

INTEGRATION OF TECHNOLOGIES DRIVEN BY SUSTAINABILITY PRINCIPLES ROOTED IN INDUSTRY 4.0

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Abstract: Companies are rethinking their business strategies and looking for new ways to operate as global concern for sustainability grows. Industry 4.0 integration (I4.0) can assist businesses in building more competitive and sustainable organizational processes. This article is based on recent scientific literature and provides companies with guidelines for developing the economic, social, and environmental elements of sustainability. This study examines transformation driven by sustainability principles rooted in Industry 4.0, which entails the integration of advanced technologies such as the Internet of Things (IoT), cloud computing, and big data, with the potential to fundamentally change how businesses engage in sustainability. This study applies a qualitative literature review strategy that focuses on concerns based on information gleaned from document studies.

Keywords: *Integration of technologies, Triple Bottom Line, Internet of Things 4.0, Digitalization, sustainability principles*

INTRODUCTION

Industry 4.0 has brought about profound changes in the way we view and execute industrial processes. With ever-evolving technology, we now have the opportunity to integrate sustainability principles within the entire industrial ecosystem. Sustainability is no longer an option, but an imperative, and Industry 4.0 is the catalyst that enables us to make this happen.

In recent years, corporate sustainability (CS) has been widely recognized as an essential aspect of successful businesses. Customers nowadays are far more attuned to the social and environmental responsibilities of businesses, as well as the quality of the goods and services they purchase. Based on the work of Angert et al. (2016) As a result, many businesses are taking a fresh look at their methods and developing plans for the long-term sustainability of their supply chains and products. Formentini and Taticchi discovered this in 2016. When environmentally friendly goods and services are made available, markets may be subdivided and specialized to satisfy the needs of "green" consumers. The 2016 study by Blumengartner and Rauter. Corporate social responsibility (CS) becomes a more relevant and practical definition when the idea of sustainability is applied to the business context. Referring to the integration of economic, social, and environmental considerations (the "triple bottom line") In TBL Corporate social responsibility (CS) becomes a more relevant and practical definition when the idea of sustainability is applied to the business context. The triple bottom line (TBL) refers to the financial, social, and ecological impacts of an organization. From Angert et al. (2016). Taking steps based on the TBL may be beneficial to a business because of the careful consideration given to their consequences and interdependencies. All three must be taken into account to make sure that one (or two) of them doesn't get the short end of the stick. See also: (Formentini & Taticchi, 2016) and (Hahn et al., 2015).

These studies have provided pertinent data regarding how I4.0 is affecting computer science. However, given that many businesses continue to struggle with creating and implementing sustainability, this topic presents opportunities for further research. (Tjahjadi et al., 2021). Although the literature contributes greatly to this field of study, no studies were found that offer recommendations for actions that should be taken while implementing I4.0 to

shift to sustainable business models (Ejsmont et al., 2020). This is in line with the findings of a bibliometric analysis conducted to confirm the effects of I4.0 on CS. Despite the literature's significant contributions to the subject, no studies were located that provided advice for what should be done throughout the implementation of I4.0 to transition to sustainable business models. The study was driven by the inquiry, "How can I4.0 ideas and technology help with the growth of business sustainability?" How do the environmentally friendly tenets of Industry 4.0 manifest themselves in concrete ways that affect technological integration? For what reasons should modern industry welcome the Internet of Things (IoT) support for technology integration? To what extent do industries that already make use of the IoT feel the effects of the incorporation of 4.0 technology motivated by sustainable principles? This paper aims to answer this issue by suggesting drivers for the advancement of CS via I4.0. All types and sizes of companies making sustainable transitions are targeted by the drivers.

In this article, we'll discuss how Industry 4.0's emphasis on integrating technology might serve as a crucial facilitator for green practices. More sustainable and productive businesses may now exist thanks to advancements in areas such as big data, AI, digitalized manufacturing, and the IoT, all of which will be discussed.

As part of the Industry 4.0 framework, we will also discuss the significance of renewable energy, waste management, and environmentally friendly supply chain tactics.

Through smart technology integration, we can create a more environmentally friendly industrial environment, reduce waste, save resources, and overall create long-term sustainability. By integrating technology and sustainability principles, we can achieve the common goal of facing the global challenges of climate change and the preservation of natural resources. In this article, we will discuss this concept in more detail, illustrate its implementation in various industrial sectors, and identify the benefits and challenges that may be faced on the road to sustainability in Industry 4.0.

