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Building a sustainable future: the relationship between industrial production and sustainability

-Construindo um futuro sustentável: a relação entre a produção industrial e a sustentabilidade

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ABSTRACT

This study aims to analyze the relationship between human industrial production and sustainability, considering the concepts of Industry 4.0, Manufacturing, Green Marketing, and the Sustainability Triple Bottom Line, to identify innovative and sustainable solutions for manufacturing goods. The methodology adopted is a bibliographic review of specialized literature, emphasizing sustainability and discussing it from social, environmental, and economic aspects. A balanced approach to these three pillars is proposed, seeking a conscious, responsible, and integrated manufacturing that is aligned with the interests of society and the planet. Opportunities for innovation and reducing environmental and social impacts are presented through Industry 4.0, Manufacturing, and Green Marketing. The Sustainability Triple Bottom Line highlights the importance of social responsibility, environmental preservation, and economic viability. It is crucial that all stakeholders involved in industrial production commit to adopting sustainable and innovative solutions that promote a balanced and prosperous future. This study emphasizes the urgency of responsible manufacturing practices, which are essential for sustainable development in the 21st century.

Keywords: Industry 4.0; Green Marketing; Industrial production; Manufacturing; Sustainability; Sustainability Tripod .

RESUMO

Este estudo tem como objetivo analisar a relação entre a produção industrial e a sustentabilidade, levando em consideração os conceitos de Indústria 4.0, Manufatura, Marketing Verde e a abordagem da Sustentabilidade Triple Bottom Line. O objetivo principal é identificar soluções inovadoras e sustentáveis para a fabricação de bens no contexto empresarial, a fim de conciliar o desenvolvimento econômico com a preservação ambiental e a responsabilidade social. A metodologia adotada baseia-se em uma revisão bibliográfica da literatura especializada, com ênfase na sustentabilidade e na análise dos aspectos sociais, ambientais e econômicos relacionados à produção industrial. Busca-se uma abordagem equilibrada desses três pilares, com o propósito de promover uma fabricação consciente, responsável e integrada, alinhada às

demandas da sociedade e aos princípios de preservação do meio ambiente. No estudo são apresentadas oportunidades de inovação e de redução dos impactos ambientais e sociais por meio da aplicação dos princípios da Indústria 4.0, das estratégias de Manufatura sustentável e das práticas do Marketing Verde. Destaca-se a relevância do conceito Triple Bottom Line da Sustentabilidade, o qual enfatiza a importância da responsabilidade social, da preservação ambiental e da viabilidade econômica como critérios essenciais para a busca da sustentabilidade no âmbito empresarial. É imprescindível que todos os stakeholders envolvidos na produção industrial assumam o compromisso de adotar soluções sustentáveis e inovadoras, visando promover um futuro equilibrado e próspero. Este estudo ressalta a urgência da implementação de práticas de fabricação responsáveis, as quais desempenham um papel fundamental no desenvolvimento sustentável no século XXI.

Palavras-chave: Indústria 4.0; Marketing verde; Produção industrial; Manufatura; Sustentabilidade; Triple Bottom Line.

INTRODUÇÃO

Human manufacturing is a process that involves from the conception of the product to its production and distribution, using human labor (COSTA, 2019). With a focus on the third millennium, the discussion focuses on future trends and challenges in human manufacturing, with emphasis on the importance of sustainability.

With the advent of artificial intelligence, the industrial productive means undergo a significant transformation, with the automation of processes and the use of increasingly advanced technologies, such as those brought by Industry 4.0 (SANTOS *et al.*, 2020). Human manufacturing, which involves the participation of human labor in the entire production process, can be optimized with the use of intelligent systems.

Artificial intelligence within the advances of industry 4.0 can be applied in the design of the product, through computer-aided design tools (CAD, CAE etc.), which assist in the creation of virtual models, in the simulation of production scenarios and in the creation of prototypes (OLIVEIRA *et al.*, 2019). In addition, the use of industrial robots and computer vision systems in production can increase the efficiency and accuracy of processes (ZHOU *et al.*, 2021).

However, in this case it is important to consider that the adoption of artificial intelligence in human manufacturing also brings challenges in relation to the safety of workers and ethics in the use of data. It is necessary to ensure that the automation of processes does not endanger the physical integrity of workers and that the data collected are used responsibly and transparently (MACCARI *et al.*, 2020).

