



Original Article

Industry 5.0 in India: A Study on Technology, Ecology, and the Road to Sustainable Growth

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Abstract

Acid rain, hazardous waste, resource depletion, air and water pollution, soil degradation, global warming, and health problems like silicosis and pneumoconiosis have all been brought about by industrialisation, which has long fuelled economic growth by generating wealth and jobs. In the twenty-first century, striking a balance between economic expansion and environmental conservation has grown more challenging. The advent of Industry 5.0, which is defined by increased automation, digitalisation, and human-machine collaboration, presents both opportunities and environmental risks. With an emphasis on India, this study investigates the environmental consequences of Industry 5.0, including how it affects emissions, resource consumption, and sustainable practices. Its objectives include reviewing changes to traditional industrial processes, assessing the effects on the environment, and looking at sustainability initiatives, laws, and new technologies that encourage more environmentally friendly industrial development. Through a comprehensive analysis of literature, government reports, industry publications, and regional case studies, the study evaluates policy gaps and offers solutions to link economic progress with environmental conservation in India.

Keywords: Industry 5.0, Industrial Development, Environment conservation and Sustainable Practices

Introduction

Due to industrialisation and urbanisation, which have seriously harmed the environment, natural resources are under extreme stress. This recurring pattern highlights the critical need for sustainable methods that balance industrial expansion with ecological protection. Preventing environmental damage and promoting environmentally friendly industrial practices are necessary to achieve this equilibrium. The Industrial Revolution significantly altered land use patterns by converting vast tracts of agricultural land to industrial use. Because to the use of chemical pesticides, fertilisers, and fossil fuel-powered machinery, agriculture itself became industrialised. While these advancements increased output, they also increased greenhouse gas emissions, degraded soil, and contaminated the air and water. Large-scale land conversion exacerbated climate issues by further diminishing natural carbon sinks. Research indicates that transforming traditional industries into eco-industrial systems using green technologies can support resource conservation and long-term economic sustainability. Environmental sustainability is crucial in deciding future industrial advancement because many ecosystems have reached their limits as a result of rapid industrial growth, population expansion, and urbanisation. The shift to eco-industrial networks requires integrated planning that synchronises industrial activities with environmental considerations. Localised empirical evidence, current conditions, and historical trends must all be taken into consideration when developing context-specific solutions. In this context, an evaluation of India's industrial development and environmental degradation was conducted. Causal chain analysis showed the significant negative impacts of industrialisation on ecosystems and identified key variables. Long-term plans to lower pollution in India and other similar regions of the world are developed based on these observations.

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Objectives Of the Study

The present study is based on following objectives

1. To examine changes made to traditional industrial processes,
2. To assess the effects on the environment,
3. To assess new technology, policies, and sustainability initiatives

Methodology

This report was produced using a systematic literature review, which is a structured and transparent method of locating and evaluating relevant papers on a topic. It examined ESG, sustainability, and supply chain management in the fast fashion industry. When collecting data from scholarly journals, research papers, and trustworthy websites, strict criteria were applied to confirm source quality and trustworthiness. The goals were to collect pertinent secondary data and assess the extent of prior high-caliber research. By using thematic analysis to the qualitative data they had gathered, the researchers were able to identify significant themes, patterns, and insights in the literature.

Society 5.0: The Social Revolution

Surprisingly, similar to industrial progress, social advancement is believed to be on the verge of entering its 5.0 stage. The four earlier phases, sometimes referred to as the "supersmart society," were known as the Hunting civilisation (Society 1.0), Agricultural Society (Society 2.0), Industrial Society (Society 3.0), and Information Society (Society 4.0). With the help of cutting-edge digital technologies like robotics, artificial intelligence (AI), big data analytics, and the Internet of Things, Society 5.0 aims to create an inclusive and sustainable socioeconomic system. By combining the internet and physical space into a single technological framework, this paradigm shift provides robust support for Society 5.0. The fifth period is regarded as the "smart" age.

