ISSN-E: 2737-6419

Athenea Journal,
Vol. 4, Issue 11, (pp. 23-31)

https://doi.org/10.47460/athenea.v4i11.51

Smart models for cleaner production in Industry 4.0: A Scoping Review

Franyelit Suárez-Carreño
http://orcid.org/0000-0002-8763-5513
franyelit.suarez@udla.edu.ec
Universidad de las Américas, Facultad de Ingeniería y Ciencias Aplicadas, Carrera de Ingeniería Industrial
Quito-Ecuador

Marco Briceño-León
https://orcid.org/0000-0001-6900-7460
marco.briceno@udla.edu.ec
Universidad de las Américas, Facultad de Ingeniería y Ciencias Aplicadas, Carrera de Ingeniería Ambiental
Quito-Ecuador

Received (10/09/2022), Accepted (09/01/2023)

Abstract. - A scoping review is presented to know the new artificial intelligence trends in developing environmental proposals for industry 4.0. A review of 13 academic papers published in high-impact journals was carried out to evaluate the environmental proposals of expert researchers for the digitized industry. The main results show that there is a high tendency to research in the area of environmental process management, waste management, and treatments. In the material analyzed, there are no contributions from engineering developments or software developments for creating new and better materials that contribute to the environment and cleaner production plans.

Keywords: Smart models, cleaner production, industry 4.0, artificial intelligence, environmental developments.

Modelos inteligentes para una producción más limpia en la Industria 4.0: una revisión de alcance

Resumen: Se presenta una revisión del alcance para conocer las nuevas tendencias en inteligencia artificial en el desarrollo de propuestas ambientales para la industria 4.0. Se realizó una revisión de 13 documentos académicos publicados en revistas de alto impacto, para evaluar las propuestas ambientales de investigadores expertos para la industria digitalizada. Los principales resultados muestran que existe una alta tendencia hacia la investigación en torno a la gestión de procesos ambientales, gestión de residuos y tratamientos. Se observó que en el material analizado no hay aportes de desarrollos de ingeniería o desarrollos de software para la creación de nuevos y mejores materiales que contribuyan al medio ambiente y planes de producción más limpios.

Palabras clave: Modelos inteligentes, producción más limpia, industria 4.0, inteligencia artificial, desarrollos ambientales.

I. Introdución

Cleaner production is a form of industrial production that reduces the use of non-renewable resources and waste and the emission of harmful materials such as greenhouse gases and chemicals. This is achieved by adopting clean technologies, improving existing production processes, introducing new, cleaner, and more efficient production processes, and eliminating hazardous materials or processes [1]. It can help significantly reduce production costs, improve product quality, increase productivity, reduce energy consumption and operating costs, improve occupational safety and worker health, and reduce air and water pollution. These benefits can be particularly important for local businesses and small and medium-sized enterprises (SMEs) that may need more resources to invest in cleaner technologies [2].

Cleaner production is becoming a priority for many companies as it helps them improve their reputation and comply with environmental regulations. This, in turn, allows them to take advantage of new business opportunities, such as producing products with green labels, which attract consumers interested in environmental protection. It also contributes to sustainable economic growth once improved productivity and reduced production costs [3]. This, in turn, generates employment, increases competitiveness, and improves the quality of life of the population.

In short, cleaner production is a form of industrial production based on continuous improvement and reduction of pollution, energy efficiency, and the use of resources to achieve sustainable industrial production. Several countries are promoting cleaner production through initiatives such as the Kyoto Protocol, the Stockholm Convention, and the United Nations Environment Programme [3], [4]. These initiatives set goals and standards to reduce pollution and improve the energy efficiency of industrial production to achieve sustainable development. In short, cleaner production is an essential tool for sustainability and sustainable economic development. This technique helps companies improve their reputation, reduce production costs, increase productivity, and contribute to sustainable development. In addition, governments also promote cleaner production to achieve sustainable development globally.

This paper will describe the elements that characterize the cleaner production process in digitized industries and the participation of artificial intelligence in the formulation of new sustainable proposals. In this sense, this work aims to show the contributions of artificial intelligence in cleaner production processes in the new business and industrial vision. Therefore, it consists of four main sections, the introduction, where the essential elements of the study problem have been described. A second section, where the theoretical aspects that support this research will be described, then the methodology and the results obtained are reflected to expose the conclusions finally.

II. Industry 4.0 and its participation in environmental improvements

Industry 4.0 focuses on increasing efficiency and productivity using digital and connected technologies to improve production processes. This is achieved by connecting production systems, automating processes, and collecting and analyzing data [4]. This also allows production to be more flexible and production changes faster. In addition, Industry 4.0 also cares about the environment. This is achieved by reducing production costs, which reduces the energy and resources needed to produce a product. It is also achieved through using renewable energy to power production systems. This helps reduce carbon emissions and other greenhouse gases, minimizing environmental impact [5], [4].