In addition, sustainability is an increasingly relevant topic in human manufacturing and artificial intelligence can contribute to reducing the environmental impact of production processes. For example, the use of energy optimization algorithms can reduce electricity consumption and greenhouse gas emissions (HOU *et al.*, 2021). The adoption of artificial intelligence in human manufacturing can bring several benefits in terms of efficiency and sustainability, especially when considered in the context of Industry 4.0 and the tripod of sustainability.

The tripod of sustainability is composed of the economic, social, and environmental dimensions (MMA, 2019). The adoption of artificial intelligence can contribute to sustainability in these three dimensions, through the optimization of energy consumption, the reduction of waste and the increase of worker safety (BORGES *et al.*, 2020). However, it is important to consider that the implementation of artificial intelligence systems in human manufacturing can also bring ethical and safety challenges. It is necessary to guarantee data privacy and avoid discrimination,

in addition to ensuring the safety of workers in relation to automated machines and robots (COSTA, 2021).

The adoption of artificial intelligence in human manufacturing can bring significant benefits in terms of efficiency, sustainability, and Industry 4.0. However, it is necessary to carefully consider the ethical and safety challenges involved in the implementation of these technologies, as well as the need to promote Green Marketing practices and incorporate the *Triple Bottom Line* (society, environment, and profitability) in all phases of production, to ensure the long-term sustainability of production processes (SILVA; SAINTS, 2021).

The guiding question of the study is "What is the relationship between the concepts of human industrial production and sustainability in the third millennium?". The methodology used in the production of the text of this study is fundamentally theoretical, based on reflections and concepts on sustainable human manufacturing and its application in the third millennium. The intention is to include topics relevant to the topic addressed, such as Industry 4.0, Green Marketing, the Triple Bottom Line (TBL) and Sustainability, to provide a broader and updated view on the subject.

METHODOLOGY

The appropriate research methodology for the text in question is the bibliographic review. To achieve the goal of exploring the relationship between the concepts of human industrial production and sustainability in the third millennium, the author has compiled a series of ideas and theoretical concepts. For this, it was based on principles such as waste reduction, conservation of natural resources, reduction of carbon footprint and promotion of social equity, which were obtained through the bibliographic review of articles, books and other materials related to the theme (REIS *et al.*, 2019). The bibliographic review is a methodology that allows the identification and critical analysis of the existing scientific and technical literature on a given theme, being fundamental for the construction of scientific knowledge (GIL, 2010).

This study aims to theoretically analyze the relationship between sustainable human manufacturing and sustainability in the third millennium, to encourage the adoption of sustainable practices in industrial production. The methodology adopted is based on reflections and concepts related to the theme in question, such as Industry 4.0, Green Marketing, the Triple Bottom Line (TBL) and Sustainability (GONÇALVES; MACHADO, 2019).

It is important to highlight that the ideas and concepts addressed in this study can be applied in practice. In this sense, the theoretical methodology can be complemented by empirical

practices and observation of real cases, enabling a more effective application, and adapted to the reality of each company or organization (CRESWELL, 2014).

In summary, this study aims to foster sustainable human manufacturing, integrating both theory and practice, and encouraging the adoption of sustainable practices in industrial production. Thus, it is emphasized that the methodology used in this study is based on reflections and theoretical concepts, but that empirical practices and observation of real cases can enrich the analysis and improve the actions and decisions taken in practice (EISENHARDT, 1989).

MANUFACTURING

Manufacturing, in general, is the process of transforming raw materials into finished products through various stages such as design, production, and distribution. The difference between human and non-human manufacturing lies in the fact that non-human manufacturing is conducted primarily by machines and automation, while human manufacturing is conducted by human workers (PATEL, 2020). Non-human manufacturing is considered more efficient and accurate than human manufacturing, since machines can perform repetitive tasks faster and more consistently than a human worker (PATEL, 2020). However, human manufacturing offers an advantage in terms of flexibility and adaptability, as human workers can adjust the production process in real time and make decisions based on sensitive information such as product quality (DAVIS; EDISON, 2021).

As far as sustainability is concerned, human manufacturing may be more socially and environmentally sustainable than non-human manufacturing. This is because non-human manufacturing may require a large consumption of energy and natural resources to operate the machines, as well as generating substantial amounts of waste and pollutant emissions (LIAO *et al.*, 2021). On the other hand, human manufacturing may involve the adoption of sustainable practices such as the use of recycled materials and the promotion of fair work and safe working conditions for workers (KLEIN *et al.*, 2020). In addition, human manufacturing can help create jobs and support the local economy, which can contribute to social sustainability (DAVIS; EDISON, 2021).

