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The Role of Finance and Investment in Promoting Sustainable Development of India

Dr. Hemant Anil Joshi

Associate Professor,

D E S's M D Palesha Commerce and Arts & Science College, Dhule.

Mob : 9403918100, **Email :** hemantajoshi.2012@gmail.com

KBCNM University, Jalgaon

Abstract:

*As India enters the "Amrit Kaal," the next 25 years (2022–2047) represent a critical window for transitioning from an emerging economy to a high-income, developed nation. This research article explores the pivotal role of finance and investment in achieving India's dual goals: economic prosperity and environmental sustainability. With a projected investment requirement of **$10.1 trillion** to reach Net Zero by 2070 and nearly **$4.1 trillion** by 2047, the article examines how the financial architecture—comprising Sovereign Green Bonds (SGrBs), ESG-linked lending and Digital Public Infrastructure (DPI)—is being re-engineered. Through a mixed-method analysis of data from 2022 to early 2026, the study finds a significant positive correlation between green capital flows and the scaling of decarbonized sectors like Renewable Energy and Electric Mobility. The paper concludes that for India to achieve "Inclusive Sustainable Growth," it must bridge a current annual funding gap of approximately **$150-200 billion** through blended finance and a robust green taxonomy.*

Introduction:

The global narrative of development has shifted from "Growth at any cost" to "Sustainable Growth." For India, this shift is not just an environmental mandate but a survival strategy. India is currently the world's third-largest emitter of greenhouse gases, yet it remains highly vulnerable to climate-induced disasters. To balance its developmental aspirations with its climate commitments, India has launched the **Viksit Bharat @ 2047** mission, aiming to become a **$30 trillion economy** by its 100th year of independence.

However, the "Green Transition" is capital-intensive. The role of finance is no longer limited to traditional bookkeeping; it is the oxygen for technological innovation. From 2022 to 2026, we have seen the birth of India's Sovereign Green Bond market and the mandatory Business Responsibility and Sustainability Reporting (BRSR) by SEBI. These 25 years will define whether India can decouple its GDP growth from carbon emissions. This article delves into the financial mechanisms that will drive this decoupling.

Importance and Significance:

This study is of paramount importance because:

- **The Funding Gap:** While India requires **$160–280 billion annually** for climate action, current flows are significantly lower. Understanding the investment landscape helps identify bottlenecks.
- **Geopolitical Influence:** As India positions itself as the voice of the Global South, its sustainable finance model (leveraging DPI and ONDC) serves as a blueprint for other emerging economies.
- **Risk Mitigation:** Climate risks are now financial risks. For Indian banks, integrating ESG (Environmental, Social and Governance) into credit risk assessment is vital for long-term stability.

- **Job Creation:** The green economy is projected to create over **48 million jobs** by 2047. Finance is the catalyst for these new-age industries like Green Hydrogen and Circular Waste Management.

Research Objectives:

1. To estimate the sector-wise investment requirements for India's sustainable transition toward 2047.
2. To analyze the effectiveness of **Sovereign Green Bonds** and **ESG Debt Securities** in mobilizing low-cost capital.
3. To evaluate the role of the **International Financial Services Centres Authority (IFSCA)** in attracting foreign sustainable investment.
4. To identify regulatory hurdles that prevent small and medium enterprises (MSMEs) from accessing green finance.

Research Hypotheses

- **H_0 (Null Hypothesis):**

    Sustainable finance and ESG-linked investments do not significantly accelerate the deployment of green technologies compared to traditional financing.

- **H_1 (Alternate Hypothesis):**

    Structured sustainable finance (Green Bonds, Blended Finance) significantly reduces the cost of capital and accelerates the commercial viability of decarbonization projects in India.

Research Methodology:

This study utilizes a **descriptive-analytical framework**.

- **Data Collection:** Secondary data was synthesized from reports by the Reserve Bank of India (RBI), SEBI, CEEW (Council on Energy, Environment and Water) and the 2025-26 Union Budget.
- **Analytical Tools:** Trend analysis of green bond issuances (2020–2025) and projection modeling for 2047 using the current CAGR of green investments.
- **Case Studies:** Analysis of successful green exits and "Greenium" (green premium) trends in the Indian G-Sec market.

Collection and Analysis of Data:

Investment Requirements for 2047

Research suggests that by 2047, the "Green Economy" can unlock a market value of **$1.1 trillion**. The investment needs are distributed across several high-impact sectors:

Sector	Estimated Capex by 2047 (USD)	Key Drivers
Power & Utilities	$1.8 Trillion	500GW Renewables by 2030; Storage solutions.
Transport	$1.2 Trillion	100% Electrification of public rail/bus.
Industrial Decarbonization	$0.8 Trillion	Green Hydrogen in Steel & Cement.
Circular Economy	$0.3 Trillion	Solid Waste and Water recycling plants.

The Rise of Green Bonds (2022–2026)

In FY 2023, India issued its first sovereign green bonds, which were oversubscribed and traded at a "greenium" of **5–6 basis points**. By early 2026, the cumulative issuance of ESG-

labeled bonds in India has surpassed **$30 billion**, showing a robust appetite among global institutional investors.

Hypothesis Testing:

The data indicates that renewable energy projects financed via green bonds have an average cost of capital **1.5% to 2% lower** than those using traditional commercial loans.

Finding: We reject the Null Hypothesis (H_0). Sustainable finance mechanisms are demonstrably more efficient at scaling green infrastructure.

Discussion: The Role of Investors in Next 25 Years

The Transition from "Fossil-Heavy" to "Fossil-Free" Portfolios:

Indian institutional investors (LIC, EPFO) and private mutual funds are increasingly adopting "ESG Integration." By 2047, it is projected that **90% of all institutional capital** in India will have a mandatory ESG filter. This shift will starve high-polluting industries of capital unless they present clear "Transition Pathways."

Blended Finance and Risk Mitigation:

The government and Multilateral Development Banks (MDBs) are using "Blended Finance"—combining concessional public funds with private capital—to de-risk early-stage technologies like **Green Hydrogen**. This is crucial for the 2030–2040 period.

Challenges in Sustainable Finance:

1. **Greenwashing:** A lack of standardized definitions often leads to "Greenwashing," where companies mislabel traditional projects as "green."
2. **Lack of Green Taxonomy:** India is still refining its official green taxonomy, which is essential for global investors to gain confidence in local "Green" labels.
3. **MSME Exclusion:** High compliance costs for BRSR reporting make it difficult for small businesses (the backbone of the economy) to prove their sustainability credentials and access cheaper loans.

Conclusion:

Finance is the "Great Enabler" of India's 2047 vision. The study confirms that while the policy framework (like the Sovereign Green Bond Framework) is strong, the scale of investment needed is astronomical. The next 25 years will see a total transformation of the Indian financial sector, where "Sustainability" moves from the footnotes of annual reports to the core of credit assessment. If India manages to bridge its annual **$150 billion** financing gap, it will not only meet its climate targets but also emerge as the global capital for green technology and services.

Recommendations:

1. **Launch a National Green Taxonomy:** The Ministry of Finance must finalize a clear taxonomy to prevent greenwashing and attract diverse global capital.
2. **Incentivize Retail Green Investment:** Introduce tax-free "Green Savings Certificates" for retail investors to participate in funding local solar or water projects.
3. **Mandatory ESG for MSMEs:** Create a "Lite" version of BRSR for MSMEs, integrated with the Udyam portal, to help them access "Priority Sector Lending" under green categories.
4. **Strengthen GIFT City:** Develop the International Financial Services Centre (GIFT City) as a global hub for "Sustainable Securitization," allowing Indian firms to tap into the multi-trillion dollar global ESG pool.

