



## **Impact of It-Enabled Technologies on Environmental Sustainability in Manufacturing: A Study of Tamil Nadu**

**<sup>1</sup>Dr. M. Prince Rani**

Assistant Professor, Department of Commerce, Vivekananda College of  
Arts and Sciences for Women (Autonomous) Tiruchengode, Tamil Nadu, India  
Email: mjjprince2016@gmail.com

**<sup>2</sup>Mrs M. Miniyammal**

Assistant Professor, Department of Commerce,  
Vivekanandha College of Arts and Sciences for Women (Autonomous)  
Email: srichandhri@gmail.com

**<sup>3</sup>Mrs. R. Menagarani**

M.Com, M.Phil, (Ph.D)  
Assistant Professor, Department of Commerce, Sengunthar Arts and Science College  
(Autonomous), Tiruchengode, Namakkal, Tamil Nadu, India.

**<sup>4</sup>Dr. Chris Daniel Wong**

International Provost,  
Chartered Institute of Digital Economy (CIDE)

### **ABSTRACT**

The manufacturing industry has been compelled to adopt sustainable practices as concerns about ecological degradation, resource depletion, and climate change grow. In this regard, IT-enabled solutions are now essential for promoting environmental sustainability by improving resource efficiency, lowering emissions, and encouraging greener manufacturing practices. The study's objective is to investigate how these technologies enhance compliance with environmental requirements, minimize waste production, optimize raw material utilization, and lower energy use. 100 managers and technical staff from specific manufacturing sectors in Tamil Nadu to collect primary data using a descriptive and analytical study approach. Government reports, business publications, and scholarly literature are the sources of secondary data used to support the analysis. ANCOVA analysis, mean computations, and percentage analysis are among the statistical techniques used. The study found that IT-enabled technologies are essential for promoting environmental sustainability in Tamil Nadu's manufacturing sector.

**Keywords:** *IT-enabled technologies, Environmental sustainability, Sustainable manufacturing; Digitalization, Manufacturing industries, Tamil Nadu.*

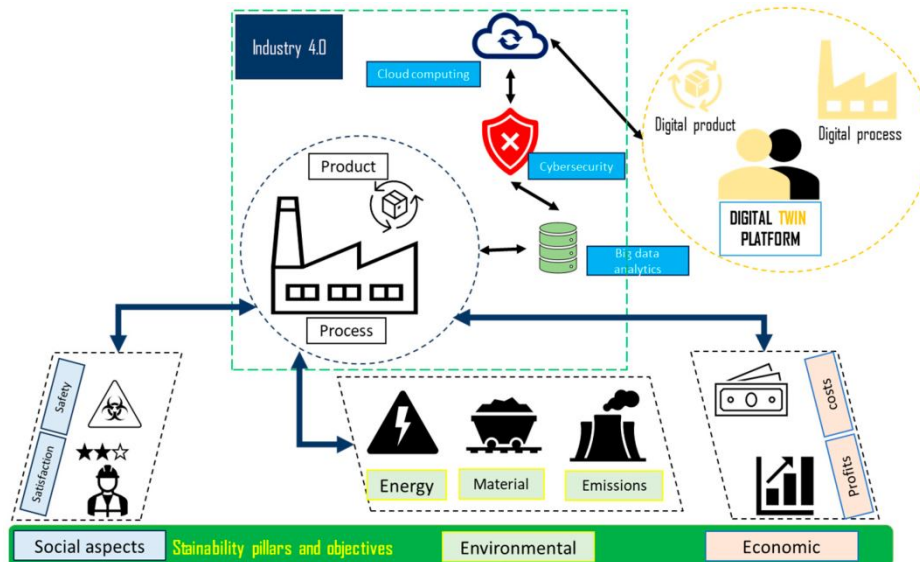
### **I. INTRODUCTION**

Rapid industrialization and economic growth have significantly worsened environmental problems such resource depletion, pollution, and increased carbon emissions. Governments, regulatory bodies, and the general public are putting increasing pressure on the manufacturing sector to adopt ecologically friendly practices because it is one of the main causes of environmental degradation.<sup>[1]</sup> In light of this, it is now crucial to ensure environmental sustainability in production. This entails introducing cleaner industrial methods, reducing waste and emissions, and increasing the efficiency of resource utilization.