Thus, Industry 4.0 is concerned with efficiency, productivity, and the environment. This makes it an ideal solution for companies looking for more sustainable production. In addition, this technology also helps to improve product quality, which contributes to higher customer satisfaction.

This, in turn, improves the image of the company and its financial results. In summary, Industry 4.0 is a solution that brings benefits both in terms of productivity and sustainability. This makes it an ideal solution for any company looking to improve production [6], [7].

In addition, this technology also helps to improve the quality of the product, which contributes to greater customer satisfaction and improves the image of the company and its financial results. For these reasons, Industry 4.0 is an ideal solution for any company looking to improve its production. In conclusion, Industry 4.0 offers an ideal solution for companies looking to improve their products and care about the environment [6], [8]. This technology offers benefits in terms of productivity and sustainability, as well as contributing to improving product quality, customer satisfaction, and the company's financial results. For this reason, Industry 4.0 is an ideal solution for all those companies that want to improve their products responsibly.

A. Industry 4.0 and cleaner production

Industry 4.0 is a new industrial revolution that combines information and communication technologies (ICT) and automation to improve productivity, efficiency, and quality [9]. This is achieved by optimizing production processes, reducing errors, improving customer service, and reducing costs. This industrial revolution also allows the production of higher-quality products with fewer resources. Cleaner production is a concept related to Industry 4.0. It is a systemic approach to industrial production that improves productivity and efficiency by reducing waste, risks, and environmental costs [5], [10]. This involves a design approach focusing on reducing pollution and energy use, improving production processes, and using more efficient materials to reduce environmental impact. This contributes to the sustainability of industrial production [11].

Finally, Industry 4.0 and cleaner production are directly related. Industry 4.0 enables greater efficiency and productivity by automating production processes, while cleaner production focuses on reducing waste, risks, and environmental costs [12]. This contributes to the sustainability of industrial production. These concepts promote industrial innovation and produce higher-quality products with fewer resources [13]. This helps to improve the competitiveness of companies, reduce costs and improve the efficiency of production processes.

B. Artificial intelligence in the industry

Artificial intelligence is projected to play an essential role in cleaner production through process automation and resource optimization. For example, AI is expected to help reduce energy consumption and carbon emissions by optimizing energy efficiency in factories and implementing green technologies [14]. AI is also expected to help improve waste management and material recovery. In addition, AI is expected to assist the industry in decision-making and sustainable planning.

Artificial intelligence [15] plays an essential role in generating eco-sustainable materials, as it can help identify new ways to produce materials with less environmental impact. Some examples of how AI is used in the generation of eco-sustainable materials include:

Material design: AI can help design new materials with specific properties, such as higher strength or lower environmental impact [16].

Production processes: AI can help optimize production processes to reduce energy consumption and waste [2].

Recycling: AI can help improve material recycling by automated material identification and optimization of separation processes [15].

AI is expected to create a circular economy where waste is turned into valuable resources through advanced technologies [17].

A circular economy process with AI could include the following stages:

Waste collection and sorting: AI could use machine learning and image processing technologies to automatically sort waste and separate it by type. This could help reduce the time and costs associated with manual sorting [14].

Optimization of recycling processes: AI could use algorithms to optimize recycling processes and maximize the recovery of valuable materials [18]. For example, you could use machine learning techniques to predict the best method for each type of waste and adjust the processing parameters accordingly.

Material design: AI could use machine learning techniques to design new materials from recycled waste [11]. This could help reduce dependence on natural resources and create new sustainable products and solutions.
Demand prediction: AI could use machine learning techniques to predict future demand for products and materials, helping the industry plan production and resource use more efficiently.

Monitoring and evaluation: AI could use data analysis techniques to monitor and evaluate the performance of circular economy processes and determine areas for continuous improvement.

Overall, the use of AI in the circular economy could help improve efficiency and sustainability at all stages of the product lifecycle, from production to recycling and the design of new materials [15], [17], [14], [19].

III. Methodology

In this work, a non-in-depth literature review was carried out to know what contributions artificial intelligence offers to the best environment within industry 4.0 to initiate new research. Scientific articles from primary sources were evaluated, showing interest in formulating new proposals that help the best climate in the digital sector. Figure 1 presents the characteristics of the references made, taking into account the sources and the contributions they offer.