The Evolution Of Industrial Revolutions

Throughout history, there have been five distinct industrial revolutions. The first industrial revolution, which used steam and diesel-powered businesses and occurred in the 1780s, was characterised by mechanisation. With the beginning of the second industrial revolution in 1870, the era of electrification—defined by the use of machinery driven by electricity—began. The third industrial revolution started in the 1970s with the development of computers and the automation of factories. The fourth industrial revolution, often known as Industry 4.0, started about 2010 and focused on digitalisation and the use of technology in manufacturing. The most recent industrial revolution, also known as Industry 5.0, began in 2020 and is centred on the convergence of technology-driven production processes with elements of environmental, social, governance, and human issues (Heartland, 2022).

Understanding Esg: Environmental, Social, And Governance

ESG, or environmental, social, and governance, refers to standards for moral business practices that help investors assess related benefits. It addresses moral governance, environmental conservation, and social responsibility. Businesses implement ESG practices such as data security,

diversity, waste reduction, and green energy. ESG research has increased significantly, especially in 2019 and 2020.

Industry 5.0: Pioneering The Next Phase Of Industrial Progress

The concept of Industry 5.0 may be a solution to the unintended consequences of industrial growth. This innovative approach offers a unique opportunity to simultaneously increase industrial and social development, making it a feasible route for progress. The transition from Industry 4.0 to Industry 5.0 has occurred in a remarkably short period of time—just ten years—highlighting the industry's incredible rate of innovation. The manufacturing environment could be significantly changed by either of the two versions of Industry 5.0. In particular, industry 5.0 has the ability to totally change the manufacturing process and increase the autonomy of cooperating robots. In addition to speeding up operations, this shift will give products a new sense of uniqueness and creativity as robots take on repetitious tasks. In the future, humans will be able to reach their full creative and intellectual potential, according to this evolution. Because of the convergence of manufacturing advances and the digitisation of production systems, the industry is shifting away from mass production and towards a more customised manufacturing strategy. Industry 5.0 has the capacity to address pressing societal challenges and bring about a time where innovation and sustainability coexist in addition to rethinking industrial processes.

Perspectives On Industry 5.0

In 2021, the European Commission introduced the concept of Industry 5.0. In the futuristic fifth industrial revolution, or "5.0," humans and robots collaborate to promote creativity and innovation. This modification makes it possible for robots to carry out repetitious tasks, according to Miraz et al. (2022). Human centricity is the core principle of 5.0, according to Rozanec et al. (2022). Additionally, 5.0 can be seen as the next bio-economy-based industrial revolution that achieves a good balance between industry, society, and the environment, according to Demir and Cicibas (2019). Bednar and Welch (2020) describe 5.0 as a world of "smart working practices," ushering in the "Age of Augmentation." These days, humans and machines coexist together within the constraints of our planet, resulting in a strong, human-centered, and sustainable manufacturing sector. Baranauskas (2019) claims that 5.0 uses bioinspired technology, artificial intelligence, human-robot collaboration, and smart materials to accomplish mass personalisation. The transition from mass production to custom manufacturing requires modern manufacturing techniques, digitisation, and the intelligentization of production systems, according to Vaidya et al. (2018). 5.0 introduces the concept of mass personalisation, where companies focused on consumer data, behavioural analysis, and communication flow management are better suited, whereas mass customisation is typically associated with product-driven organisations where changes occur at the operational management level (Baranauskas 2019). Big Data, the Internet of Things (IoT), and gadgets with sensors that allow for thorough understanding are some of the technologies that make Industry 5.0 possible. Artificial intelligence algorithms provide intelligent decision-making,



and the usage of collaborative robots (cobots) ensures accuracy, quality, and improved output while permitting higher degrees of customisation. The new spectrum of opportunities brought forth by Industry 5.0 includes jobs focused on creative and innovative thinking, technology interface management, cobot supervision, artificial algorithm development, and more. Industry 5.0 presents a unique set of challenges in addition to its many opportunities.