The use of additive manufacturing in prototyping is revolutionizing product production, allowing you to create customized and complex objects with less waste of raw material and reduced time (NANDY *et al.*, 2021). To reach its full potential, it is necessary to integrate it into Industry 4.0, which involves the digitalization and automation of production processes (ZHANG *et al.*, 2019). The use of sensors, internet of things (IoT) and artificial intelligence allows factories to become more efficient and connected, enabling on-demand and customized production (VAN

HOORN *et al.*, 2019). Artificial intelligence is essential in Industry 4.0, enabling the analysis of enormous amounts of data and real-time decision-making (GARG *et al.*, 2019).

In additive manufacturing, artificial intelligence can optimize the printing process by identifying faults and adjusting settings for more accurate and efficient production (FAN *et al.*, 2018). The combination of these three technologies brings significant benefits, such as cost reduction, increased productivity, and improved product quality (SHAHIN *et al.*, 2019), in addition to opening new possibilities for the creation of innovative solutions and boosting the competitiveness of companies in the global market.

The combination of additive manufacturing, Industry 4.0 and sustainable human manufacturing brings significant benefits to the environment, the economy and society (LIAO *et al.*, 2021). The use of additive manufacturing reduces the waste of raw material and energy (KLEIN *et al.*, 2019), while Industry 4.0 promotes a more efficient and customized production (TEIXEIRA, R. L. P. *et al.*, 2019; ZHANG *et al.*, 2019). In turn, sustainable human manufacturing seeks to reconcile industrial production with the preservation of the environment and social development (XU *et al.*., 2021), allowing for a fairer and more balanced production.

The assertion that the combination of additive manufacturing, Industry 4.0 and sustainable human manufacturing brings significant benefits to the environment, the economy and society can be supported by several references. For example, according to research conducted by researchers at Purdue University, additive manufacturing is a technology that allows you to significantly reduce material and energy waste compared to traditional manufacturing processes (GEBISA EJECTA *et al.*, 2020).

In addition, the literature also points out that Industry 4.0 can promote a more efficient and customized production, reducing production time, waste, and costs (Kagermann *et al.*, 2013). Sustainable human manufacturing is an approach that seeks to reconcile industrial production with the preservation of the environment and social development, allowing a fairer and more balanced production (MOHANTY *et al.*, 2018).

As for the role of artificial intelligence in realizing sustainable human manufacturing, there is a lot of research that highlights its potential. For example, according to a study conducted by researchers at Stanford University, artificial intelligence can help in identifying opportunities for resource optimization and waste reduction, contributing to the financial sustainability of companies (ZHAO *et al.*, 2019).

In addition, the literature also points out that artificial intelligence can contribute to the improvement of employees' working conditions, allowing workers to focus on tasks that require more specialized skills (BRYNJOLFSSON; MCAFEE, 2014). Finally, regarding its role in the environmental dimension, studies indicate that artificial intelligence can be used to optimize

energy consumption and waste management, reducing the environmental impact of manufacturing (WANG *et al.*, 2018).

TRIPOD OF SUSTAINABILITY AND INDUSTRY 4.0

Industry 4.0 is a technological concept that emerged in Germany in 2011 and aims to improve industrial production using advanced technologies such as IoT, Big Data and cloud computing (FORSCHUNGSUNION, 2013). In addition to the technologies mentioned, artificial intelligence (AI) is also an important contribution to manufacturing in Industry 4.0 (TEIXEIRA; TEIXEIRA, 2022; Gartner, 2019). Through real-time data analysis, AI can optimize production, improve product quality, and reduce costs (ACCENTURE, 2019). In addition, AI can also be used to identify and correct potential problems in production before they even occur, increasing efficiency and reducing waste (PWC, 2018).

AI can be employed in manufacturing in several areas, including predictive maintenance and advanced robotics (Accenture, 2019). Predictive maintenance uses sensors and algorithms to predict equipment failures, allowing them to be repaired before they affect production (PWC, 2018). This approach increases equipment availability and reduces downtime, contributing to productive efficiency (ACCENTURE, 2019). Advanced robotics enables the use of AI-equipped robots to perform complex and varied tasks, adapting quickly to changes in production and increasing the flexibility of the production line (FORSCHUNGSUNION, 2013).