The research carried out is simplified, with the fundamental purpose of evaluating the conceptual knowledge, theories, or characteristic elements of artificial intelligence as a tool for the generation of sustainable environmental proposals in industry 4.0. To this end, the methodology proposed by Kirtchenham and Okoli, and Schabram on desk review, which in practice is similar to the PRISMA [11] (Preferred Reporting Items for Systematic reviews and Meta-Anayses) review model, was considered. The proposed method consists of three phases: planning, development, and reporting of the systematic review, which are carried out following eight steps for its execution: determine the purpose of the evaluation; define the protocol and training; Perform literature search; screening for inclusion; quality assessment; data extraction; study synthesis and review writing.

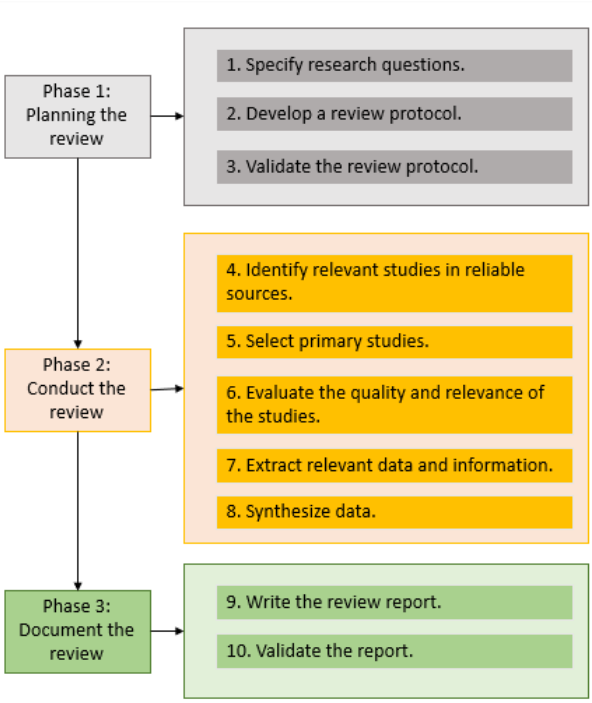

Fig. 1. Methodology proposed by Kirtchenham and Okoli and Schabram [11]

Phase 1: In this phase, the research questions have been defined, considering the relevance and timeliness of the topic of study, in this sense the questions posed are:

Q1: How does artificial intelligence participate in cleaner production processes in Industry 4? 0?
Q2: How do smart models look in environmental proposals for Industry 4. 0?
Q3: What variables have been considered in the new proposals for intelligent models for clean production?

The search process consists of conducting research of scientific documents that allow finding studies related to the subject of study, specifically in the environmental area for industry 4.0 and the contributions of artificial intelligence in this regard. In addition, the search is limited to the most recent years, from 2020 to 2023, as it is a current topic, it is intended to analyze the new proposals for intelligent models for cleaner production in the digitized industry. The Scopus database and the publications of the Elsevier publishing house that were open access were used.

A first search chain was defined based on the title and central field of the subject studied, with these elements the search chain is redefined considering the titles found, the keywords, the referenced studies, to finally achieve the following search chains:

- Smart AND modelsAND for AND cleaner AND production AND inAND industry 4.0 (6 documents).
- Artificial AND intelligence AND inAND environmental AND proposals (153 documents).
- Smart AND models AND environment (190 documents).

In Table 1, the first results found in different Scopus journals are sampled, only in the year 2023.

Table 1. Length as a function of time, (a) theoretical valúes, (b) experimental values.

Revista	Artículos
Mathematics	1
Journal of Cleaner Production	5
Sustainability	1
The 5th International Workshop on Environment and Geoscience	1
Procedia Computer Science	1
International Journal of Organizational Analysis	1
International Journal of Environmental Research and Public Health	1
Machines	1
Science of the Total Environment	1
Proceedings - 25th ACM/IEEE International Conference on Model Driven Engineering Languages and Systems, MODELS 2022	1

The manuscripts analyzed were classified according to the year of publication, in addition to the journal where it was published, the corresponding database, the number of citations, the methodology used, where experimental research, industrial case studies, and bibliographic reviews had priority.

The primary research was obtained through a chain of queries from the research questions. To know the findings of the articles and the quality of the topics, four criteria were applied: population, intervention, comparison, and outcome (PICO). In this sense, the population refers to published studies. The intervention is related to artificial intelligence and cleaner production in the new proposals of industry 4.0. The comparison refers to carefully selected studies with artificial intelligence in environmental proposals and the type of research. The result includes published studies on artificial intelligence in new environmental developments and its participation in Industry 4.0; based on PICO, five new questions were asked to ensure the quality of the extracted articles, as shown in Table 2.

