Journal Homepage: -www.journalijar.com

INTERNATIONAL JOURNAL OF ADVANCED RESEARCH (IJAR)

Article DOI:10.21474/IJAR01/19403
DOI URL: http://dx.doi.org/10.21474/IJAR01/19403

RESEARCH ARTICLE

CRAFTING A SUSTAINABLE TEXTILE INDUSTRY: CHALLENGES AND OPPORTUNITIES FROM FIBRE TO FABRICS

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Manuscript Info

Manuscript History
Received: 28 June 2024
Final Accepted: 30 July 2024
Published: August 2024

Key words:-
Textile, Textile Industry, Pollution, Environment, Sustainability, TOWS Matrix

Abstract

The textile industry is a major global sector, playing a crucial role in economic development, especially in countries like India. However, the industry's resource-intensive processes and pollution create significant environmental challenges(Gopalakrishnan, 2018). The textile industry in India is a blend of traditional craftsmanship and modern industrialization. It remains a vital sector for the Indian economy, providing employment to millions and contributing significantly to export earnings This paper explores the TOWS Matrix of the textile industry, highlighting the connections between the Textile Industry, Environment, and Sustainability (TIES). It examines the industry's environmental impact, the evolution of sustainable practices, and the future directions for achieving sustainable growth.Byanalysing the TOWS Matrix, the paper identifies how the textile industry's strengths, weaknesses, opportunities, and threats relate to environmental sustainability. It delves into the industry's current environmental impact, including the depletion of natural resources, water pollution, and carbon emissions. The paper also traces the development of sustainable practices within the industry, such as the adoption of organic fibres, energy-efficient technologies, and waste management strategies.Looking forward, the paper emphasize s the importance of integrating traditional knowledge with modern technology to drive the textile industry toward more sustainable practices. By doing so, the industry can achieve a balance between economic growth and environmental stewardship. The paper argues that this integration is essential for transitioning the textile industry to a more sustainable future, ensuring that it continues to contribute to economic development while minimizing its environmental footprint.

Introduction:-

The textile industry has been an integral part of human civilization for millennia, evolving from traditional handloom weaving to modern industrial-scale production. In India, the textile sector is a cornerstone of the economy, being the second-largest employment provider and a significant contributor to the country's GDP. However, the industry's environmental footprint is considerable, necessitating a shift toward sustainable practices. (Chourasiya et al., 2022). The industry's future lies in balancing heritage and innovation, ensuring sustainable

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practices, and enhancing competitiveness on the global stage.he textile sector is one of the oldest and most significant industries in the world, playing a crucial role in the global economy. It encompasses the production of a wide range of products, from raw materials like cotton and wool to finished goods such as clothing, home textiles, and industrial fabrics. The industry is highly diverse, including the cultivation of natural fibers, the manufacturing of synthetic fibers, the weaving and knitting of fabrics, and the design and production of apparel and other textile products.

Evolution of the Textile Industry

The history of the textile industry in India is deeply intertwined with the country's cultural and economic development. From the ancient Indus Valley civilization, where evidence of cotton spinning and weaving has been found, to the flourishing textile trade during the Mughal era, the industry has evolved significantly.(Gopalakrishnan, 2018) The colonial period, particularly the dominance of the British East India Company, led to the industrialization of textile production, which continued post-independence with the establishment of mills and the rise of synthetic fibers. The Swadeshi Movement in the early 20th century emphasized the use of domestically produced textiles, symbolizing resistance against colonial rule. (Chourasiya et al., 2022)Post-independence, the focus shifted to modernization, increasing production capacity, and promoting exports. Today, the Indian textile industry is a global leader, with a significant share in the world's textile and apparel trade.

Growth of Textile Industry in India

The Indian textile and apparel industry is booming, contributing significantly to the country's economy. India's textile exports have surged, reaching a total of US$ 36.68 billion during the fiscal year 2022-23. This growth is fueled by a large workforce of 45 million, including 3.5 million handloom workers. The industry is poised for further expansion, with exports expected to reach US$ 65 billion by 2026.(Prakash et al., 2020)

Key factors for Textile Industry Opportunities and challenges:

The key factors influencing the growth and development of the textile industry in India. It highlights the essential elements that need to be addressed to ensure the industry's success in the new era.Key factors such as fixed capital, human capital, raw materials, technology, innovative processes, financial resources, government support, international standards, and the domestic market play a crucial role in the success of the textile industry.(Chourasiya et al., 2022) Fixed capital, including land, buildings, machinery, and equipment, forms the backbone of the industry's infrastructure. A skilled workforce, or human capital, is essential for efficiently operating this infrastructure and ensuring smooth production processes. The industry relies heavily on a steady supply of raw materials like cotton, wool, and synthetic fibers to maintain consistent production levels. Upgrading technology and machinery is vital for enhancing productivity, improving product quality, and maintaining efficiency in manufacturing.(Becker & Gries, 2023)

The adoption of innovative processes and techniques helps the industry stay competitive and differentiate its products in the global market. Adequate financial resources, including working capital and access to credit, are necessary to support these investments and sustain operations. Government policies and incentives, such as foreign direct investment (FDI), tax benefits, and reforms in labor laws, create a conducive environment for the industry's growth by facilitating access to capital, skilled labor, and raw materials.(Hiremath et al., 2012)

Adhering to international standards and regulations is crucial for the industry to access global markets and remain competitive. Capturing the domestic market is equally important for sustaining growth and ensuring long-term success(Rathore, 2022). The interconnectedness of these factors is evident, as investing in fixed capital and technology requires sufficient financial resources, while a skilled workforce is necessary to operate modern machinery effectively. Government support plays a pivotal role in enabling the industry to thrive by providing the necessary infrastructure, incentives, and regulatory framework.(Hiremath et al., 2012)

Textile Industry in India: TOWS MATRIX Approach

TOWS MATRIX INDIAN TEXTILE INDUSTRY	Internal Opportunities(O) 1.Growing global demand for textiles 2. Rising disposable incomes in developing countries 3.Increasing demand for technical textiles 4.Government initiatives promoting textile exports	External Threats (T) 1.Competition from low-cost producers (e.g., Vietnam) 2.Fluctuations in cotton prices 3.Stringent environmental regulations 4.Rising labor costs
External Strengths (S) 1.Strong raw material base (cotton, silk). 2.Large and skilled workforce. 3.Established textile industry infrastructure. 4.Competitive production costs	SO Strategies (Leveraging Strengths & Opportunities): 1.Focus on innovation and development of high-value, technical textiles to meet growing demand **(S: skilled workforce, O: demand for technical textiles).** 2.Utilize strong raw material base and competitive costs to expand exports to new markets **(S: raw materials, costs, O: global demand).**	ST Strategies (Leveraging Strengths & Threats): 1.Invest in modern technologies to improve efficiency and productivity, offsetting rising labor costs **(S: workforce, T: labor costs).** 1.Develop sustainable production practices to comply with environmental regulations **(S: established infrastructure, T: regulations).**
Internal Weaknesses (W) 1.Fragmented industry with many small players 2.Lack of investment in research & development 3.Outdated technology in some segments 4.Skill gaps in certain areas (e.g., technical textiles)	WO Strategies (Overcoming Weaknesses & Opportunities) Consolidate industry and encourage collaboration among players to improve R&D and technology adoption **(W: fragmented industry, O: opportunities).** Address skill gaps through training programs to meet evolving industry needs **(W: skill gaps, O: diverse demand).**	WT Strategies (Minimizing Weaknesses & Threats) 1.Request government for policies that incentivize R&D and technology upgrades **(W: outdated technology, T: competition).** 2.Diversify raw material sourcing to reduce dependence on cotton and price fluctuations **(W: reliance on cotton, T: cotton prices).**

Figure 1:- TPWS Matrix Indian Textile Industry.
Source: Author Compilation

The TOWS matrix for the Indian textile industry provides a strategic analysis by examining its strengths, weaknesses, opportunities, and threats. Here's how it applies in the Indian context:

Strengths (S):
Strong raw material base:
India has abundant resources of cotton and silk, providing a competitive advantage in raw material availability.

Large and skilled workforce:
The industry benefits from a vast pool of skilled labor, crucial for maintaining productivity and quality.

Established textile industry infrastructure:
India has a well-established infrastructure for textile production, supporting efficient manufacturing processes.

Competitive production costs:
Lower production costs in India enable the industry to compete effectively in global markets.

Weaknesses (W):
Fragmented industry with many small players:
The industry is highly fragmented, with numerous small enterprises, leading to inefficiencies.

Lack of investment in research & development:
Insufficient investment in R&D hampers innovation and the development of new technologies.

Outdated technology in some segments:
Some parts of the industry still rely on outdated technology, reducing competitiveness.