Opportunities And Challenges of Industry 5.0

Opportunities:

- **Tailored Customisation:** Industry 5.0 uses highly automated manufacturing methods to provide clients with unmatched customisation by accurately matching products to their preferences
- **Promoting Creativity:** Industry 5.0 fosters an atmosphere that invites creative talent to contribute and stimulates innovation by optimising human efficiency
- **Adaptive Machinery:** Industry 5.0 machines are flexible and adaptive, meeting a variety of worker requirements while producing excellent results.
- **Involved Operators:** Increased operator involvement in the planning process boosts productivity and promotes creative problem-solving
- **Design Freedom:** Industry 5.0 frees up product design, allowing "design to function" and making it easier to create highly customised and distinctive goods
- **Real-time Market Insights:** By incorporating real-time market data, producers may quickly make well-informed decisions and modify production to satisfy changing market demands;
- **Increased Safety:** By taking up dangerous jobs, cobots greatly increase workplace safety and lower dangers for human workers
- **Customer Satisfaction:** Tailored goods and services increase client satisfaction and encourage enduring loyalty
- **Growth and Profitability:** Increased market share and earnings are positively impacted by increased customer loyalty and recommendations
- **Innovation Ecosystem:** More interaction between humans and machines fosters research and development, which in turn promotes innovation
- **Global Reach:** By effectively delivering high-quality services to far-off places, businesses can reach a wider audience and attract new clientele.

Challenges:

- **Workforce Disparity:** Alongside highly skilled people coexisting alongside lower-skilled individuals, Industry 5.0 may worsen workforce inequities and potentially deepen societal divisions
- **Complex Skill Development:** Adopting Industry 5.0 calls for extensive skill development initiatives, such as worker training, the use of cutting-edge technology, and a shift in culture towards innovation;
- **Autonomous Systems:** The transition to smart manufacturing systems necessitates an increase in

autonomy, which puts conventional decision-making frameworks and procedures to the test;

- **Financial Investment:** Industries, especially small and medium-sized businesses • Financial Investment: Industries, especially small and medium-sized businesses (SMEs) and startups, may have difficulties due to the substantial financial commitment needed to achieve full Industry5.0 implementation;
- **Accountability Complexities:** Automation-heavy environments may make it more difficult to determine who is responsible for system mistakes or failures;
- **Adjusting to Customer-Centricity:** Industry 5.0 places a high priority on customer-centric operations, necessitating that businesses adjust to changing consumer preferences, which can be unpredictable and dynamic; and
- **Agile Business Strategies:** Due to changing consumer expectations and market dynamics, maintaining competitiveness in Industry 5.0 requires agile and adaptable business strategies
- **Cyber security concerns:** Industry 5.0's increased connection and common communication protocols raise cyber security concerns, necessitating strong security measures to safeguard critical data;

The Nexus Between Industrial Development And The Environment

Industrialisation has had a major impact on the environment, particularly the air, water, soil, and natural ecosystems. Air pollution, which is mostly caused by the burning of fossil fuels, is one of the most important consequences of this. Organisations such as the U.S. Environmental Protection Agency (EPA) keep an eye on dangerous industrial pollutants like asbestos, lead, and chromium (Harold, 1979). Despite laws, industries are still a major global source of air pollution. Water contamination is another significant problem, especially in places where factories are located near rivers and lakes. Industrial waste, whether solid, liquid, or gaseous, can have an impact on adjacent water sources, as the contamination of the River Nile shows (Clark, 1972). Soil pollution is caused by heavy metals and toxic compounds that permeate into the soil and food chain (Ljubo, 2015). Industrial expansion exacerbates habitat destruction and biodiversity loss through mining, infrastructure development, and deforestation (Sandra, 2014). To solve these problems and preserve ecosystems and promote sustainable development, strict laws, eco-friendly technology, and effective waste management are required.