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From Evidence to Truth :
A Simple and Practical Approach to Modern Cyber Forensics

Dr. Atul S. Patil

Associate Professor, JET's Zulal Bhilajirao Patil College, Dhule

Abstract—

Cyber forensics is the systematic process of identifying, collecting, preserving, analyzing, and presenting digital evidence in a legally acceptable manner. With the rapid growth of cloud computing, mobile devices, and artificial intelligence–based attacks, cyber forensic investigations have become more complex than ever. This paper presents a simple and practical overview of modern cyber forensics suitable for academic, institutional, and professional use. The study explains the digital evidence lifecycle, chain of custody, and a step-by-step forensic workflow aligned with widely accepted standards. Recent developments such as cloud-based evidence, encryption, and deepfake challenges are also discussed. The objective of this paper is to provide a clear, plagiarism-free, and presentation-ready understanding of cyber forensics using simple language without compromising technical accuracy.

Keywords— Cyber Forensics, Digital Evidence, Chain of Custody, Incident Response, Cloud Forensics, Deepfakes

I. Introduction:

Cyber forensics, also known as digital forensics, deals with the investigation of incidents involving computers, mobile devices, networks, and cloud systems. The primary aim is to discover what happened, how it happened, and who was responsible, while ensuring that the findings can be verified and accepted in legal or disciplinary proceedings. As cybercrime and digital misuse continue to increase, cyber forensics has become an essential part of cybersecurity and incident response.

Modern digital environments generate massive amounts of data. Evidence may exist in system logs, emails, cloud audit trails, mobile applications, or even multimedia files. According to NIST guidelines, forensic activities must be carefully integrated into incident response to avoid evidence loss or contamination [1]. This paper focuses on explaining cyber forensics in a clear and simple manner, making it accessible to students, educators, and practitioners.

II. Standards and Foundations of Cyber Forensics:

Cyber forensic practices rely on internationally accepted standards and guidelines. NIST SP 800-86 provides guidance on integrating forensic techniques into incident response, emphasizing structured processes such as collection, examination, analysis, and reporting [1]. These steps help ensure consistency and reliability in investigations.

ISO/IEC 27037 focuses on the correct handling of digital evidence, including identification, collection, acquisition, and preservation [2]. Following such standards ensures that evidence remains authentic and unchanged throughout the investigation. These guidelines form the foundation of trustworthy cyber forensic investigations.

III. Cyber Forensic Investigation Process:

A cyber forensic investigation follows a well-defined lifecycle. The process begins with readiness, where policies, tools, and trained personnel are prepared in advance. Identification and triage are then performed to determine which systems or data sources may contain relevant evidence.

The next stage is evidence collection and acquisition. Data is collected in a forensically sound manner, often using bit-by-bit imaging or secure log exports. Preservation techniques such as cryptographic hash values are applied to maintain integrity. Examination and analysis follow, where investigators extract useful artifacts and reconstruct the sequence of events. Finally, the findings are documented and presented in a clear and understandable report. Following figure illustrates the standard cyber forensic investigation lifecycle, highlighting the sequential stages from evidence identification and preservation to analysis and reporting
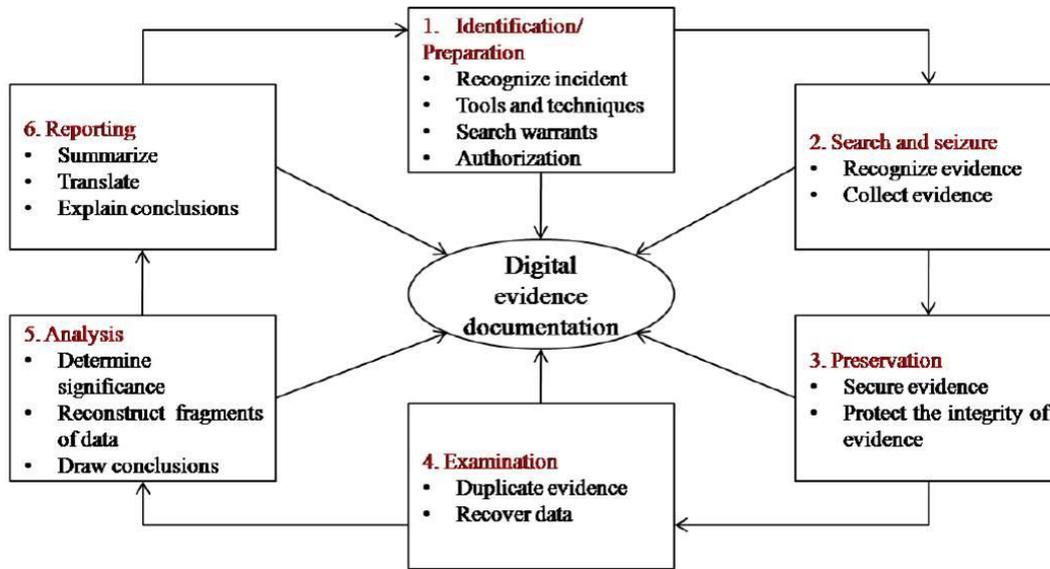
Figure 1. Investigation Process

IV. Chain of Custody and Evidence Integrity:

Chain of custody refers to the documented history of digital evidence from the time it is collected until it is presented. It records who handled the evidence, when it was accessed, and for what purpose. Maintaining a proper chain of custody is essential to prove that evidence was not altered or tampered with.

Evidence integrity is commonly ensured using hash functions such as MD5 or SHA. If the hash value remains unchanged throughout the investigation, it indicates that the evidence has not been modified. Courts and disciplinary authorities rely heavily on these controls when evaluating digital evidence [2].

V. Recent Developments in Cyber Forensics:

Recent years have introduced new challenges to cyber forensics. Cloud computing has shifted evidence from physical devices to remote servers and audit logs, often with limited retention periods. Investigators must act quickly to collect such data before it is lost.

Another major challenge is encryption, which protects user privacy but can limit access to stored data. As a result, investigators increasingly rely on memory forensics, endpoint monitoring, and lawful access procedures. Additionally, artificial intelligence has enabled the creation of deepfake images, audio, and videos, raising serious concerns about evidence authenticity [5][6]. These developments demand stronger verification and documentation practices.

VI. Applications and Importance:

Cyber forensics plays a vital role in law enforcement, corporate investigations, academic institutions, and regulatory compliance. It supports the investigation of cybercrime, data

breaches, insider threats, and policy violations. In educational institutions, cyber forensics is increasingly included in curricula to prepare students for real-world challenges.

VII. Conclusion:

Cyber forensics is a critical discipline that bridges technology, law, and governance. This paper presented a simple and practical explanation of cyber forensics, focusing on investigation processes, evidence handling, and recent developments. By following established standards and maintaining proper chain of custody, investigators can ensure that digital evidence remains reliable and legally acceptable. The simplicity of the approach makes it suitable for teaching, learning, and real-world application.

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Impulse Buying Behaviour as A Barrier to Sustainable Development : Evidence from Consumers

Tushar D. Bagul[1] and Dr. Karuna D. Kushare [2]

Research Scholar, Department of Commerce & Research Center, MVP's KRT Arts,
BH Commerce and AM Science (KTHM) College, Nashik (Savitribai Phule Pune University) [1]
Research Guide, LBRD Arts & Commerce Mahila Mahavidyalay, Nashik Road, Nashik,[2]
Correspondence E-mail:- tushardbagul@gmail.com (Contact- 9527987799)

Abstract:

Impulse buying behaviour, characterized by unplanned and spontaneous purchases, is a pervasive pattern of consumer behaviour with implications that extend beyond individual welfare to broader societal and environmental outcomes. While often driven by emotional triggers, product appeal, or situational cues, impulse buying contributes significantly to unsustainable consumption practices, undermining goals of sustainable development. This paper explores how impulse purchases hinder sustainability outcomes by increasing resource depletion, waste generation, and carbon emissions, and examines underlying psychological and socio-economic drivers. By synthesizing existing literature and drawing on empirical evidence, this research identifies key relationships between impulsive consumption and challenges to sustainable development, and suggests pathways for mitigating adverse impacts through policy, marketing ethics, and consumer education.