Information technology (IT)-driven technologies have demonstrated efficacy in transforming traditional manufacturing processes into intelligent, efficient, and environmentally sustainable operations. Manufacturers can collect, process, and analyze real-time data throughout the manufacturing lifecycle thanks to technologies including digital monitoring systems.<sup>[2]</sup>

These technologies improve decision-making, increase operational efficiency, and support the adoption of sustainable manufacturing practices by lowering energy consumption, optimizing material utilization, and diminishing environmental effect.<sup>[3]</sup> One of India's most industrialized states, Tamil Nadu has a strong manufacturing sector in a number of industries, including autos, textiles, electronics, cement, chemicals, and engineering items.<sup>[4]</sup> The state's economic growth has been greatly aided by the industrial clusters found in areas like Chennai, Coimbatore, Tiruppur, Erode, and Hosur. However, the rapid expansion of manufacturing activities in Tamil Nadu has raised concerns about waste management, energy use, and environmental contamination. In order to address these issues, creative, technological solutions that balance industrial growth with environmental protection must be incorporated.<sup>[5]</sup>

By implementing IT-enabled technology, Tamil Nadu's manufacturing sector has significant potential to improve environmental sustainability.<sup>[5]</sup> By enabling real-time monitoring of emissions, energy consumption, and resource flows, these technologies promote compliance with environmental rules and the use of proactive environmental management methods. The extent to which IT-enabled solutions are embraced and successful in advancing environmental sustainability varies by industry and state region, notwithstanding their potential benefits.<sup>[6]</sup>



Sources: [www.industry4.0.com](http://www.industry4.0.com)

## II. IT-Enabled Technologies in Manufacturing

- ❖ **Big Data Analytics:** This processing of the large amounts of data that are generated by the manufacturing processes in both structured and unstructured form is referred to as big data analytics.<sup>[6]</sup> It assists in detecting inefficiency, demand forecasting, waste reduction, and schedule changes, all of which reduce the environmental effects.<sup>[7]</sup>



- ❖ (ERP) Systems: ERP systems combine some of the most important business processes such as production scheduling, inventory control, purchasing, finance, and human resources just to mention a few.<sup>[8]</sup> ERP systems can minimize the amount of waste of different materials, enhance resource utilization and enhance energy efficiency by offering real-time information, and increasing coordination.<sup>[9]</sup>
- ❖ Cloud Computing: For computer power and data storage, cloud computing provides scalable and adaptable solutions.<sup>[10]</sup> It lessens the need for physical infrastructure, uses less energy, and makes it easier for everyone in the company to access data about sustainability.<sup>[11]</sup>
- ❖ Digital Monitoring and Control Systems: These systems offer real-time monitoring of environmental factors, emissions, and industry processes. They assist producers in implementing continuous improvement techniques and adhering to environmental regulations.<sup>[12]</sup>

### **III. Environmental Sustainability in Manufacturing**

This is referred to as environmental sustainability in manufacturing where procedures and technology are used to reduce harmful effects that are caused by manufacturing processes and to ensure high and efficient production activities. Recycling water, renewable sources and machinery that conserve energy are all useful in reducing adverse impacts of industrial activities in the environment.<sup>[13]</sup> The manufacturing sector accounts to a large percentage of greenhouse emissions. Green manufacturing underlines the necessity to minimize carbon emission by means of energy efficient technologies, low carbon technologies and better supply chain management. <sup>[14]</sup>

Adherence to Environmental Regulations is necessary to ensure sustainability. By adhering to environmental norms and rules set by governmental and regulatory bodies, manufacturers are encouraged to adopt eco-friendly activities. By considering environmental effects at every stage of the product life cycle, manufacturers may produce goods that are long-lasting, recyclable, and less harmful to the environment.<sup>[15]</sup>

IT-Enabled Technologies: IT-enabled solutions have been crucial in supporting environmental sustainability in the manufacturing industry during the last many years. Real-time monitoring of pollutants, trash, and energy use is made possible by digital tools. Ensuring environmental sustainability in manufacturing is essential. It supports a well-rounded approach that combines environmental conservation with economic growth.<sup>[16]</sup>

### **OBJECTIVES**

- ❖ To examine the idea of environmental sustainability in manufacturing.
- ❖ To outline the difficulties that manufacturers encounter in putting into practice IT-enabled technologies aimed at environmental sustainability.