Table 2. Evaluation of the quality of the documents analyzed.

Quality Control (QA)	Quality Assessment Questions	Answer
QA1	Does the paper describe the contributions of artificial intelligence to the new industry 4.0 environmental proposal?	(+1) Yes/ (+0) No
QA2	Does the document specify the characteristics of artificial intelligence developments in environmental proposals?	(+1) Yes/ (+0) No
QA3	Does the paper present any discussion of the findings surrounding artificial intelligence in environmental developments in industrial 4.0?	(+1) Yes/ (+0) No
QA4	Are the limitations present in the current environmental proposals of Industry 4.0 considered?	(+1) Yes/ (+0) No
QA5	Are future projections made for new industry 4.0 environmental proposals?	(+1) Yes/ (+0) No

The inclusion and exclusion criteria aim to find significant primary documents to answer the research questions posed. The agreement between the evaluators was resolved by applying Cohen's Kappa coefficient = 0.5 with a percentage of agreement of 87.1%, which implies a moderate agreement among the evaluators.

The inclusion criteria were that the preliminary research is associated with publications in journals on the contributions of artificial intelligence in the new environmental proposals for industry 4.0, that the year of publication is recent, between 2019 and 2022, that the document is presented in a high-impact journal, preferably in English. While the exclusion criteria were the preliminary study is limited, literature review articles and similar articles from different sources.

IV. Results

The documents analyzed to show that artificial intelligence offers an essential contribution to the generation of new environmental proposals for industry 4.0. In this sense, the review showed that many investigations are being carried out around the opportunities offered by artificial intelligence in environmental applications. It was mainly found that the proposals are framed in process and quality management, noting that many challenges for new materials and engineering developments have yet to be substantially defined, just as no proposals for software developments with artificial intelligence that contribute to new research.

The research is only an outline to open future work since the development of new materials that could be designed using artificial intelligence will have to be considered. Some examples might include:

Bioplastics: AI could help design bioplastics from organic waste, such as agricultural or food waste. These bioplastics could be used in various applications, such as packaging and single-use products. That the study of the following materials can also be included within the category of bioplastics:

Polyathide polyester (PLA): This bioplastic is produced from organic substrates such as sugar cane or beets and is one of the most common bioplastics. It is biodegradable and used in various applications, including packaging and single-use products.

Aliphatic polyester (PBAT): This bioplastic is produced from a mixture of polylactic acid and aliphatic polyester polyesters. It is biodegradable and is mainly used in packaging applications.

.

Polyactidic acid (PHA) polyester: This bioplastic is biodegradable from microorganisms metabolizing carbohydrates. It is used in various applications, including packaging, single-use products, and toys.

Cellulose polyester (Cellulose): This bioplastic is biodegradable from wood pulp or plant cellulose. It is used in stationery and packaging applications.

Starch-based: This bioplastic is biodegradable from cereal or tuber starch. It is used in various applications, including packaging, single-use products, and toys.

Composite materials: AI could help design new composite materials from recycled and natural waste. These materials could have improved properties, such as increased strength and lower environmental impact.

Building materials: AI could help design new building materials from recycled waste, such as glass, plastic, and metal. These materials could be used in various applications, such as ceilings and flooring.

Hybrid materials: AI could help design new hybrid materials that combine the properties of different existing materials, improving their characteristics and performance.

Superconducting materials: AI could help design new superconducting materials with improved characteristics, such as increased energy efficiency and transmission capacity.

Overall, using AI to design new materials could help create more sustainable and efficient solutions, reducing environmental impact and increasing the efficiency of production processes.

The answers to the research questions resolved from the analysis to the studies collected in the literature review are presented below. Q1 How does artificial intelligence participate in cleaner production processes in Industry 4. 0? The documents analyzed show that the most significant participation is being presented in the management of processes and products, improvements in waste treatment, and process management that optimize productivity. Q2: How do intelligent models look in environmental proposals for Industry 4. 0? The documents analyzed show that intelligent models have a long way to go, and their development and participation in Industry 4.0 as an alternative for cleaner production is still incipient. Q3: What variables have been considered in the new proposals for intelligent models for clean production? The review showed that the main variables analyzed are occupational health and safety and the human-machine relationship for production improvement.

A high percentage of the works analyzed (64%) shows that process management for improvements in production, occupational safety, and health within environmental contexts are the most studied aspects concerning cleaner production in industry 4.0. It is essential to continue with extensive studies on artificial intelligence and its contribution to environmental improvements. Hence it is also necessary to include engineering developments that directly influence products and services for cleaner production.

Conclusions

The review is fundamental and needs to include an in-depth analysis of the selected articles. However, it allowed the yielding of relevant results that characterize the contributions of cleaner production in industry 4.0.