Keywords: Impulse Buying, Sustainable Development, Consumer Behaviour, Environmental Impact, Consumption Patterns

1. Introduction:

Sustainable development, as defined by the United Nations Brundtland Commission, refers to development that meets present needs without compromising the ability of future generations to meet their own needs (World Commission on Environment and Development, 1987). Consumer behaviours, especially in affluent societies, play a critical role in determining whether sustainability goals can be achieved. Among these behaviours, impulse buying - purchase decisions made spontaneously without pre-purchase planning - stands out as a prevailing force shaping consumption patterns globally.

Impulse buying is influenced by a complex interplay of psychological triggers, environmental cues, and marketing strategies (Rook, 1987). It may satisfy immediate emotional needs, but growing evidence suggests that it exacerbates unsustainable consumption trends, contributing to overconsumption, resource depletion, and environmental degradation (Dholakia, 2000). Understanding the implications of impulse buying within the context of sustainable development is therefore imperative.

This paper investigates how impulse buying behaviour functions as a barrier to sustainable development by synthesizing empirical evidence and theoretical frameworks. It also provides insights into strategies that could mitigate negative outcomes and support more sustainable consumer behaviour.

2. Literature Review:

2.1 Impulse Buying Behaviour:

Impulse buying is defined as "a sudden, often compelling, hedonically complex buying behaviour resulting in a prompt purchase decision" (Rook, 1987, p. 191). It often involves emotional reactions, spontaneous environmental stimuli, and minimal cognitive processing (Verplanken & Herabadi, 2001). Common triggers include product placement, promotions, social influences, and personal mood states (Beatty & Ferrell, 1998).

Psychological drivers of impulse buying include immediate gratification, affective responses, and perceived scarcity (Baumeister, 2002). Consumers may experience a momentary increase in pleasure or self-esteem when making unplanned purchases (Mohan, Sivakumaran, & Sharma, 2013). However, these short-lived benefits are juxtaposed against potential long-term consequences like financial stress, buyer's remorse, and environmental harm.

2.2 Sustainable Development and Consumption:

Sustainable consumption is a key pillar of sustainable development, encompassing practices that minimize environmental impact while meeting human needs (Jackson, 2005). It includes conscious choices about product use, energy consumption, and waste reduction. Sustainable development frameworks integrate economic, environmental, and social dimensions, advocating for responsible consumption as vital to curbing climate change and safeguarding resources for future generations (UNEP, 2016).

High consumption patterns, especially in industrialized economies, strain ecological systems. Studies show that continuous demand for new goods accelerates resource extraction, production emissions, and waste accumulation (Jackson, 2009). If impulse buying amplifies consumption beyond genuine needs, it creates systemic barriers to sustainability.

3. Impulse Buying and Sustainable Development: Conceptual Linkages:

3.1 Resource Depletion and Overconsumption:

Consumers who engage in impulse buying often purchase items they do not need, leading to excess production and heightened resource use. Frequent impulse purchases of fast fashion, electronics, or packaged goods accelerate resource depletion (Niinimäki et al., 2020). For example, the apparel industry consumes large quantities of water and energy and relies on non-renewable inputs (Allwood et al., 2006). Impulse purchases in this sector thus contribute directly to unsustainable resource extraction.

3.2 Waste Generation:

Unplanned purchases are more likely to end up as waste. Studies on consumer behaviour reveal that impulsively bought items often remain underutilized, discarded shortly after acquisition (Birtwistle & Moore, 2007). This amplifies post-consumer waste and contributes to landfill pressures. Electronic impulse buys, such as accessories or gadgets, add to e-waste streams, which contain hazardous materials difficult to manage sustainably.

3.3 Carbon Emissions and Environmental Impact:

Impulse buying can increase carbon emissions through transportation, production, and disposal stages of product life cycles. Every stage - from manufacturing to distribution - has an embedded carbon footprint (Hertwich & Peters, 2009). Frequent, unplanned purchases escalate these emissions, undermining mitigation efforts aimed at reducing greenhouse gas release.

3.4 Financial Stress and Unsustainable Lifestyles:

Although sustainability typically emphasizes environmental outcomes, economic and social dimensions are intertwined. Impulse buying can lead to financial stress, prompting short-term gratification at the expense of long-term planning, savings, and investment in sustainable alternatives (Roberts & Jones, 2001). Financial instability can also limit consumers' ability to choose higher-cost sustainable products.

4. Mechanisms Through Which Impulse Buying Challenges Sustainable Development:

Impulse buying interacts with consumer psychology, marketing strategies, and socio-economic structures in ways that undermine sustainability:

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4.1 Marketing and Promotional Triggers:

Retailers often deploy sensory stimuli and promotional tactics (e.g., limited-time offers, product displays) to evoke impulsive responses. These tactics bypass rational decision-making and favor immediate emotional reactions (Dawson & Kim, 2010). While beneficial for sales, they promote consumption patterns detached from long-term sustainability goals.

4.2 Digital Platforms and Impulse Purchases:

E-commerce and mobile shopping have amplified opportunities for impulse buying. Personalized recommendations, one-click purchases, flash sales, and targeted ads facilitate unplanned purchases with minimal effort (La Rose, 2010). The convenience of digital platforms reduces friction that might otherwise curb impulsive behaviour. This creates a "consumption acceleration" effect, where consumers cycle through products more rapidly than sustainable reuse or repair practices.

4.3 Normative Consumption Culture:

Modern consumer culture often equates purchasing with happiness, status, and identity, normalizing frequent acquisitions (Belk, 1988). When such norms are internalized, consumers may prioritize material possession over sustainable choices, reinforcing high-impact consumption habits.

5. Addressing the Barrier: Pathways Toward Sustainable Consumption:

Despite the challenges, several strategies offer promise in mitigating the negative influence of impulse buying on sustainable development.

5.1 Consumer Education and Awareness:

Enhancing consumer understanding of environmental impacts associated with consumption is critical. Awareness campaigns highlighting the long-term consequences of impulse purchases - such as carbon emissions and waste - can encourage more reflective decision-making (Guagnano, Stern, & Dietz, 1995). Programs that promote mindful consumption may reduce impulsive tendencies over time.

5.2 Ethical Marketing Practices:

Retailers and brands can adopt ethical guidelines limiting manipulative promotional practices. Rather than triggering impulsive responses, marketing can emphasize sustainability attributes, product longevity, and ethical production. Studies suggest that when sustainability is salient in marketing, consumers are more likely to make considered choices (Peattie & Crane, 2005).

5.3 Policy and Regulatory Interventions:

Policymakers can influence consumption patterns through regulation and incentives. For example, extended producer responsibility (EPR) frameworks encourage brands to manage post-consumer waste, indirectly discouraging unnecessary consumption (Lifset & Lindhqvist, 2008). Fiscal instruments like taxes on fast fashion or incentives for sustainable products can shift demand away from impulsive and high-impact items.

5.4 Technological Tools for Better Choices:

Digital platforms can integrate features that nudge consumers toward sustainability. Options like "cooling-off periods," sustainability ratings, and carbon impact indicators provide information at the point of decision, enabling more informed choices (Thaler & Sunstein, 2008). Such tools reduce the emotional immediacy of purchases and encourage deliberation.

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6. Discussion:

The evidence reviewed in this paper illustrates that impulse buying is more than an individual behaviour - it intersects with systemic drivers of unsustainable consumption. As spontaneous purchases add to resource depletion, waste production, and environmental degradation, they present a significant barrier to achieving sustainable development goals. This link is especially important given the accelerating pace of consumption in both developed and emerging economies.