The recommendations for the implementation of Industry 4.0 presented to the German federal government in 2013 were developed with the aim of improving the efficiency and competitiveness of German industrial production in the global market (BAUERNHANSL *et al.*, 2014). However, it is necessary to consider that sustainability must be present in all stages of the production process, from the design to the distribution of products (WITJES *et al.*, 2016). It is important to highlight that Industry 4.0 technologies must be applied responsibly and sustainably (TAO *et al.*, 2018). It is critical to ensure that the benefits of smart production are achieved without harming the environment or worker safety (BAI *et al.*, 2020). Therefore, it is necessary to think of solutions that can ensure a balance between productive efficiency and environmental preservation (SACCO *et al.*, 2020). Technological advancement cannot be dissociated from the concern with sustainability. It is necessary, therefore, to seek solutions that meet the needs of the present without compromising the well-being of future generations in all its dimensions, promoting social inclusion, environmental preservation, and sustainable economic development.

Industry 4.0 is considered a natural evolution of the industrial revolution that occurred in the eighteenth century, with the introduction of steam engines (SCHWAB, 2016). The second industrial revolution, in the early twentieth century, was marked by mass production and

electrification. The third industrial revolution, in the 1970s, brought automation and information technology (RIFKIN, 2011). Now, the fourth industrial revolution, with Industry 4.0, is bringing the integration of systems, machines, and people, through connectivity (CONCEIÇÃO *et al.*, 2022). It promotes a radical change in the way industrial production is conducted, with the introduction of technologies that allow more efficient communication and better use of data (HERMANN *et al.*, 2016). The internet of things (IoT) allows devices to communicate with each other, creating an intelligent network that can collect and transmitting data in real time. Big Data, in turn, can process and analyze enormous amounts of data, generating valuable information for decision making (LI *et al.*, 2018). In addition, Industry 4.0 promotes systems integration, allowing information to be shared between different areas of the company, optimizing production, and reducing response time.

Industry 4.0 promotes the integration of systems, allowing information to be shared between different areas of the company, optimizing production, and reducing response time (TEIXEIRA; TEIXEIRA, 2022; WANG; WANG, 2021). Cloud computing enables remote access to this data, making real-time collaborative work possible (GARG *et al.*, 2020). It has a strong focus on the security and reliability of systems, with the introduction of advanced cybersecurity and data backup technologies (PETER *et al.*, 2019). This ensures that information is protected from attacks and failures, keeping production up and running.

Industry 4.0 is a technological revolution that is transforming industrial production worldwide, making it more efficient, collaborative, and safe (TEIXEIRA, 2021; KAGERMANN *et al.*, 2013). Its implementation can be a great challenge for companies, but it brings great benefits in terms of competitiveness and efficiency in the global market (HANSEN *et al.*, 2018). It is a high-tech strategy that aims to improve the efficiency and sustainability of industrial production (DE OLIVEIRA *et al.*, 2021; SINGH *et al.*, 2020). Although sustainability is not linked to Industry 4.0, it can be achieved by optimizing production and incorporating concepts of social and environmental responsibility (MÜLLER *et al.*, 2018). In addition, Industry 4.0 can lead to more efficient and profitable processes that are socially and environmentally responsible (KÜHLMANN *et al.*, 2021).

Countries such as the United States, Germany and China are among the world leaders that are renewing their industries for Industry 4.0. The American strategy is known as Advanced Manufacturing, in China as Made in China, and in Germany as Industry 4.0 (WANG et al., 2017). Industry 4.0 incorporates a set of innovative technologies connected to the internet, with the aim of making production systems more efficient, flexible, and sustainable (VORSTIUS *et al.*, 2019). By incorporating advanced technologies, such as IoT and Big Data, it is possible to promote a balance between the economic, social, and environmental dimensions, which are fundamental for sustainable development (TEIXEIRA *et al.*, 2022; UN, 1987).

In this sense, Industry 4.0 can be an important ally in the search for more efficient and sustainable processes in various sectors, including transportation, logistics and agriculture (BRAGA *et al*., 2020). In addition, the tripod of sustainability, which integrates the three dimensions mentioned, can be a useful tool to evaluate the economic, social, and environmental performance of an organization (ELKINGTON, 1997). In this way, Industry 4.0 can be an important strategy to promote a more sustainable future, when combined with the tripod of sustainability (BRAGA *et al*., 2020).

The concept of the Triple Bottom Line (TBL) is related to the sustainability tripod model and the UN Sustainability Manifesto. According to Elkington (1997), TBL is a concept that proposes that companies evaluate their performance not only based on their financial profits, but also on their social and environmental impact. The tripod of sustainability is a holistic model that seeks to balance the economic, social, and environmental dimensions to achieve sustainable development (WCED, 1987).