The analyzed documents reveal a more significant trend of studies that focus on managing environmental processes, waste treatment, and production management using intelligent tools rather than developing engineering proposals that affect the composition of materials and promote other treatment alternatives.

The limitations of this work lie in the fact that only contributions in English and open access were analyzed, ruling out possible contributions from other countries, which could include the development of intelligent software that offers new materials and waste reduction models.

References

[1] Y. Aleman, P. Alarcon, G. Monzon, and K. Pastor., «Education priorities in the wake of the COVID-19 Pandemic,» Minerva Journal, vol. 2, nº 5, pp. 5-12, 2021.
[2] C. A. Ávila-Samaniego and M. F. Granda-Juca, «Adopción de Tics y sus Efectos sobre los Procesos en las Pymes. Una Revision de Literatura,» Revista Polo del Conocimiento, pp. 1287-1303, 2022.
[3] Banco Mundial, «Banco Mundial,» 17 agosto 2022. [En línea]. Available: https://www.bancomundial.org/es/home.
[4] M. Dini and G. Stumpo, Mipymes en América Latina: un frágil desempeño y nuevos desafíos para las políticas de fomento, Santiago de Chile: CEPAL, 2021.
[5] J. González-Mendoza, J. Sánchez-Molina and M. Cárdenas-García, «Pensamiento estratégico y restructuración industrial.,» Desarrollo Gerencial, pp. 1-20, 2022.
[6] O. Flor, H. Tillerías, B. Mejía, C. Proaño, M. Rodriguez, F. Suarez and C. Chimbo, «Impact of Industrial Automation in Employability,» IEEE Xplore, pp. 157-162, 2022.
[7] V. Tripathi, S. Chattopadhyaya, A. Mukhopadhyay and S. Sharma, «A Sustainable Methodology Using Lean and Smart Manufacturing for the Cleaner Production of Shop Floor Management in Industry 4.0,» Mathematics, vol. 10, nº 347, 2022.
[8] A. Garzón-Posada, M. Jiménez-Ramírez and L. Gómez-Campos, «Redes de colaboración empresarial para pymes,» Revista Facultad de CIencias Económicas, 2022.

[9] J. Lemos, P. Gaspar, and T. Lima, «Environmental Risk Assessment and Management in Industry,» Machines, vol. 10, nº 702, p. 103390, 2022.
[10] J. Ramírez, V. López, S. Hernández and M. Morejón, «LEAN SIX SIGMA E INDUSTRIA 4.0, UNA REVISIÓN DESDE LA ADMINISTRACIÓN DE OPERACIONES PARA LA MEJORA CONTINUA DE LAS ORGANIZACIONES,» UNESUM Ciencias, pp. 151-168, 2021.
[11] G. Tebes, D. Peppino, P. Becker y L. Olsina, «Especificación del Modelo de Proceso para una Revisión Sistemática de Literatura . Specifying the Process Model for a Systematic Literature Review,» Universidad Nacional de la Pampa, La Pampa, 2019.
[12] M. Ramirez, F. Suárez y E. Ascencio, «Enseñanza de diseño de procesos para la industria 4.0,» Rev. Univer.Cienc.Tecnologia, pp. 129-136, 2021.
[13] D. Mendoza, Y. Rojano y E. Salas, «El pensamiento estratégico como herramienta de innovación tecnológica en las PYMES,» Sotavento MBA, pp. 50-65, 2018.
[14] J. Mora, «La Evolución de la Inteligencia Artificial,» 2016. [Online]. Available: https://mundocontact.com/la-evolucion-de-la-inteligencia-artificial/.
[15] B. Martín del Brío, «Redes Neuronales y Sistemas Borrosos,» Eds Ra-Ma, pp. 43-47, 2001.
[16] A. Álvarez, G. Rego, J. Leira, A. Gomis, R. Caramés y M. Andrade, «Innovación Turística: Perspectivas Teóricas y Objetos de Estudio,» ROTUR, pp. 19-50, 2018.
[17] D. Montaño, «Evaluation digital of tolos for the management the portafolio educational,» Minerva Journal, vol. 2, nº 4, pp. 55-61, 2021.
[18] M. Pérez, «¿Podremos crear máquinas verdaderamente inteligentes?,» 2018. [Online]. Available: https://elpais.com/tecnologia/2018/03/27/actualidad/1522139782_730950.html..
[19] J. Sanz, «Qué es la Lingüística Computacional,» 2018. [Online]. Available: http://www.full-on-net.com/blog/inteligencia-artificial/qu-es-la-lingstica-computacional.