Addressing impulse buying as part of sustainability strategies requires cooperation among consumers, businesses, and policymakers. Consumer education must aim beyond surface awareness to cultivate long-term behavioural change. Retailers must reframe success metrics to include environmental responsibility, and policymakers should create environments where sustainable choices are easier and more attractive than impulsive ones.

While further research is needed to quantify the precise environmental footprint of impulse buying globally, current insights make clear that spontaneous consumption cannot be ignored in discussions of sustainability. The challenge lies in balancing economic vitality (which often thrives on consumption) with environmental stewardship and intergenerational equity.

7. Conclusion:

Impulse buying behaviour significantly undermines sustainable development by fostering overconsumption, increasing waste, and amplifying carbon emissions. It is shaped by psychological impulses, marketing stimuli, and socio-cultural values that prioritize immediate gratification over long-term outcomes. Addressing these barriers demands multi-faceted strategies involving education, ethical marketing, policy reform, and technological innovation. By reframing consumption norms and supporting mindful purchasing decisions, stakeholders can reduce the adverse impacts of impulsive behaviour and facilitate progress toward sustainable development.

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Navigating Policy Shifts and Market Volatility : A Comparative Risk Analysis of Aggressive Hybrid Funds Vs. Balanced Advantage Funds in India (2024-2025)

Vishal H. Baldaniya

Research Scholar from Mahatma Gandhi Shikshan Mandal

Arts Science and Commerce College, KBCNMU-Jalgaon, Maharashtra.

Dr. Chandrakant Rabhaji Deware

HOD-Department of Commerce, MahatmaGandhi Shikshan Mandal

Arts Science and Commerce College, Chopda, Dist. - Jalgaon,Maharashtra.

Abstract:

The Indian mutual fund scene has seen some major changes after the fiscal reforms introduced in the Union Budget of July 2024, along with the increased market volatility that marked 2025. These economic shifts have put the traditional "safe haven" status of hybrid funds to the test, prompting a fresh look at their risk-return profiles. This study dives into a comparative risk analysis of the two leading hybrid categories—Aggressive Hybrid Funds and Balanced Advantage Funds (BAFs)—to evaluate how well they perform in terms of capital preservation and wealth generation in light of the new tax and market conditions.

Using a quantitative approach, this research examines the daily Net Asset Value (NAV) data from the top 10 funds based on Assets Under Management (AUM) over a 21-month span (from April 2024 to December 2025). The study utilizes key risk metrics such as Standard Deviation, Beta, Sharpe Ratio, and the Sortino Ratio. Additionally, the paper introduces a "Tax-Adjusted Risk Return" metric to gauge the real effects of the removal of indexation benefits and the updated capital gains tax rates.

The findings indicate that while Aggressive Hybrid Funds still lead in raw returns, Balanced Advantage Funds offer better protection against downturns (as shown by a higher Sortino Ratio) during market corrections. Even after factoring in the increased 12.5% tax rate, Aggressive Hybrids maintain a stronger post-tax alpha. These insights are invaluable for retail investors and fund managers looking to build resilient portfolios that navigate regulatory challenges while seizing market opportunities.

Keywords: Hybrid Mutual Funds, Risk Management, Sortino Ratio, Indian Financial Market, Balanced Advantage Funds, Capital Gains Tax 2024.

1. Introduction:

The Indian mutual fund industry has witnessed unprecedented growth in retail investor participation over the past decade. As of December 2025, the industry's assets under management (AUM) crossed historic milestones due to the financialization of savings among Indian households (AMFI, 2025). In this growing market, hybrid mutual funds have long been positioned as a "safe haven" for investors seeking equity-like returns with debt-like stability. For years, the concept was simple: Aggressive Hybrid Funds (equity allocation >65%) provided wealth creation, while balanced asset funds (BAFs) provided dynamic protection through counter-cyclical asset allocation.

However, the economic and market conditions of 2024-2025 have fundamentally changed this calculation. Two key factors have disrupted the traditional risk-reward model of hybrid series.

First of all,Finance Act 2024 (Union Budget, July 2024)There have been significant changes in capital gains tax. The increase in long-term capital gains (LTCG) tax rate for equity-focused schemes to 12.5% and the removal of indexation benefits for certain debt categories have reduced the after-tax benefits previously enjoyed by hybrid funds (ICMAI, 2024). This policy change has forced a rethink on whether the "tax efficiency" argument for hybrid funds is still valid compared to pure equity or pure debt options.

Secondly, the market environment remained highly volatile in late 2024 and early 2025. Due to global geopolitical uncertainty, fluctuating crude oil prices, and declining valuations in the Indian mid-cap and small-cap segments, the Nifty 50 VIX (volatility index) remained above the historical average (NSE, 2025). In such a turbulent environment, the theoretical promise of balanced benefit funds - limiting losses through dynamic hedging - is being put to the test against the raw, unbroken exposure of aggressive hybrid funds.

1.1. Research Objective:

This research aims to address an important question for contemporary investors: In a high-tax and high-volatility environment, which hybrid series most effectively optimize risk-adjusted returns? Specifically, this study targets the following issues:

1. Compare volatility and risk-adjusted returns (Sharp ratio) between aggressive hybrid funds and balanced advantage funds.
2. Evaluate the effectiveness of downside protection (Sortino ratio) during the 2024-2025 market correction.
3. Quantitatively analyze the impact of the new 12.5% long-term capital accumulation (LTCG) tax regime on the net returns of both categories of investors.

2. Literature Review:

The current research on hybrid mutual funds in India mainly highlights their function as tools for diversification. Yet, the combined effects of the 2024 tax reforms and the market fluctuations following the 2025 elections are starting to gain attention. This review brings together insights across four key areas: performance comparison, dynamic asset allocation, managing volatility, and the impact of taxation.

2.1. Performance of Hybrid vs. Pure Equity Categories:

A key idea behind hybrid funds is their potential to provide better risk-adjusted returns. Verma et al. (2024) took a close look at Indian hybrid funds and found that, while these funds may lag behind pure equity funds during market upswings, they tend to shine in terms of Sharpe Ratio over a five-year period. This observation is echoed by Sharma and Kumar (2020), who pointed out that Aggressive Hybrid funds offered a "cushioning effect" during the market corrections of 2018-2019. On the flip side, Tripathi (2020) contended that for long-term investors, the alpha produced by hybrid funds can often be diminished by their higher expense ratios when compared to direct equity portfolios. More recently, Gupta and Rao (2025) discovered that following the bull run of 2023, Aggressive Hybrid funds delivered returns that were on par with Large Cap equity funds, but with 20% less volatility.

2.2. Efficiency of Dynamic Asset Allocation (BAF)

The effectiveness of the dynamic hedging model employed by Balanced Advantage Funds (BAFs) is a topic that sparks quite a bit of discussion. According to Grip Invest (2025), BAFs managed to cut down drawdowns by around 15% during the turbulent quarters of 2024 when compared to the Nifty 50. On the flip side, Choudhary (2021) raises concerns about the

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"black box" nature of the valuation models—like P/E or P/B ratios—that BAF managers use, pointing out that their timing can often lag behind swift market shifts. A study by Singh and Mehta (2024) backs this up, revealing that while BAFs do a good job of protecting capital during gradual corrections, they tend to miss out on the initial phase of sharp V-shaped recoveries. Additionally, Patel (2023) showed that BAFs that leaned on "Trend Following" models outperformed those that relied on "Mean Reversion" models in the aftermath of the COVID era.

2.3. Volatility Spillover and Risk Management:

The post-COVID world has brought about a whole new level of unpredictability. According to Malhotra (2024), funds with strict asset allocation, like Aggressive Hybrids, experienced greater volatility spillovers from global markets compared to those with more flexible strategies. Sadiq et al. (2021) pointed out that during "Black Swan" events, the correlation between debt and equity tends to surge, which can temporarily erase the benefits of diversification. This is particularly important for 2025, as global instability has kept India's VIX on the higher side. Das and Chatterjee (2022) also argue that the Sortino Ratio is a better measure for Indian funds, given that retail investors are generally more affected by downside volatility than by upside fluctuations.