LITERATURE REVIEW.

The concept of technology integration can be seen from two terms, namely integration and technology. The word integration comes from the English word "integration" which means integrating or merging. According to the Indonesian dictionary, the word integration means unification (until it becomes whole). Meanwhile, technology comes from the Greek 'techne' which means method and "logos" which means knowledge, and can be interpreted as knowledge of methods. By looking at the meaning of these two words, technology integration means unification, incorporation of knowledge of ways. Heinich, Molenda and Russell (1993) cited by Prawiradilaga & Siregar (2004) say that technology as a knowledge applied by humans to solve problems and carry out tasks in a systematic and scientific way, consisting of hardware and software technology.

The principles of sustainability are the foundations of what this concept represents. Therefore, sustainability is made up of three pillars: the economy, society, and the environment. These principles are also informally used as profit, people and planet.

In recent years, the logistics industry has undergone a significant transformation in response to the era of Industry 4.0. This article explores the role of technology and sustainability principles in the transformation of logistics within the context of Industry 4.0. To fully harness the potential of Industry 4.0 in the transformation of logistics, logistics companies need to integrate technology that aligns with sustainability principles. This will help improve operational efficiency, meet sustainability demands, and reduce environmental impact within the logistics sector. While challenges exist, the long-term potential benefits of this integration make it a crucial step in the advancement of modern logistics. Furthermore, here are some references from experts on this case study.

SUBJECT	AUTHOR	RESULT	KYEWORD
INTEGRATION OF TECHNOLOGY	Routledge	A technology infrastructure is a collection of tools and processes that help people achieve these goals.	Assessment, technology, large-scale, classroom, formative, summative.
SUSTAINABLE PRINCIPLE	Paul Shrivastava a & Stephanie Berger	Provides a framework to ensure that there is a coordinated, efficient, and results-driven approach to the international wine industry's commitment to environmental sustainability	sustainability; sustainable development; principles; codes; guidelines
INDUSTRY 4.0	Morteza Ghobakhloo	While some communities may still be in denial about the magnitude and significance of Industry 4.0, leading organizations have been implementing advanced digital technologies such as IIoT, AVR, industrial robotics, cloud computing, AI, and HPC-CADM in preparation for the rise of the new digital industrial revolution. Scholars and Industrialists think that Industry 4.0 will have a good influence on sustainability, and this research aimed to investigate this. develop an interpretative model of the Industry 4.0 sustainability	Industry 4.0; smart manufacturing; digitization; sustainability; environmentalism; industrial internet.

		function that explains the methods by which the Industrial digitalization, as well as the underlying technological developments and design ideas, can contribute to the fulfillment of economic, environmental, and social sustainable development goals.	
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Smith, J., & Johnson, L. Integration of Sustainability in Industry 4.0: A Systematic Review conducted an extensive evaluation pf previous research on the subject Integration of Sustainability in Industry 4.0: A Systematic Review of environmental friendliness concerning Industry 4.0. There is an examination of the successes and failures of using IoT, big data, and AI to specific business problems. Several real-world case studies from a range of sectors are included in the study.

Garcia, D., & Lopez, C. Sustainability and Industry 4.0: A Review of Key Enablers and Challenges. including the role of technologies such as IoT, blockchain, and robotics. They also identify challenges that need to be overcome in realizing the vision of industrial sustainability supported by advanced technology. across different countries. They found differences in biodiversity approaches between countries and highlighted solutions that have been implemented in various industrial environments.

Kim, S., & Jang, Y. Sustainable Manufacturing in Industry 4.0. A Cross-Country Comparison of Challenges and Opportunities across different countries. They found differences in biodiversity approaches between countries and highlighted solutions that have been implemented in various industrial environments

Schumacher, A., & Erol, S. 1. Industry 4.0 and Sustainability: Implications and Contributions of Digital Technologies This article reviews the impact of Industry 4.0 technologies on aspects of poverty, including energy efficiency, waste management, and sustainable supply chain ecosystems. They also explore the contribution of digital technologies towards achieving the desired goals.

Martin, R., & Schumann, M. 2. Sustainability in Industry 4.0: A Comprehensive Survey of Emerging Technologies and Practices This study provides a comprehensive insight into the various technologies that can be used in Industry 4.0 to achieve poverty. They discuss the latest practices that have emerged in various industry sectors.

This literature review can provide a deep insight into how technology integration driven by the principles of desirability can shape the future of industry in the Industry 4.0 era. You can use these references as a foundation to develop your research framework and methods.