### **V. STATEMENT OF THE PROBLEM**

Despite being a significant contributor to Tamil Nadu's economic expansion, the manufacturing sector also poses serious environmental issues because of its high energy consumption, waste creation, pollution, and overuse of natural resources. The increase in industrial activity has made environmentally friendly production methods crucial. In Tamil

Nadu's manufacturing sectors, there are still differences in the adoption and effective use of these technologies. Many companies continue to use conventional manufacturing methods because of high implementation costs, a lack of technical know-how, a lack of digital infrastructure, and a resistance to change. Therefore, the expected benefits of IT-enabled solutions for the environment are not fully realized. This study attempts to bridge this gap by examining the impacts of IT-enabled technologies and pinpointing barriers to their effective implementation.

## VI. METHODOLOGY

**Primary Data:** Data were collected by means of systematic questionnaire that included 100 managers, supervisors and technical employees who were employed in specific manufacturing facilities. The purpose of the questionnaire was to collect data on environmental sustainability practices, the use of IT-enabled technologies, and implementation issues.

**Secondary Data:** The published sources where secondary data were collected were research journals, books, government reports, industry publications, websites, and reports

**Sampling Technique:** To choose manufacturing facilities and respondents from various Tamil Nadu industrial sectors, the study employed a convenience sampling technique.

**Tools:** To analyze data, basic statistical tools were employed, such as Mean and ANCOVA analysis to examine the connection between IT-enabled technologies and environmental sustainability, and percentage analysis to comprehend respondent profiles.

## ANALYSIS AND INTREPRETATION

Table: 1:1: Impact of IT-Enabled Technologies on Environmental Sustainability

1. Strongly Disagree 2. Disagree 3. Neutral 4. Agree 5. Strongly Agree

S. No	Statements	1	2	3	4	5	Mean
Adoption of IT-Enabled Technologies							
1	ERP systems are used in our company's manufacturing processes.	4	6	10	45	35	4.01
2	Production processes make advantage of digital systems and automation.	3	7	9	46	35	4.03
3	IoT devices are utilized to keep an eye on resources and machines.	5	6	11	44	34	3.96
4	Operational tasks are supported by cloud computing.	4	8	10	43	35	3.97
5	Manufacturing choices are supported by data analytics tools.	3	7	12	44	34	3.99
Environmental Sustainability							
6	IT innovations aid in lowering energy usage.	3	6	9	47	35	4.05
7	Digital systems facilitate recycling and waste reduction.	4	6	8	46	36	4.04

8	IT tools aid in lowering water consumption.	5	7	10	44	34	3.95
9	IT systems are used to monitor pollutants and emissions.	4	8	11	42	35	3.96
10	Adoption of IT promotes green industrial techniques.	3	6	9	46	36	4.08
<b>Operational Efficiency</b>							
11	Production efficiency is increased via IT systems.	3	5	10	47	35	4.06
12	Material waste is decreased by digital monitoring.	4	6	9	45	36	4.03
13	Automation maximizes the use of raw materials	5	6	10	44	35	3.98
14	IT solutions cut down on machine downtime	4	7	11	43	35	3.93
15	Adoption of IT increases supply chain efficiency.	3	6	10	46	35	4.04
<b>Economic &amp; Organizational Benefits</b>							
16	Technologies facilitated by IT lower operating expenses	4	7	10	44	35	3.99
17	Business performance is enhanced by sustainability measures.	3	6	9	46	36	4.06
18	Adoption of technology increases competitive advantage	4	6	10	45	35	4.01
19	IT-based sustainability initiatives are supported by management.	3	7	9	46	35	4.03
20	Workers are trained on IT systems.	5	8	12	41	34	3.91

Source: Primary data SPSS 2025

### **INTERPRETATION OF PERCENTAGE AND MEAN ANALYSIS ( $N = 100$ )**

The percentage and mean analysis clearly demonstrate a high level of agreement among respondents about the employment of IT-enabled technologies and their effects on organizational benefits, operational efficiency, and environmental sustainability in Tamil Nadu's manufacturing sector.

**IT-Enabled Technology Adoption:** The mean ratings for all five assertions range from 3.96 to 4.03, indicating the widespread acceptance of IT technologies such as ERP systems, automation, IoT devices, cloud computing, and data analytics. Tamil Nadu's manufacturing enterprises have greatly integrated digital technologies into their daily operations, as seen by the substantial majority of respondents who selected Agree and Strongly Agree.

**Environmental Sustainability:** This demonstrates the respondents' strong belief that IT-enabled technologies are crucial for reducing energy consumption, minimizing waste, conserving water, monitoring emissions, and promoting green industrial practices. The fact

that green manufacturing methods had the highest mean score (4.08) highlights the significance of IT in encouraging environmentally friendly production.