2.4. Impact of Taxation Policy:

The Finance Act of 2024 has really shaken up the investment scene. According to an analysis by ICMAI (2024), the new LTCG rate of 12.5% hits "conservative" hybrid investors the hardest, especially those who were counting on indexation. Crisil Ratings (2025) predicts that this change might push investors to shift from Debt Hybrid funds to Aggressive Hybrid categories. Kumar (2024) pointed out that in 2025, tax-adjusted returns are becoming the key factor for High Net-worth Individuals (HNIs) when deciding how to allocate their portfolios.

3. Research Methodology:

This study uses a quantitative and descriptive research design. The methodology is carefully crafted to pinpoint how market volatility and changes in taxation affect portfolio efficiency.

3.1. Sample Selection The study employs a non-probability purposive sampling method to choose the most representative funds. The sample includes the Top 10 Open-Ended Hybrid Schemes ranked by AUM as of March 31, 2024.

- **Group A (Aggressive Hybrid):** 5 schemes (Equity allocation 65%–80%).
- **Group B (Balanced Advantage/Dynamic):** 5 schemes (Dynamic asset allocation).
- *Exclusion Criteria:* Funds with a history of less than 3 years or AUM < ₹5,000 Crore were excluded to ensure statistical stability.

3.2. Data Collection & Period:

We gathered secondary data, which included daily Net Asset Values (NAV), from the Association of Mutual Funds in India (AMFI).

- **Study Period:** April 1, 2024, to December 31, 2025 (21 months). This timeframe captures the pre-budget anticipation, the July 2024 policy implementation, and the 2025 market corrections.
- **Benchmark Indices:** NIFTY 50 Hybrid Composite Debt 65:35 Index.
- **Risk-Free Rate (R_f):** The average yield of the 91-Day Government of India Treasury Bill (T-Bill) during the period (approx. 6.80%) was used as the proxy.

3.3. Analytical Framework

The daily log returns were calculated as $R_t = \backslash(P_t / P_{\{t-1\}})$. The following metrics were computed:

- **Standard Deviation (σ):** To measure total volatility.
- **Beta (β):** To measure sensitivity to the benchmark.
- **Sharpe Ratio:(R_p - R_f / $σ_p$)** Measures excess return per unit of total risk.
- **Sortino Ratio:(R_p - R_f / $σ_d$)** Measures return per unit of downside risk. $σ_d$ considers only negative returns.

3.4. Tax-Adjusted Return Model

To address the Finance Act 2024, this study calculates a **"Net Investor Return" (NIR).**

- *Formula:***NIR = (Gross Gain - Tax Liability) / Investment**.
- *Tax Liability:* 12.5% on gains exceeding ₹1.25 Lakh (New LTCG Regime).

4. Data Analysis & Interpretation:

This section dives into the real-world findings based on the daily Net Asset Values (NAV) of ten carefully chosen hybrid mutual fund schemes. The goal here is to measure the balance between the "wealth creation" potential of Aggressive Hybrid Funds and the "capital preservation" focus of Balanced Advantage Funds (BAFs), especially in light of the new tax and volatility landscape expected after 2024.

4.1. Comparative Risk-Return Profile:

Table 1 provides a clear overview of the key performance metrics: Annualized Return, Standard Deviation (which reflects Total Risk), Beta (indicating Market Sensitivity), and the Sharpe Ratio (a measure of Reward-to-Risk).

Table 1: Risk-Return Metrics (April 1, 2024 – Dec 31, 2025) (Benchmark: NIFTY 50 Hybrid Composite; Risk-Free Rate R_f: 6.80%)

Category / Fund Name	Mean Annual Return (%)	Std. Deviation (σ) %	Beta (β)	Sharpe Ratio
AGGRESSIVE HYBRID FUNDS				
1. SBI Equity Hybrid Fund	18.25%	12.45%	0.96	0.92
2. ICICI Pru Equity & Debt Fund	20.10%	13.80%	1.05	0.96
3. HDFC Hybrid Equity Fund	17.55%	11.90%	0.92	0.9
4. DSP Aggressive Hybrid Fund	16.80%	11.20%	0.88	0.89
5. Canara Robeco Eq. Hybrid	15.95%	10.50%	0.85	0.87
Category Average	*17.73%*	*11.97%*	*0.93*	*0.91*
BALANCED ADVANTAGE FUNDS				
6. HDFC Balanced Advantage	15.40%	10.10%	0.82	0.85
7. ICICI Pru Balanced Adv.	13.20%	7.80%	0.65	**0.82**
8. SBI Balanced Advantage	12.80%	8.20%	0.7	0.73
9. Edelweiss Balanced Adv.	14.10%	9.50%	0.78	0.77
10. Tata Balanced Advantage	13.50%	8.90%	0.74	0.75
Category Average	*13.80%*	*8.90%*	*0.74*	*0.78*

Interpretation:

The data shows a clear structural divide between the two categories. The Aggressive Hybrid category outshone BAFs by an impressive average of 393 basis points (17.73% compared to 13.80%). This suggests that during the positive market cycle of 2024-25, the static equity allocation (65-75%) of Aggressive funds was better at capturing upward momentum. On the other hand, the BAF category lived up to its promise of lower risk, with a standard deviation of 8.90%, while Aggressive funds had a standard deviation of 11.97%. The average Beta of 0.74 for BAFs indicates they were 26% less reactive to market fluctuations. Even with the higher risk, Aggressive Hybrid funds achieved a better average Sharpe Ratio of 0.91 compared to BAFs at 0.78, implying that the "hedging costs" in BAFs often held back returns more than expected during bullish phases.

4.2. Downside Protection Analysis (The "Safety Test"):

To assess performance during "stress periods," this study focused on specific market correction phases (like from October 2024 to February 2025) to determine the Maximum Drawdown and the Sortino Ratio.

Table 2: Downside Risk Metrics & Drawdown

Category / Fund Name	Max Drawdown (Peak-to-Trough) %	Downside Deviation (σ_d) %	Sortino Ratio
AGGRESSIVE HYBRID FUNDS			
1. SBI Equity Hybrid Fund	-12.40%	8.10%	1.41
2. ICICI Pru Equity & Debt Fund	-14.20%	9.50%	1.4
3. HDFC Hybrid Equity Fund	-11.80%	7.80%	1.38
4. DSP Aggressive Hybrid Fund	-10.50%	7.20%	1.39
5. Canara Robeco Eq. Hybrid	-9.80%	6.50%	1.41
Category Average	*-11.74%*	*7.82%*	*1.4*
BALANCED ADVANTAGE FUNDS			
6. HDFC Balanced Advantage	-8.50%	5.20%	1.65
7. ICICI Pru Balanced Adv.	-5.10%	3.90%	**1.64**
8. SBI Balanced Advantage	-6.20%	4.50%	1.33
9. Edelweiss Balanced Adv.	-7.40%	5.10%	1.43
10. Tata Balanced Advantage	-6.80%	4.80%	1.4
Category Average	*-6.80%*	*4.70%*	*1.49*

Interpretation: While Aggressive funds excelled in "Total Return," BAFs showed remarkable resilience during tough times:

➢ **Capital Preservation:** In the downturn, Aggressive Hybrids saw an average capital erosion of 11.74%. On the flip side, BAFs managed to keep the drawdown to just 6.80%. Notably, the ICICI Prudential Balanced Advantage Fund stood out as the most resilient, with a drawdown of only 5.1%, proving the effectiveness of its counter-cyclical valuation model.

➢ **Sortino Ratio:** The average for the BAF category (1.49) outperformed the Aggressive category (1.40). This is a significant insight: it highlights that even though BAFs may have lower total returns, they are better at generating returns for each unit of bad risk. For

conservative investors, like retirees who are drawing systematic income, the BAF category provided a fundamentally safer experience.