The Manifesto on Sustainability, launched by the UN in 1987, defined sustainable development as one that meets the needs of the present without compromising the well-being of future generations in all its dimensions: economic, social, and environmental (WCED, 1987). This manifesto emphasized the need for more balanced and sustainable development, considering the needs of present and future generations.

The TBL is a valuable tool for companies to evaluate their performance in relation to the economic, social, and environmental dimensions of the sustainability tripod, in line with the recommendations of the Sustainability Manifesto. According to Elkington (1997), by considering the three dimensions in an integrated way, companies can promote a sustainable and balanced development, meeting the needs of the present without compromising the well-being of future generations.

In other words, TBL refers to the "triple bottom line," that is, the idea that companies should measure their performance not only based on financial profits, but also in relation to their social and environmental impact. Thus, TBL emphasizes the importance of sustainability in all its dimensions, and not only from a financial point of view (ELKINGTON, 1997).

Therefore, the TBL and the tripod of sustainability are related since both emphasize the importance of sustainability in all its dimensions. By adopting the concept of TBL, companies can evaluate their performance not only in relation to financial profit, but also in relation to their social and environmental impact, which is in line with the tripod of sustainability. In this way, TBL can be seen as a valuable tool to promote sustainability in all its dimensions and contribute to long-term sustainable development. (TEIXEIRA *et al.*, 2022; ELKINGTON, 1997; WCED, 1987).

GREEN MARKETING AND SUSTAINABILITY

Green marketing, according to Kotler *et al.* (2017), is a strategy that can contribute to the promotion of sustainability in the market. This approach has become increasingly relevant in a context in which society seeks more conscious and responsible alternatives in relation to the environment and society, as pointed out by Silva, Teixeira and de Araújo Brito (2022). In this sense, the consideration of the tripod of sustainability, which encompasses the social, environmental, and economic dimensions, is essential to achieve the necessary balance for sustainable development and for the survival and success of companies in the long term, as defended by Elkington (1998).

In this context, corporate social responsibility is an important part of green marketing, as it involves the permanent commitment of companies to adopt ethical behavior and contribute to economic development, while simultaneously improving the quality of life of their employees, their families, the local community, and society in general, as stated by Carroll (1991). The ISO ABNT NBR 26000 standard is an important reference for the practice of corporate social responsibility and can be a useful tool for companies that wish to adopt sustainable practices and promote green marketing. To substantiate the importance of green marketing, it is possible to cite Kotler *et al.* (2017), who state that this strategy aims to promote products or services that are environmentally correct and sustainable (BARBOSA; SILVA; TEIXEIRA, 2022). The adoption of green marketing is a growing trend in the market, as sustainability is an increasingly important topic in the current context, with society seeking more conscious and responsible alternatives in relation to the environment and society.

In addition, one can mention the importance of the tripod of sustainability, which involves the social, environmental, and economic dimensions, as mentioned by Elkington (1998). The balance between these dimensions is fundamental for the promotion of sustainable development and for the long-term survival and success of companies.

Regarding the "4 Ss" of green marketing, one can cite Carroll (1991) to substantiate the importance of social acceptance of products and services, since the company must be able to demonstrate that its products and services are socially responsible and compatible with society's expectations. In addition, the ISO ABNT NBR 26000 standard can be mentioned as an important reference for the practice of corporate social responsibility, which is an important part of green marketing.

ENVIRONMENTAL MANAGEMENT SYSTEM AND ISO 14000

In recent years, there has been a growing concern of society in relation to the environment and sustainability. In this context, green *marketing* emerges as a fundamental strategy for companies that want to stand out in the market and align with new consumer demands. According to Kotler *et al.* (2017), green marketing consists of promoting products or services that are environmentally friendly and sustainable. This strategy aims to show consumers that the company cares about the environment and the society in which it operates, and that it seeks to offer solutions that minimize the environmental impact of its products or services.

The adoption of green marketing has become an increasingly strong trend in the market, and companies from various sectors have invested in marketing strategies that value sustainability. This is due to changing consumer behavior, which is increasingly concerned about environmental and social issues. Green marketing can also bring several benefits to the companies that adopt it. In addition to contributing to the construction of a positive image of the company before society, this strategy can generate significant savings in terms of natural resources and waste reduction (SILVA; TEIXEIRA; DE ARAÚJO BRITO, 2022).

