.

On the other hand, Figure 4 shows a great variety of approaches by the researchers of the scientific publications regarding the PY, since it is possible to observe the absence of a great concentration of citations for a specific author; those shown in the graph are researchers who have at least 3 citations.

Likewise, Figure 5 shows the affinities of the methodology, with respect to the subcategories of the lean system and lean manufacturing, since the purpose and purpose of the application of these methodologies or process philosophies are the same, to increase productivity, reduce waste or errors, to be more efficient, in this case all within the manufacturing sector.

Finally, in the case of Fig. 6, the importance of a methodology being multidisciplinary is highlighted, since the PY, apart from being of great importance for engineering, where 30% of the research published so far belongs to this area, currently 20% and growing corresponds to the area of business management and accounting, and 14% for computer science, which shows that this methodology fulfills its purpose regardless of the area it is in, which is to reduce the largest number of errors or defects in one or several processes at once.

V. CONCLUSIONS

It can be concluded that the PY methodology has wide applications in different areas of research and work, in this case, the manufacturing sector shows the positive impact of this methodology, as it applies to different levels of the organization interested in applying it.

Also, this review shows that, in several research applications, the PY methodology has an important contribution regarding quality control, which seeks to reduce the most errors in the most complicated processes, such as parts failures and defective productions, in some cases this methodology in conjunction with other methodologies and engineering tools can reduce human error to 100%.

Similarly, the integration of the PY with other methodologies such as Lean Manufacturing, Kanban, SMED, among others; seeks to increase quality, improve production and reduce the number of resources to be used, a joint work of these methodologies can achieve these three objectives, in addition to the implementation of one opens the bases to implement a system of these methodologies.

Finally, based on the publications made and the increase of more scientific investigations of the PY during the years, as well as the multidisciplinary that it can become, it is concluded that it is a methodology that has an important contribution to the industry that can be applied, under the parameters that the industry requires, The PY can be adapted in most cases and its impact becomes significant in the processes and the economy of the company that is interested in this, therefore it is rescued that continue to increase interest in this methodology and this project is support or basis to investigate further scientific research based on the PY.

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