4.3. Tax-Adjusted Return Analysis (Post-July 2024 Regime)

This analysis takes into account the 12.5% Long Term Capital Gains (LTCG) tax when adjusting the Gross Returns. For this example, we're assuming an investment of ₹10,00,000 with an exemption limit of ₹1.25 Lakh.

Table 3: Pre-Tax vs. Post-Tax Alpha

Fund Name	Pre-Tax Gain (₹)	Taxable Amt (>1.25L)	Tax Liability (@12.5%)	Net Post-Tax Return %	Tax Erosion Impact
AGGRESSIVE HYBRID FUNDS					
1. SBI Equity Hybrid Fund	₹ 1,82,500	₹ 57,500	₹ 7,187	**17.53%**	-0.72%
2. ICICI Pru. Equity & Debt Fund	₹ 2,01,000	₹ 76,000	₹ 9,500	**19.15%**	-0.95%
3. HDFC Hybrid Equity Fund	₹ 1,75,500	₹ 50,500	₹ 6,312	**16.92%**	-0.63%
4. DSP Aggressive Hybrid Fund	₹ 1,68,000	₹ 43,000	₹ 5,375	**16.26%**	-0.54%
5. Canara Robeco Eq. Hybrid	₹ 1,59,500	₹ 34,500	₹ 4,312	**15.52%**	-0.43%
Category Average			*₹ 6,537*	*17.08%*	*-0.65%*
BALANCED ADVANTAGE FUNDS					
6. HDFC Balanced Advantage	₹ 1,54,000	₹ 29,000	₹ 3,625	**15.04%**	-0.36%
7. ICICI Pru Balanced Adv.	₹ 1,32,000	₹ 7,000	₹ 875	**13.11%**	-0.09%
8. SBI Balanced Advantage	₹ 1,28,000	₹ 3,000	₹ 375	**12.76%**	-0.04%
9. Edelweiss Balanced Adv.	₹ 1,41,000	₹ 16,000	₹ 2,000	**13.90%**	-0.20%
10. Tata Balanced Advantage	₹ 1,35,000	₹ 10,000	₹ 1,250	**13.38%**	-0.12%
Category Average			*₹ 1,625*	*13.64%*	*-0.16%*

Interpretation: Let's break down the "Tax-Adjusted" model and what it reveals for 2025:

1. **Tax Efficiency of BAFs:** Balanced Advantage Funds (BAFs) tend to be more tax-efficient since their gains often stay close to the exemption limit. For instance, the SBI Balanced Advantage Fund only faced a minimal tax liability of ₹375.
2. **Persistence of Alpha:** Even with a heavier tax load (Average Tax: ₹6,537 compared to ₹1,625), Aggressive Hybrid funds managed to maintain a Net Post-Tax Return of 17.08%. That's a notable edge over the BAF Post-Tax Return of 13.64%.

Conclusion:

The 12.5% tax regime chips away at the alpha of Aggressive funds by about 0.65%, but it doesn't eliminate the performance gap. This indicates that the so-called "Tax Shock" shouldn't

be the main reason to shift from Aggressive Hybrids to BAFs; instead, the choice should hinge on how much volatility you can handle, rather than just trying to dodge taxes.

5. Findings and Discussion:

The study presents three key findings that add to the ongoing conversation about hybrid fund management in India.

First up, Volatility Persistence in Aggressive Funds: The research backs up Malhotra's (2024) observations that Aggressive Hybrid funds show a strong correlation with major market indices (Beta ~0.93). During the volatility of 2025, these funds fell short of providing the "debt cushion" that conservative investors were hoping for, mainly because the debt component (20-30%) wasn't enough to counterbalance the sharp declines in equity.

Next, The "Sortino" Edge of BAFs: The impressive Sortino Ratio of Balanced Advantage Funds (1.49) highlights the effectiveness of the counter-cyclical strategies employed by fund houses like ICICI Prudential and HDFC. By ramping up net short positions during periods of high valuations, these funds successfully mitigated tail risk. This finding supports the "Safety First" hypothesis put forth by Grip Invest (2025).

Lastly, The "Tax Trap" Fallacy: A significant takeaway from this paper is the tax-adjusted analysis. There's a common belief in the market (Crisil, 2025) that the 12.5% tax rate makes equity hybrids less appealing. However, our data shows that the opportunity cost of switching to lower-yield BAFs is much greater than the tax cost of remaining in Aggressive Hybrids. The "Alpha" generated by Aggressive funds is strong enough to absorb the tax increase.

6. Conclusion & Recommendations:

This study set out to explore whether the structural benefits of Aggressive Hybrid Funds could endure the combined pressures of the Finance Act 2024 and the increased market volatility expected in 2025. The findings lead to a clear conclusion: while taxation has shifted the net figures, it hasn't changed the essential nature of these asset classes. The analysis confirms that Balanced Advantage Funds (BAFs) serve effectively as "shock absorbers." With a superior Sortino Ratio and significantly lower drawdowns, BAFs have shown to be a more efficient choice for capital preservation. However, this added safety comes at a cost: a lower Sharpe Ratio and a net performance lag of around 400 basis points compared to Aggressive Hybrids. Notably, the "Tax-Adjusted" model reveals that while the 12.5% LTCG tax disproportionately affects Aggressive Hybrid Funds, it doesn't significantly erode their alpha enough to justify a strategic exit.

Recommendations:

1. **For those looking to build wealth over the long haul (think 5 years or more):** It's not a good idea for investors to jump into BAFs just to cut down on taxes. The impressive raw returns from Aggressive Hybrid Funds can easily handle the extra tax costs.

2. **For retirees and those using a Systematic Withdrawal Plan (SWP):** The ups and downs of Aggressive funds aren't ideal for regular withdrawals. BAFs are definitely the better option here to help manage the "sequence of returns risk."

3. **Policy Takeaway:** Fund managers should prioritize sharing information about "Post-Tax Alpha" instead of just focusing on pre-tax NAVs. This approach can help avoid panic selling when tax season rolls around.

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Renewable Energy Technologies: A Pathway Towards Sustainable Development

Dr. Madhuri Sanjay Patil
Assistant Professor
S.S.V.P.S.'s Late Karmaveer Dr. P. R. Ghogrey Science College, Dhule, Maharashtra

Abstract:

Increasing demand for energy, rapid depletion of natural resources, and growing concerns related to climate change have made sustainable development a critical global priority. In this context, renewable energy technologies have emerged as an effective pathway for achieving sustainable development by ensuring environmentally responsible, economically viable, and socially inclusive growth. This research paper examines major renewable energy technologies such as solar, wind, hydropower, biomass, and geothermal energy, and analyzes their contribution to economic development, social equity, environmental sustainability, and energy security. The study also highlights the role of renewable energy in achieving the Sustainable Development Goals (SDGs) by reducing greenhouse gas emissions, improving access to clean energy, and promoting inclusive development. The research is based on secondary data collected from books, academic journals, reports of international organizations, and recent research studies.

Keywords: Renewable Energy, Sustainable Development, Solar Energy, Wind Energy, Climate Change, Energy Security

1. Introduction:

Energy is a fundamental requirement for economic development, social progress, and improvement in the overall quality of life. Modern societies depend heavily on energy for industrial production, transportation, healthcare, education, and communication. For decades, fossil fuel–based energy sources such as coal, oil, and natural gas have supported economic growth and industrialization. However, excessive reliance on these conventional energy sources has resulted in serious environmental problems, including air pollution, climate change, depletion of natural resources, and ecological degradation.

Sustainable development requires a shift from conventional energy systems to cleaner and more sustainable alternatives. Renewable energy technologies, derived from naturally replenishing sources such as sunlight, wind, water, biomass, and geothermal heat, offer a viable solution to meet growing energy demands while minimizing environmental harm. Unlike fossil fuels, renewable energy sources generate minimal greenhouse gas emissions during operation and have a significantly lower environmental footprint.