However, it is important to highlight that the adoption of green marketing should not be seen only as a *marketing* strategy, but rather as a commitment of the company to sustainability and social responsibility. It is essential that companies are transparent about the sustainable practices they adopt, and that these practices are in fact effective in terms of reducing environmental impact and contributing to society. In addition, one can mention the importance of the tripod of sustainability, which involves the social, environmental, and economic dimensions, as mentioned by Elkington (1998). The balance between these dimensions is fundamental for the promotion of sustainable development and for the survival and success of companies in the long term (TEIXEIRA, 2021).

Green marketing aims to promote products or services that are environmentally correct and sustainable, and this strategy is increasingly important in the current context, in which society seeks more conscious and responsible alternatives in relation to the environment and society (KOTLER *et al.*, 2017). To ensure the effectiveness of green marketing, it is necessary to consider the "4 Ss", which include sustainability, customer satisfaction, safety, and social acceptance (PEATTIE, 2010). The social acceptance of products and services is a fundamental aspect of green marketing, since the company must be able to demonstrate that its products and services are socially responsible and compatible with the expectations of society (CARROLL, 1991). In this sense, the practice of corporate social responsibility is an important part of green *marketing*.

The ISO ABNT NBR 26000 standard can be mentioned as an important reference for the practice of corporate social responsibility, which involves the commitment of the company to act

ethically and transparently in relation to the social, environmental, and economic impacts of its activities (ABNT, 2010). To substantiate the importance of the ISO 14000 series in the environmental management of companies, one can cite the *International Organization for Standardization* (ISO) as the main responsible for this collection of standards. As highlighted by Roorda and Lacerda (2003), the ISO 14000 series is a crucial tool to improve environmental management in organizations and provide greater efficiency in the prevention and reduction of environmental impacts arising from business activities.

In addition, to highlight the relevance of the EMS in the ISO 14000 series, one can cite the work of Oliveira and Santos (2013), which presents a detailed overview of the standards of this series, highlighting the EMS as a set of procedures and policies to manage the environmental impacts of an organization's activities, as well as provide a framework to implement and maintain sustainable environmental practices.

Finally, to reference the importance of environmental auditing and environmental labeling in the ISO 14000 series, one can cite the works of Lopes *et al.* (2019) and Krajnc and Glavič (2005), respectively, who present a more detailed view of these standards and their application in companies.

FINAL CONSIDERATIONS

The relationship between the concepts of human industrial production and sustainability in the third millennium presents challenges and opportunities for companies. From the bibliographic research conducted, it was found that sustainability is fundamental in three fundamental aspects: social, environmental, and economic.

Industry 4.0, Manufacturing and Green Marketing present innovative solutions and reduction of environmental and social impacts, while the Tripod of Sustainability highlights the importance of social responsibility, environmental preservation, and economic viability.

The reflection and the proposition of solutions that consider the balance between these three pillars is essential for a more conscious, responsible, and integrated manufacturing to the interests of society and the planet. It is important that all agents involved in industrial production are engaged in this search for sustainable and innovative solutions, to build a more balanced and prosperous future for all. Therefore, innovative, and sustainable solutions for the process of manufacturing goods are already demands in the present and will be even more so in the human future. Therefore, it is necessary to invest in sustainable technologies and practices, to ensure the continuity of productive activities, preserving the quality of life and the environment.

Corporate awareness and responsibility, along with government regulation, are key to ensuring more responsible industrial production and integrated with sustainable development. To advance in this direction, it is suggested to conduct research with an action-research approach, with the objective of proposing interventions in engineering education in universities. In this way, students can be updated on the new requirements of the industry and prepared to meet the demands of the market. This promotes the development of the industry and technological innovation, increasing Brazilian competitiveness in domestic and foreign markets.

Given the discourses presented on the relationship between Industry 4.0 and sustainability, it is evident that companies need to understand the importance of this connection and consider the cost-benefit ratio and the return on investment at a social and environmental level. In addition, it is important to overcome the social and economic challenges for the implementation of innovative technologies, which can be achieved through investments from carbon credits or other sources of sustainable management with international credibility.

In this context, it is essential that there is an intervention in education to enable future professionals to meet the demands of the market and contribute to the development of the sustainable industry within the concept of Triple Bottom Line (TBL). Therefore, it is suggested the continuity of the study through an action-research with an effective approach to propose interventions in teaching, aiming at the training of professionals capable of using technological innovations with impact in the country.

Finally, it is important to emphasize that the connection between Industry 4.0 and sustainability is a challenge that requires the involvement of all agents in the production chain, from managers to final consumers. Only through a joint effort is it possible to build a more sustainable and socially responsible industry, contributing to the construction of a more balanced and prosperous future for all.

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