Skill gaps in certain areas (e.g., technical textiles):
There are specific skill shortages, particularly in specialized areas like technical textiles, which can limit growth in these segments.

Opportunities (O):
Growing global demand for textiles: India can capitalize on the increasing global demand for textiles by expanding its export markets.

Rising disposable incomes in developing countries:
As disposable incomes rise in developing countries, demand for textiles, including Indian products, is expected to increase.

Increasing demand for technical textiles:
The growing market for technical textiles presents an opportunity for India to diversify and innovate within the industry.

Government initiatives promoting textile exports:
Government initiatives, such as export incentives and infrastructure support, can boost the industry's growth.

Threats (T):
Competition from low-cost producers (e.g., Vietnam): India faces stiff competition from other low-cost producers, particularly in countries like Vietnam.

Fluctuations in cotton prices:
Volatility in cotton prices can impact the profitability of the industry, which heavily relies on cotton.

Stringent environmental regulations:
Increasingly strict environmental regulations may pose challenges for compliance and increase operational costs.

Rising labor costs:
As labor costs rise, the industry's cost advantage may diminish, making it harder to compete globally.

By analysing these factors, the TOWS matrix helps the Indian textile industry strategize by leveraging strengths to seize opportunities while addressing weaknesses and mitigating threats.

Challenges and Opportunities:
The approach also highlights the challenges and opportunities facing the Indian textile industry. Challenges include ensuring a consistent supply of raw materials, addressing labor issues, and complying with international standards. Opportunities lie in technological advancements, innovative product development, and expanding into new markets.(Raj & Maha, 2020)

Environmental Impact of the Textile Industry:
The textile industry is one of the most resource-intensive sectors, consuming large quantities of water, energy, and raw materials. The environmental impact is profound, ranging from water pollution due to chemical dyes and effluents to air pollution from factory emissions. The extensive use of synthetic fibers, which are non-biodegradable, adds to the growing problem of microplastic pollution in the oceans. Here we have provided the Statistical Data of Textile Industry and Water Pollution.(Leal Filho et al., 2022)

Water Pollution:
The dyeing and finishing processes in textile production are major sources of water pollution(Through & Ages, n.d.). Toxic chemicals and dyes are often discharged into water bodies without adequate treatment, affecting aquatic life and human health. Some effect of Water Polluton given in the following tables:

S.NO	PROCESS	CHEMICAL DISCHARGE	POLLUTANTS	HEALTH EFFECTS
1.	Sizing	Benzene	Resins, fats, waxes, starch and glucose	Carcinogenic, mutagenic and affects central nervous system,
2.	Bleaching	Cyanide	Wax, grease, soda ash, sodium silicate	Prolonged exposure will affect kidney and liver and leads to death
3.	Dyeing	Sulphate	Sulphides, acetic acid, mordant	Eye and respiratory problem
4.	Printing	Nitrate, phosphate	Starch, gums, mordant acids,	Harmful health hazards
5.	Finishing	Lead	Starch, salts, finishing agents	Suppression of hematological system

Source: Slideshare.com/textile and Environment.

Purpose	*Per cent water use*	
	Cotton textile	*Synthetic textile*
Steam generation	5.3	8.2
Cooling water	6.4	–
Dematerialised or RO water for specific purpose	7.8	30.6
Process water	72.3	28.3
Sanitary use	7.6	4.9
Miscellaneous and fire fighting	0.6	28.0

Figure 2:- Water Usage in Textile Mills.
Source:S.C.Bhatia(2017) Pollution Control in Textile Industry, Woodhead Publishing India Pvt. Ltd. ISBN: 978-93-85059-22-3

Process	Requirements in litres/1000 kg of product
Sizing	500–8200
Desizing	2500–21000
Scouring	20000–45000
Bleaching	2500–25000
Mercerising	17000–32000
Dyeing	10000–300000
Printing	8000–16000

Figure 3:- Water Requirement for Manufacturing Cotton textile

Source:S.C.Bhatia(2017) Pollution Control in Textile Industry, Woodhead Publishing India Pvt. Ltd. ISBN: 978-93-85059-22-3

Air Pollution:

The burning of fossil fuels for energy in textile mills leads to significant air pollution, contributing to global warming and health issues in surrounding communities.