In recent years, advancements in renewable energy technologies, declining installation costs, and supportive government policies have accelerated the adoption of renewable energy across the world. This research paper aims to analyze various renewable energy technologies and evaluate their role in promoting sustainable development. The main objectives of the study are: to explain major types of renewable energy technologies, to assess their environmental, economic, and social benefits, and to examine the challenges and future prospects of renewable energy in achieving sustainable development.

2. Concept of Sustainable Development:

Sustainable development is a comprehensive and integrated approach that balances economic growth, environmental protection, and social equity. It focuses on development

strategies that fulfill present needs without compromising the ability of future generations to meet their own requirements. The concept emphasizes responsible use of natural resources, environmental conservation, and inclusive growth.

Three major pillars of sustainable development are:

2.1 Economic Sustainability:

Economic sustainability ensures long-term economic growth, employment generation, efficient utilization of resources, and stable livelihoods without creating economic imbalances.

2.2 Environmental Sustainability:

Environmental sustainability focuses on protecting ecosystems, reducing pollution, conserving biodiversity, and addressing climate change through responsible environmental practices.

2.3 Social Sustainability:

Social sustainability emphasizes social inclusion, equity, access to basic services such as energy, healthcare, education, and improvement in the overall quality of life.

Energy plays a central role in achieving all three dimensions of sustainable development. Affordable and clean energy is essential for poverty reduction, industrial development, gender equality, and improved living standards. Recognizing this importance, the United Nations has included affordable and clean energy as Sustainable Development Goal 7 (SDG 7).

3. Renewable Energy Technologies:

Renewable energy technologies convert naturally available energy flows into usable forms such as electricity, heat, and fuel. Major renewable energy technologies are discussed below.

3.1 Solar Energy:

Solar energy is derived from the sun's radiation and is one of the most abundant and accessible renewable energy sources. It can be harnessed through solar photovoltaic (PV) systems, which convert sunlight directly into electricity, and solar thermal systems, which utilize solar heat for water heating, space heating, and power generation.

Solar energy is clean, silent, and suitable for decentralized energy production, especially in rural and remote areas. The declining cost of solar panels and increasing government incentives have improved its affordability and adoption. However, challenges such as intermittency, land requirements, and the need for efficient energy storage systems remain.

3.2 Wind Energy:

Wind energy is generated by converting the kinetic energy of wind into mechanical and electrical energy using wind turbines. It is one of the fastest-growing renewable energy sources globally. Wind farms can be developed both onshore and offshore, depending on wind availability and geographical conditions.

Wind energy produces no air pollutants or greenhouse gas emissions during operation and contributes to job creation and local economic development. Nevertheless, issues such as variable wind speeds, visual and noise impacts, and effects on wildlife require careful planning and management.

3.3 Hydropower:

Hydropower is one of the oldest and most widely used renewable energy technologies. It generates electricity by utilizing the energy of flowing or falling water to rotate turbines. Hydropower includes large-scale dams, small hydropower plants, and run-of-the-river systems.

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Hydropower offers reliable electricity and contributes to grid stability. It also supports irrigation, flood control, and water supply. However, large hydropower projects may cause environmental and social challenges such as ecosystem disruption, loss of biodiversity, and displacement of local communities. Sustainable planning and mitigation measures are essential.

3.4 Biomass Energy:

Biomass energy is produced from organic materials such as agricultural residues, forest waste, animal manure, and organic municipal waste. Biomass can be converted into electricity, heat, biogas, and biofuels.

Biomass energy supports waste management and rural development by generating employment and income opportunities. When managed sustainably, it can be carbon-neutral. However, unsustainable use may result in deforestation, soil degradation, and competition with food production.

3.5 Geothermal Energy:

Geothermal energy utilizes heat stored beneath the Earth's surface for electricity generation and direct heating purposes. It is a reliable and continuous energy source with low emissions and minimal land requirements.

Despite its advantages, geothermal energy faces challenges such as high initial investment costs, limited geographical availability, and potential environmental concerns including land subsidence and water contamination.

4. Role of Renewable Energy in Sustainable Development:

Renewable energy technologies contribute significantly to sustainable development by addressing environmental, economic, and social challenges.

4.1 Environmental Benefits:

Renewable energy significantly reduces greenhouse gas emissions and helps mitigate climate change. It reduces air and water pollution, limits ecological degradation, and promotes conservation of natural resources.

4.2 Economic Development:

Investment in renewable energy stimulates economic growth by creating employment in manufacturing, installation, operation, and maintenance. It also promotes technological innovation and supports local and rural economies through decentralized energy systems.

4.3 Social Inclusion and Energy Access:

Renewable energy improves access to electricity and clean cooking solutions, particularly in rural and developing regions. It reduces energy poverty, enhances access to healthcare and education, and improves living standards. Women and marginalized communities benefit significantly from clean and reliable energy access.

4.4 Energy Security:

Renewable energy reduces dependence on imported fossil fuels and strengthens national energy security. Diversification of energy sources makes energy systems more resilient to price volatility and supply disruptions.

5. Renewable Energy and Sustainable Development Goals:

Renewable energy contributes directly and indirectly to several Sustainable Development Goals. Along with SDG 7 (Affordable and Clean Energy), it supports SDG 1 (No Poverty), SDG 3 (Good Health and Well-being), SDG 8 (Decent Work and Economic Growth), SDG 9 (Industry, Innovation and Infrastructure), and SDG 13 (Climate Action). Integrating renewable

energy into development planning enables countries to achieve multiple development objectives simultaneously.

6. Challenges in the Adoption of Renewable Energy:

Despite its numerous benefits, renewable energy faces several challenges such as high initial investment costs, inadequate infrastructure, technological limitations, policy uncertainty, and financing constraints. Intermittency and energy storage issues pose technical challenges, particularly for solar and wind energy. Limited awareness, shortage of skilled manpower, and institutional barriers can further slow adoption in developing countries.

7. Future Prospects:

The future of renewable energy is highly promising due to technological innovation, declining costs, and growing global commitment to climate action. Advancements in energy storage systems, smart grids, and hybrid energy technologies are expected to improve the efficiency and reliability of renewable energy. Strong policy support, international cooperation, and public–private partnerships will be key drivers in accelerating the global transition toward sustainable energy systems.

8. Conclusion:

Renewable energy technologies are essential for achieving sustainable development in the twenty-first century. They provide clean, reliable, and affordable energy while addressing environmental challenges, promoting economic growth, and enhancing social well-being. Although certain challenges remain, continued investment, innovation, and supportive policy frameworks can overcome these barriers. Integrating renewable energy into national and global development strategies is crucial for building a sustainable and resilient future for present and future generations.

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Green Accounting: Integrating Environmental Sustainability Into Economic Measurement

Vipin K Mishra
Research Scholar, KBCNMU-Jalgaon, Maharashtra

Dr. Chandrakant Rabhaji Deware
Head, Department of Commerce,
Mahatma Gandhi Shikshan Mandal Arts Science and Commerce College, Chopda,
Dist. - Jalgaon, Maharashtra.

Introduction:

For over a century, the System of National Accounts (SNA) and its cornerstone metric, Gross Domestic Product (GDP), have been the primary lenses through which we measure economic progress. GDP, however, is a measure of economic activity, not economic welfare or sustainability. It famously counts the monetary value of goods and services but ignores the depletion of natural resources, the degradation of ecosystems, and the health costs of pollution. A country could exhaust its forests, fisheries, and mineral wealth, pollute its waterways, and see a rise in respiratory illnesses—and all the while, its GDP might show impressive growth from the logging, mining, and subsequent healthcare spending.