RESEARCH METHOD:

The analysis is conducted by a literature study, and the research strategy is qualitative. In the age of Industry 4.0, with all the many technologies available now, it will describe how the methodology, results, and conclusions from the study subject will be used to analyze the data that is gathered. Therefore, the sampling in this research will employ narrative analysis and a deeper interpretation of relevant literature (Taylor, 2019).

Specification Table

RESULT & DISCUSSION

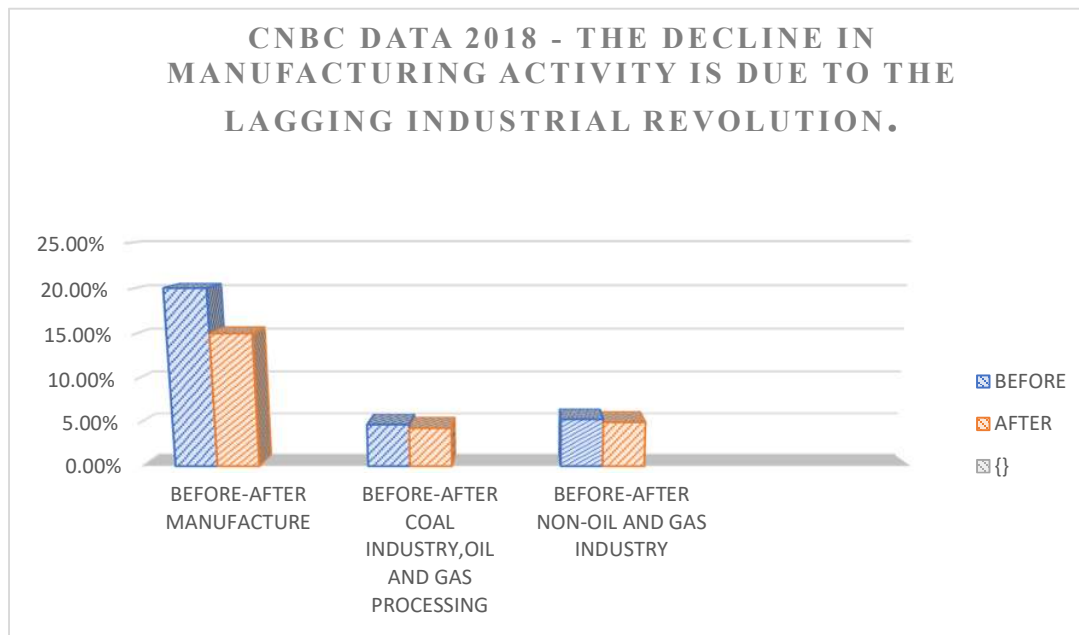
This study enhances and enriches the aforementioned investigations, producing ideas with practical applications that will aid companies in their pursuit of sustainability, therefore filling the resulting scientific void. For instance, (Kiel et al., 2017) analyzed the impact of Industry 4.0 on sustainability and presented a framework for the positive outcomes that this technological revolution will have on business, society, and the environment. Studying I4.0's potential impact on sustainable development from both a social and ecological perspective (B. C. Stock et al., 2018). Both positive and negative impacts were found throughout the two domains of the investigation.

(Luthra & Mangla, 2018) examined the obstacles to supply chain sustainability through I4.0 and concluded that organizational obstacles predominated in the sample under investigation, with technological, strategic, legal, and ethical obstacles coming in second. (Haseeb et al., 2019) examined how I4.0 can help small and medium-sized businesses (SMEs) achieve sustainable business performance. They found that the IoT and big data are most relevant to computer science (CS) and emphasized that organizational structures must support the adoption of these technologies.

(Ghobakhloo, 2020) The economic sphere is the first to feel the benefits of I4.0, which in turn invites contributions focused on environmental and socio-economic sustainability. These functions have been identified, and their impact on future generations has been investigated. The Upsides and Downsides: Studies show that there may be both favorable and unfavorable effects of implementing I4.0 on sustainable development. These include potential ethical and technological difficulties along with enhanced social and environmental well-being and increased production. Utilizing I4.0 Technologies and Concepts: This study guides how I4.0 ideas and technologies can be applied as instruments to foster sustainability inside businesses, along with doable actions that businesses of all sizes and in all industries might implement.

By integrating Industry 4.0 concepts and technologies into sustainability strategies, companies can optimize their operations, reduce environmental impact, and meet the growing demands of environmentally conscious consumers. This integration can create a balanced approach to economic, social, and environmental benefits, aligning with the triple bottom line (TBL) approach in sustainable management.