Country	Textile and apparel exports by value (US$ billions) in 2018	CO_2 emissions reduction targets
China	266.41	60–65% of 2005 level by 2030
Germany	38.99	At least 65% by 2030 compared to 1990 emission levels
Bangladesh	38.73	Unconditional 5% reduction in emissions below BAU by 2030
Vietnam	37.93	Reduce carbon intensity by 15% by 2030 relative to 2014
India	37.11	33–35% reduction in carbon intensity by 2030 compared to 2005
Italy	36.57	Reduction of 33% by 2030
Turkey	27.56	21% reductions in emissions below BAU by 2030
United States	27.14	2025 target of 26–28% reduction on 2005 baseline emissions
Hong Kong	20.43	65–70% reduction by 2030
Spain	20.20	Reducing non-ETS emissions by 26% by 2030 (compared with 2005)

(Source for Columns 1 and 2: Fibre2 Fashion, 2019).

Source:S.C.Bhatia(2017) Pollution Control in Textile Industry, Woodhead Publishing India Pvt. Ltd. ISBN: 978-93-85059-22-3

Waste Generation:

Textile production generates a considerable amount of waste, including fabric scraps, defective garments, and chemicals. Much of this waste ends up in landfills, where it contributes to soil and water pollution.

Chemical Pollution:
The use of hazardous chemicals in textile processing poses risks to both workers and the environment. Persistent organic pollutants (POPs) and heavy metals can accumulate in ecosystems, causing long-term damage.

Sustainable Practices in the Textile Industry
The textile industry is adopting several sustainable practices to reduce its environmental impact. By choosing organic fibers like cotton, hemp, and jute, companies are minimizing the ecological footprint associated with resource extraction and processing. Additionally, incorporating recycled fibers and upcycled materials helps to repurpose waste, giving it a new life.(Sharma et al., 2022)To address the issue of pollution from dyes, many manufacturers are turning to natural dyes derived from plants and minerals, which are less harmful to waterways than synthetic alternatives.Water conservation is another critical area of focus. Many MSMEs are implementing water-saving techniques, such as low liquor ratio dyeing, and installing effluent treatment plants to reduce both water usage and pollution.Energy efficiency is also being prioritized by upgrading machinery to more energy-efficient models and incorporating renewable energy sources like solar power, which significantly lowers the industry's carbon footprint.Lastly, effective waste management practices are being put in place. These include waste segregation, composting fabric scraps, and recycling wastewater, all of which contribute to a substantial reduction in waste generation.(Bhattacharya, 2021)

The Government of India is actively promoting sustainable practices in the textile sector through various initiatives. The Sustainable Apparel Coalition (SAC) is one such effort, aimed at encouraging responsible practices within the industry. Additionally, the India Organic Textile Standard (GOTS) sets guidelines for organic textile production, ensuring environmental and social criteria are met. Through the Ministry of Textiles' Scheme for Promotion of Integrated Textile Parks (SITP), the government provides financial and technical assistance to MSMEs, helping them adopt sustainable practices in their operations.(Harane, n.d.)

Green Textiles:
The development of green textiles, including organic cotton, bamboo, and recycled fibers, has gained momentum. These materials are produced with minimal environmental impact, using less water, energy, and chemicals.

Eco-Labels and Certifications:
Eco-labels like Global Organic Textile Standard (GOTS) and OEKO-TEX® Standard 100 provide consumers with information about the environmental and social sustainability of textile products. These certifications encourage manufacturers to adopt sustainable practices.

Eco-Design for Products:
Sustainable design principles are being integrated into the textile industry, focusing on durability, recyclability, and the use of eco-friendly materials. Extended producer responsibility (EPR) programs are also being implemented, making manufacturers accountable for the entire lifecycle of their products.

Carbon and Green Credits:
The introduction of carbon credit and green credit programs incentivizes companies to reduce their carbon footprint. By adopting energy-efficient technologies and sustainable practices, textile manufacturers can earn credits that can be traded or sold, providing an economic incentive for sustainability.

Waste Management:
Innovative waste management practices, such as upcycling and recycling of textile waste, are being implemented to reduce landfill waste. Circular economy models are being explored, where waste materials are reintegrated into the production cycle, minimizing the need for virgin resources.

Challenges to Sustainability in the Textile Industry
Despite the progress made, several challenges hinder the widespread adoption of sustainable practices in the textile industry.

Cost and Investment:
Transitioning to sustainable practices often requires significant investment in new technologies and processes. Small and medium-sized enterprises (SMEs) may find it challenging to bear these costs without financial support.