Causes And Consequences Of Industrial Pollution

Industrialisation drives economic growth, but it also creates serious environmental issues. Consequences include the loss of natural resources, contamination of the air, water, and soil, global warming, acid rain, land degradation, hazardous waste creation, and health problems such as silicosis, pneumoconiosis, and skin disorders. These issues are caused by inadequate environmental legislation, unplanned industrial growth, outdated technology, inadequate waste management, resource extraction, and the limited capacity of small-scale businesses to comply.



Combating industrial pollution requires stricter regulations, environmentally friendly technologies, efficient waste management, and greater corporate responsibility. If

corrective action is not taken, industrial pollution will eventually continue to harm ecosystems and human health.

Effects of different industries on Environment

Industry	Effects on Environment	Solutions
Construction Industry	Emissions of methane, carbon dioxide, and other contaminants that fuel climate change and air pollution.	Make use of environmentally friendly building materials.
	Five percent of the world's carbon dioxide emissions come from the cement industry.	Use energy-saving building techniques.
		Reuse and recycle resources to cut down on building waste.
		Encourage LEED and other green building certifications.
Electronics Industry	Creation of hazardous domestic garbage that is frequently disposed of carelessly, causing poisonous chemicals to seep into the ground and contaminate food and water sources.	Encourage the appropriate recycling and disposal of electronic waste.
		Urge producers of electronics to consider recyclability when designing their goods.
		Encourage policies and procedures for recycling electronics.
Chemicals Industry	Emissions of greenhouse gases that contribute to global warming and climate change, including carbon dioxide, nitrogen, ammonia, and methane.	Create and execute more environmentally friendly production methods.
		Create and execute more environmentally friendly production procedures.
		Respect emissions requirements and environmental regulations to the letter.
Textiles Industry	Carbon dioxide emissions rise as a result of high energy use.	Adopt environmentally friendly and sustainable methods for producing textiles.
	Toxic chemicals are used in fabric finishing, dyeing, and bleaching, poisoning water supplies and endangering wildlife.	Water treatment can help cut down on water use and chemical discharge.
	The use of pesticides in the production of raw materials, such as cotton, damages insects, birds, and water systems.	Encourage the use of sustainable and organic resources in the manufacturing of textiles.
Food and Beverage Industry	Accounts for more than 25% of greenhouse gas emissions worldwide.	Encourage organic farming and sustainable agriculture.
	Deforestation and habitat loss result from agriculture using half of the world's livable land.	Improve supply chain management to cut down on food waste. Invest in sustainable energy sources to produce food.
Mining Industry	Soil erosion, water pollution, biodiversity loss, and sinkhole development as a result of mining activities.	Restore mined regions and use ethical mining processes.
		Create and implement eco-friendly mining techniques.
		Regularly evaluate the effects on the environment.

Conclusion

Industrialisation has led to economic prosperity, but it has also exacerbated population growth, urbanisation, and environmental stress. The burden on the ecosystem has reached a breaking point. However, there is still hope. The adoption of green strategies to transition industries into eco-industrial systems is supported by research. This safeguards resources and encourages sustainable growth. Industry 5.0 has promise since it integrates digital

technologies and the bioeconomy. Positive social changes, economic expansion, and environmental protection are all potential results. It envisions a future in which sustainable living and technology coexist for the benefit of both people and the environment. This approach can reduce the negative health consequences of pollution, solve supply-demand gaps, and create jobs in rural areas. According to UN sustainability goals, Industry 5.0 places a high priority on "Profits, Planet, and People." Immediate action is required in response to climate change. The enhanced version of



Industry 5.0 offers hope for long-term expansion. It creates opportunities for economic growth, environmental preservation, and societal well-being. The time for Industry 5.0 and its advantages has arrived.

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Conflicts of interest

The authors declare that there are no conflicts of interest regarding the publication of this paper.

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