The results and discussion provide a comprehensive view of how CS and I4.0 are interlinked and how companies can leverage I4.0 technologies to achieve their sustainability goals. In addition, this research also highlights the positive and negative impacts of I4.0 implementation, as well as concrete steps that companies can take to optimize their sustainability benefits through I4.0.



The following data is obtained from the CNBC Indonesia article:

Reported in 2018, the activities of the industrial revolution in Indonesia can be considered lagging because the manufacturing sector at that time recorded a decline in contribution to the economy (deindustrialization). The growth of the manufacturing sector, which accounts for 20.16% of the national economy, is currently on a slowing trend, to below 5%. The coal and oil and gas processing industry slowed to 4.46% (from 4.85%), while the non-oil and gas industry slowed from 5.46% to 5.14%.

The data reflects Indonesia's economic and industrial conditions in 2018, with a decline in the contribution of the manufacturing sector and slowing growth in several key sectors. Further analysis may be needed to understand in detail the factors behind these trends and develop strategies to face challenges and capitalize on opportunities in the industrial revolution.

TABLE 1. PREVIOUS RESEARCH

Article	Sustainable Principles	Key Word	Conclusion	Synthesis
Strategic perspectives of corporate sustainability management to develop a sustainable organization	To satisfy the needs of the present without sacrificing the ability of future generations to do the same, economic, environmental, and social advances are referred to as sustainable development. The role of businesses is crucial here. However, the pace of sustainability progress has been sluggish, indicating the need for more detailed guidelines to support businesses in acting strategically and prospering over the long term.	Strategic management; sustainability; corporate sustainability management; strategy; sustainability performance; environmental and social governance	Companies play a key role in any social movement toward sustainability. However, although ideas like CSR, environmental management, and Corporate sustainability management is a topic that has been under discussion for a while. years, not much has changed. As of right now, the only real progress made toward sustainable development is still modest.	BY IMPLEMENTING a strategy on sustainable principles, CHANGES IN economy and management are anticipated well. This is one of the first keys to development in the world of Industry 4.0.
Assembly system design in the Industry 4.0 era: a	The design of the assembly system defines the optimal configurations and management	Internet of things (IoT)/industrial Internet of things (IIoT)/Internet of services (IoS	Devices that operate together in a network and adhere to a	One of sustainable principles in the world of logistics industry 4.0. that affect the technology system is the internet of

general framework	strategies that will maximize the system's performance. Assembly line scheduling and balance are just two of the many facets of this problem that need to be considered. It is also important to consider the assembly system's industrial setting while developing the system. The next industrial revolution, dubbed "Industry 4.0," makes use of Internet-connected, sensor-equipped machines to crank out one-of-a-kind wares.		predefined set of rules for sending and receiving data across a network, such as the Internet. Everyday household items sit alongside complex machinery in this category.	things (IOT), That maximising process of receiving and sending data.
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Industry 4.0 and Sustainability Implications: A Scenario-Based Analysis of the Impacts and Challenges	With the use of the Internet of Things, big data analytics, and cyber-physical systems, the term "industry 4.0" describes the subsequent iteration of manufacturing and industrial processes. One area that requires further study is potential effects on sustainability and the environment. Here, it's important to note that this article examines the advantages and challenges of sustainability using a literature study. Industry 4.0 is made up of implementation, operations, and technology as well as integration, adherence to sustainable development goals, and future scenarios.	Industry 4.0; Internet of Things; sustainability; environmental sustainability; sustainable development	Large amounts of data from many sources (equipment controllers, production systems, sensors, people, files, video, audio, etc.) are collected and organized by this system. It helps with both decision-making and generating usable data for sustainable innovation by seeing trends and models.	Challenges such as privacy, data security, and changes in employment structures are evaluated, while integration with sustainable development goals is also discussed.
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Impact of Industry 4.0 on Sustainability—Bibliometric Literature Review	Recent articles on industrial processes have focused on sustainability and Industry 4.0 (I4.0). The existing literature mostly takes a technical stance towards Industry 4.0, glossing over the sustainability issues that come along with the shift to this new paradigm.	industry 4.0; sustainability; literature review; fourth industrial revolution; bibliometrics	This study contributes to the theoretical understanding of how to combine the ideas of sustainability with Industry 4.0. Analyzing the evolution of this topic and providing new patterns and ideas that are not yet completely developed but need more investigation, gives a vital addition to the state of the art in this subject.	By using bibliometric data, which includes the number and distribution of scientific publications relevant to this topic, it reveals collaborations between studies, the most prolific authors, and scientific networks in this field. Furthermore, bibliometric literature can provide an overview of research areas that have received more attention and identify knowledge gaps or certain aspects that require further research. Through this approach, the authors were able to compile a comprehensive overview of the current research status, trends, and contributions in the relationship between Industry 4.0 and sustainability, which can provide guidance for future research in this area.
Industry 4.0, digitization, and opportunities for sustainability	The Fourth Industrial Revolution, often known as Industry 4.0 and the fundamental digital revolution is progressing	Industry 4.0, Smart manufacturing, Digitalization, Sustainability Environmentalism, Industrial internet	While some communities are still denying the relevance of the new digital industrial revolution known as	Industry 4.0, Digitalisation and Opportunities for Sustainability" discusses the interplay between the fourth industrial revolution, digitalisation