**Operational Efficiency:** The operational efficiency factor again shows strong values, with mean scores between 3.93 and 4.06. Most respondents firmly agreed that IT systems improve production efficiency, maximize raw material consumption, reduce material waste, limit machine downtime, and increase supply chain efficiency. This implies that digital technology not only encourages sustainability but also improves overall industrial performance.

**Economic and Organizational Benefits:** The mean values for economic and organizational benefits range from 3.91 to 4.06, indicating a favorable opinion of cost savings, enhanced business performance, competitive advantage, management assistance, and employee training via IT adoption. Despite having a somewhat lower mean (3.91), staff training still shows a generally positive response, indicating room for additional skill development improvement. IT-enabled technologies significantly and favorably contribute to improving environmental sustainability and operational performance in Tamil Nadu manufacturing companies, as evidenced by the continuously high mean scores (above 3.9) and the predominance of Agree and Strongly Agree responses. The results provide credence to the idea that greater use of digital technologies results in better organizational outcomes and sustainable manufacturing practices.

**Table: 1.2 ANCOVA**

Constructs	Type III	Difference	Mean Square	F	Sig
MODEL	124.682	4	31.170	22.845	.000
Intercept	892.415	1	892.415	653.721	.0000
Operational Efficiency (Covariate)	58.394	1	58.394	42.781	.000
IT Adoption	49.216	2	24.608	18.023	.000
Error	194.318	145			
Total	5218.000	150			
Corrected Total	319.000	149			

Source: Primary data SPSS 2025

The ANCOVA results show that the impact of IT adoption on environmental sustainability is statistically significant ( $F = 18.023$ ,  $p < 0.01$ ) after adjusting for operational efficiency. Environmental sustainability is also significantly impacted by the covariate operational efficiency ( $F = 42.781$ ,  $p < 0.01$ ). This demonstrates that, even after accounting for variations in operational efficiency, IT-enabled solutions considerably contribute to environmental sustainability in Tamil Nadu manufacturing companies.

## HYPOTHESIS TESTING

H0: IT-enabled technology does not have a major effect on environmental sustainability.

H1: IT-enabled technology has a huge effect on environmental sustainability.

Conclusion: H is rejected while H is accepted since  $p < 0.05$ .



## VII. DISCUSSION

The study's findings demonstrate the environmental sustainability benefits of IT-enabled technologies. The introduction of technology such as ERP systems, IoT, automation, and digital monitoring tools has reduced energy consumption, material waste, and overall process efficiency, according to most respondents. Thanks to real-time monitoring and data analysis, manufacturers may enhance their environmental performance by spotting inefficiencies and acting quickly to remedy them. The level of adoption varies by industry, though, with small and medium-sized enterprises facing more challenges than major corporations due to a lack of resources and technological expertise.

## VIII. CONCLUSION

The study comes to the conclusion that environmental sustainability in Tamil Nadu's manufacturing sectors is greatly aided by IT-enabled technology. Manufacturers have been able to reduce energy consumption, optimize resource use, eliminate waste, and increase compliance with environmental standards through the adoption of technology including ERP systems, IoT, automation, and digital monitoring. Businesses that successfully apply these technologies show improved environmental performance and a stronger dedication to sustainable production methods. Nevertheless, the report indicates that the rate of adoption of the IT-enabled solutions varies across the industries; businesses must address the challenges of high costs of the implementation process. Special interventions such as financial rewards, training programs, and sensitization programs should be used to attend to these problems. To meet the long term environmental objective and at the same time maintain the industrial efficiency and competitiveness in Tamil Nadu, the researcher suggests the use of IT and enabled technology in conjunction with sustainable practices.

## FUTURE RESEARCH

Future research on IT-enabled technologies and environmental sustainability in Tamil Nadu's manufacturing sector should focus on integrating advanced digital tools with localized industrial practices. Studies could explore the role of artificial intelligence, blockchain, and predictive analytics in enhancing resource efficiency, reducing emissions, and supporting circular economy models. Comparative analyses between traditional and smart factories may reveal the extent of sustainability gains achieved through digital transformation. Additionally, research should investigate the socio-economic impacts of adopting green IT practices, particularly on small and medium enterprises that form the backbone of Tamil Nadu's industrial ecosystem. Longitudinal studies assessing policy interventions, regulatory frameworks, and industry collaborations will be crucial to understand how digital sustainability evolves over time. Finally, interdisciplinary approaches combining technology, environmental science, and economics can provide holistic insights, ensuring that IT-driven sustainability strategies are both scalable and inclusive for the region's diverse manufacturing landscape.

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