Consumer Awareness:
While awareness of sustainable products is growing, many consumers are still influenced by fast fashion trends, which prioritize low cost over sustainability. Changing consumer behavior is crucial for driving demand for sustainable textiles.

Regulatory Environment:
The lack of stringent environmental regulations in some countries allows for the continuation of unsustainable practices. Global cooperation and strong regulatory frameworks are needed to enforce sustainability standards across the industry.

Supply Chain Complexity:
The global nature of the textile supply chain makes it difficult to monitor and enforce sustainable practices at every stage, from raw material sourcing to manufacturing and distribution.

The Future of Sustainability in the Textile Industry
The future of the textile industry lies in the integration of traditional knowledge with modern technology to create a sustainable and resilient sector. Innovations such as digital printing, which reduces water and chemical use, and the development of biodegradable synthetic fibers hold promise for the future. Additionally, collaborative efforts between governments, industry stakeholders, and consumers are essential to drive the transition toward sustainability.Investment in research and development (R&D) is crucial for discovering new materials and processes that can reduce the environmental impact of textile production. Education and training programs for workers and managers can also help foster a culture of sustainability within the industry.

Conclusion:-

The textile industry, particularly in India, finds itself at a pivotal juncture where the need for sustained economic growth must be harmonized with the imperative of environmental sustainability. This paper has meticulously explored the complexities of the textile industry's relationship with the environment, using the TOWS Matrix to elucidate the strategic strengths, weaknesses, opportunities, and threats faced by the sector. The analysis underscores the critical role that sustainable practices must play in the future of the industry.

The textile industry has long been a cornerstone of India's economy, providing employment to millions and contributing significantly to the country's GDP. However, the industry's environmental footprint—characterized by substantial water and energy consumption, pollution from dyes and chemicals, and the generation of non-biodegradable waste—poses a serious threat to ecological balance. The future of the industry depends on its ability to reconcile economic objectives with environmental responsibilities. The integration of sustainable practices is not merely an option but a necessity for the industry's continued prosperity and survival.

The TOWS Matrix analysis reveals that while India enjoys inherent strengths such as a robust raw material base, a skilled workforce, and competitive production costs, it also faces significant challenges. These include a fragmented industry structure, outdated technology, and insufficient investment in research and development. Moreover, external threats like competition from low-cost producers, fluctuations in cotton prices, and stringent environmental regulations further complicate the landscape. Nevertheless, the industry can leverage opportunities such as growing global demand, rising disposable incomes, and supportive government initiatives to navigate these challenges. By strategically addressing weaknesses and mitigating threats, the Indian textile industry can position itself as a leader in sustainable practices globally.

The industry's journey towards sustainability has already begun, with several encouraging developments. The adoption of organic fibers, energy-efficient technologies, and waste management strategies signals a positive shift. Furthermore, government initiatives like the Sustainable Apparel Coalition (SAC) and the India Organic Textile Standard (GOTS) provide a strong foundation for promoting sustainable practices. However, there is still a long way to go. The industry must continue to evolve by incorporating both traditional knowledge and modern technologies, ensuring that sustainability becomes an integral part of the production process.Despite the progress made, several challenges persist. The high cost of transitioning to sustainable practices, coupled with the complexity of global supply chains, makes widespread adoption difficult. Additionally, the lack of consumer awareness and the regulatory environment in certain regions pose significant barriers. However, these challenges also present opportunities. By investing in research and development, fostering consumer awareness, and advocating for stronger

regulations, the industry can overcome these obstacles. The future of the textile industry lies in its ability to innovate and adapt. Digital printing, biodegradable fibers, and circular economy models represent just a few of the promising avenues for sustainable growth. Furthermore, collaboration between governments, industry stakeholders, and consumers will be crucial in driving the transition toward sustainability.The industry's resilience will be tested, but with collective effort and a commitment to sustainable development, it can emerge stronger and more sustainable.

To Conclude the textile industry must embrace sustainability not just as a buzzword, but as a fundamental principle guiding its operations. The stakes are high, and the choices made today will shape the future of the industry and the environment. By adopting a holistic approach that integrates economic growth with environmental stewardship, the industry can continue to thrive while safeguarding the planet for future generations. The journey toward sustainability is challenging, but it is also an opportunity for the industry to redefine itself and lead by example on the global stage. It is time for all stakeholders to act decisively, ensuring that the textile industry remains a vibrant and sustainable contributor to the global economy.

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