	quickly. Although the digital revolution is fundamentally transforming how people live and work, the public is optimistic about the promise that Industry 4.0 may offer to sustainability.		Industry 4.0, top organizations have been deploying cutting-edge digital technologies like IIoT, AVR, industrial robots, cloud computing, AI, and HPC-CADM to prepare.	processes and potential opportunities for achieving sustainability. Industry 4.0, with its application of technologies such as the Internet of Things and automation, is considered to provide opportunities to improve resource efficiency and reduce environmental impacts. Digitalisation, as a cornerstone of Industry 4.0, can create innovations and solutions that support sustainability goals.
SUSTAINABLE INDUSTRIAL VALUE CREATION: BENEFITS AND CHALLENGES OF INDUSTRY 4.0	IoT is redefining boundaries between sedulity and industriousness and presenting seasoned manufacturing organizations with new difficulties in the marketplace. new dangers in the economy. Particularly, new rivals might show up and offer either completely new business models or smart, connected	Industrial Internet of Things; Industry 4.0; Triple Bottom Line; sustainability; expert interviews; multiple case studies; qualitative study; manufacturing companies; German industry sectors	We show that for IIoT to claim ongoing industrial value production, the present TBL must be expanded along three additional dimensions: technological integration, data and information, and public context.	Industry 4.0 is considered to bring a number of benefits, such as increased operational efficiency, innovation in industrial processes, and better resource management. However, the text also identifies a number of challenges, such as data security and organisational culture change, that can arise during the implementation of Industry 4.0. The focus is on how the integration of sustainable values can be key in

	products and services. Current market leaders' dominance in terms of demand may be threatened by the rapid emergence of new connected products and services or even whole new business models. snappily, thus hanging the request position of the moment's established players. IIoT is anticipated to increase the competitiveness of manufacturers amid decreasingly fierce global competition, if established companies can designedly take advantage of accelerating request dynamics and shifting assiduity boundaries.			overcoming such challenges and optimising the benefits of Industry 4.0 to create value in line with sustainability principles.
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Good corporate governance and corporate sustainability performance in Indonesia: A triple bottom line approach	All countries now share a concern for sustainability. The Sustainable Development Goals (SDGs) were adopted by all UN members in 2015 to eradicate poverty, conserve the environment, and ensure substance by 2030. In the era of sustainable development, all businesses are required by their stakeholders to exercise more awareness while fulfilling their economic obligations, such as addressing issues related to global warming and human rights.	Good corporate governance, Corporate sustainability performance, Triple bottom line, Agency theory, Sustainability theory, Upper echelon theory.	As a result of the promises made by UN member states to achieve the Sustainable Development Goals, companies are now under pressure to assume more responsibility for sustainability concerns, such as environmental and human rights challenges.	The Triple Bottom Line approach used emphasises the assessment of corporate performance in three dimensions, namely economic, social and environmental. How ever, Good Corporate Governance still implemented by most companies that encompasses principles of corporate management that focus on transparency, accountability, fairness and so on.
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A review of Internet of Things (IoT) embedded Sustainable Supply Chain for Industry 4.0 requirements	In today's globalized environment, supply chain associations function based on needs that are ever more complicated and dynamic. To respond to rapid changes in customer requirements, sustainable supply chains have become essential. According to the study, industrial enterprises must quickly turn their attention to sustainability and make use of tools like the Internet of Things (IoT) to satisfy the association's objectives. aiming for This research paper's goal is to examine the many facets of SCM, ERP, IoT, and industry while examining the hidden gaps in the IoT sustainable power chain for the Assiduity4.0 transformation. In this paper, a thorough examination of the many aspects that have an impact on the sustainable power chain is	Sustainable Supply Chain (SSC); Closed Loop Supply Chain (CLSC); Enterprise Resource Planning (ERP); Industry 4.0; IoT; IIoT.	This paper did a detailed investigation of the many elements impacting sustainable supply chains and documented the findings. Based on the study, a framework is suggested to evaluate the degree to which supply chain organizations are prepared to fulfill the demands of the fourth Industrial Revolution from multiple viewpoints and in different colors. This framework model includes five crucial supply chain perspectives: business, technology, sustainable development, teamwork, and management strategy. This report offers metrics that businesses may assess to determine their preparation for the industrial age 4.0.	A Review of Sustainable Supply Chain Integrated with Internet of Things for Industry 4.0 Needs" indicates that the text discusses how Internet of Things technology is integrated in the supply chain to fulfil Industry 4.0 needs with a focus on sustainability. An explanation of how Internet of Things (IOT) technologies are applied in the context of the supply chain. Potential utilisation of sensors, connected devices, and real-time data analysis to improve transparency and efficiency in the supply chain. Industry 4.0 needs. Benefits and Challenges A description of the expected benefits of IoT integration in sustainable supply chains, including
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	analyzed, and the findings are documented. Based on the study, a methodology for evaluating the capacity of power chain organizations to adapt to the demands of the fourth Industrial Revolution has been put forward. Abstract Five key views of the power chain—business, technology, sustainable development, collaboration, and management strategy—have been combined to establish a framework model. The report offers parameters that businesses may use to determine their preparedness to transform into the industrial age 4.0.			increased efficiency, visibility, and positive impacts on sustainability. It may also address challenges that may arise, such as data security issues or the initial investment required. Implications for Industry 4.0
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CONCLUSION

Based on a review of 20 articles, 5 articles specifically discuss the integration of technologies driven by sustainability principles rooted in Industry 4.0. It can be concluded that sustainable principles encompass the combination of Internet of Things (IoT) and Industry 4.0 technologies, which can benefit both companies and the surrounding environment (Triple Bottom Line/TBL). Sustainable principles are deemed essential for the progress of companies, with their enablers being driven by sustainable innovation, waste reduction, transparent supply chains, and energy and resource efficiency. Challenges include the need for significant investment, threats to security and privacy, social impacts on communities not yet familiar with technology, and opportunities lie in the resilience of companies through diversification and production flexibility utilizing automation technology and production flexibility from Industry 4.0 to enhance resilience to economic and environmental changes.

Contributions and implications of implementing sustainable principles have a positive impact on both companies and the environment. Consequently, it can be concluded that best practices for integrating technological principles in Industry 4.0 involve the use of technology in industrial activities. It has been concluded that business involvement in sustainable development has integrated the concept of corporate sustainability (CS) into their business plans and processes. The Triple Bottom Line (TBL), encompassing economic, societal, and environmental components, is the focus of this CS. By combining technologies such as IoT, cloud, and big data, Industry 4.0 (I4.0) is considered a way to help the industrial world address sustainability issues. I4.0 bridges the gap between the real and virtual worlds, enabling intelligent and autonomous workforce that enhances output, social well-being, and environmental sustainability. While Industry 4.0 offers significant opportunities for logistics companies to improve their operational sustainability, there are still challenges in translating these ideas into efficient and sustainable operations..

Implications

The use of technology-assisted by the Internet of Things (IoT) in local companies/industries is measured in terms of positive and negative aspects that can be described. On the positive aspect, the use of technology (IoT) makes an impact on the company/industry's progress and development because it produces changes in efficiency and effectiveness that are much better for the company's/industry's operational activities. On the other side, the use of technology (IoT) makes an impact on companies/industries preferring advanced technology driven by (IoT), rather than using humans as labor which creates job scarcity. Implications of the research findings. It goes beyond the immediate study context and explores how the results can be applied, contribute to knowledge, and impact relevant stakeholders.

Research limitations

This section provides a transparent and honest assessment of the limitations of the study. It helps readers evaluate the strengths and weaknesses of the research and encourages future researchers to address the identified limitations to further advance knowledge in the field. So far, the number of literature examined is only 20 articles, while the articles that can answer the research question are only 8 articles. Subsequent research can use a larger number of articles with a longer time frame.

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