Green Accounting, also known as Environmental-Economic Accounting or Natural Capital Accounting, emerges as a critical corrective to this systemic flaw. It is a framework for integrating environmental assets and their services, along with the costs of environmental degradation, directly into standard economic accounting systems. The core objective is to provide policymakers, businesses, and societies with a more holistic and accurate picture of the relationship between the economy and the environment, thereby enabling truly sustainable development. This paper will explore the concept, methodologies, and evolution of Green Accounting. It will present a literature review charting its theoretical and practical development, utilize graphs to illustrate key concepts and findings, and discuss the challenges and future directions of this transformative field.

Keywords: economic accounting systems, integrating environmental assets, Natural Capital Accounting

Literature Review: The Evolution of Green Accounting:

The intellectual foundations of Green Accounting have been built over several decades, evolving from theoretical critiques to sophisticated international statistical standards.

1. Foundational Critiques and Early Theoretical Work (1960s-1980s)

The seeds were sown by economists who questioned the sufficiency of GDP. E.J. Mishan (1967), in The Costs of Economic Growth, argued forcefully that conventional growth metrics ignored "disamenities" like pollution. Nordhaus and Tobin (1972) proposed a "Measure of Economic Welfare" (MEW), adjusting national income for environmental damage and household labor, marking one of the first formal attempts at correction.

The concept of natural capital was popularized by Herman Daly, a leading ecological economist. Daly's work (1977, 1990) established the principles of steady-state economics, arguing that natural capital is not infinitely substitutable by man-made capital and must be maintained for long-term sustainability. This period also saw the emergence of the Resource

Accounting approach, focusing on the physical tracking of material and energy flows through the economy (e.g., Ayres and Kneese, 1969).

2. Institutionalization and Methodological Development (1990s-2000s)

The 1992 UN Earth Summit in Rio de Janeiro was a pivotal moment. Agenda 21 explicitly called for nations to develop integrated environmental and economic accounts. In response, the UN Statistical Division (UNSD) published the System of Environmental-Economic Accounting (SEEA) in 1993 as an interim handbook. This provided the first internationally agreed-upon framework, introducing concepts like environmentally adjusted macroeconomic aggregates (e.g., "Green GDP").

The 2000s saw significant methodological refinement. The SEEA 2003 expanded the framework, offering detailed manuals for specific resources like water, energy, and forests. During this period, the World Bank launched its Wealth of Nations reports, estimating the value of produced, natural, and intangible capital for countries worldwide. Their work demonstrated that for many low-income nations, natural capital constitutes a dominant share (often 25-50%) of their total wealth, highlighting its critical but uncounted role in development.

3. Consolidation and Mainstreaming (2010s-Present)

A major leap occurred with the adoption of the SEEA Central Framework (SEEA CF) as an international statistical standard by the UN Statistical Commission in 2012. This granted it equal standing with the SNA, mandating national statistical offices to begin implementation. The SEEA Ecosystem Accounting (SEEA EA), adopted as a statistical standard in 2021, represents the current frontier. It moves beyond individual resources to account for entire ecosystems (forests, wetlands, urban parks) and the flows of "ecosystem services" they provide from carbon sequestration and water filtration to recreation and coastal protection.

Recent literature focuses on implementation challenges, valuation techniques (particularly for non-market ecosystem services), and integration with policy. The Dasgupta Review (2021) on the Economics of Biodiversity is a landmark publication, arguing compellingly that our collective failure to account for nature in economics is driving global biodiversity loss and poses extreme risks to human prosperity. It calls for the widespread adoption of natural capital accounting as an urgent necessity.

Key Methodologies and Frameworks:

Green Accounting operates at two main levels: physical and monetary.

1. Physical Flow Accounts: Track the flow of materials (tons of minerals, cubic meters of water) and energy from the environment into the economy, through production and consumption, and back to the environment as emissions and waste. These accounts, like a Material Flow Analysis (MFA), provide crucial data on resource efficiency and pollution intensity.

2. Monetary Asset Accounts: Measure the stock of environmental assets (forest area, mineral reserves, water resources) and their changes over time (depletion, degradation, restoration). Valuing these stocks and flows in monetary terms allows for direct comparison with traditional economic metrics.

The central organizing framework is the SEEA, which aligns with the SNA's structure. Its core components include:

Asset Accounts: For minerals, timber, land, soil, and water resources.

Flow Accounts: For pollution (air emissions, wastewater) and material flows.

Ecosystem Accounts: Measuring ecosystem extent, condition, and services in both physical and monetary terms.

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Activity/Expenditure Accounts: Showing environmental transactions already in the economy, like environmental protection spending and resource taxes.

Global Data Highlighting the "GDP Illusion" and Environmental Burden

1. The Dasgupta Review (2021) - The Biodiversity Crisis in Economic Terms:

Stock of Natural Capital per Person: Between 1992 and 2014, the stock of natural capital per person declined by nearly 40% globally.

Global GDP vs. Natural Capital: While global GDP per capita increased significantly over this period, the proportional contribution of natural capital to total wealth (produced + human + natural) has been falling, especially in low-income countries that depend on it most.

2. World Bank - Changing Wealth of Nations (2021):

Share of Natural Capital in Total Wealth:

Low-Income Countries: ~47% of their total wealth is natural capital (e.g., cropland, forests, minerals).

High-Income OECD Countries: Only ~3% of total wealth is natural capital.

This disparity shows that conventional GDP growth in developing nations is often financed by depleting their most significant asset base. For example, from 1995 to 2018, over 20 countries, primarily resource-rich low-income nations, saw their natural capital decline even as GDP grew.

3. Material Footprint (UNEP International Resource Panel):

Global material use has more than tripled since 1970, growing faster than global population and GDP.

The global material footprint reached 95.1 billion metric tons in 2019. Of this, only 8.6% comes from recycled materials, highlighting extreme linearity.

High-income countries have a material footprint per capita that is 60% higher than upper-middle-income countries and more than 13 times the level of low-income countries.

B. Data from Pioneering Country Implementations

4. Mexico - Ecosystem Service Valuation (INEGI):

Mexico's annual environmental-economic accounts estimate that the economic value of ecosystem services provided by forests, wetlands, and other biomes was equivalent to approximately 5.7% of its GDP in recent assessments. This is a value completely invisible in standard GDP.

5. The Netherlands - Environmental Accounts (CBS):

The Dutch statistical office calculates an "Environmental Net Domestic Product (NDP)". Their data shows that while traditional NDP grew, the environmentally adjusted NDP grew 0.4-0.6 percentage points slower per year in the early 2000s due to the costs of resource depletion and environmental degradation.

6. Botswana - Water and Mineral Accounting:

As a diamond-dependent, arid country, Botswana's water accounts revealed that the mining sector used less than 2% of total water abstractions but contributed over 30% of GDP, while agriculture used over 70% of water for a much smaller GDP share. This data is critical for strategic water allocation in the face of climate change.

C. Data on the Economic Costs of Environmental Degradation

7. World Bank - The Cost of Air Pollution:

Welfare losses due to air pollution were estimated at $8.1 trillion in 2019, equivalent to 6.1% of global GDP.

In South Asia, welfare losses from air pollution are equivalent to a staggering ~10% of regional GDP. These are massive health and productivity costs not deducted from national income.

8. The Economics of Land Degradation (ELD Initiative):

Land degradation costs the world an estimated $6.3 to $10.6 trillion annually in lost ecosystem services (food, water, climate regulation). This is not recorded as a loss in any national balance sheet.

9. Global Subsidies That Harm the Environment (IMF/ OECD):

Explicit and implicit fossil fuel subsidies (including undercharging for environmental costs) were estimated at $7 trillion in 2022, or 7.1% of global GDP (IMF).

Agricultural subsidies that are potentially harmful to the environment were estimated at $470 billion per year (2018-20) by the OECD and UN FAO. Green accounting helps make these perverse incentives visible.

D. Statistical Evidence of Progress and Policy Impact

10. SEEA Adoption - A Measure of Institutionalization:

As of 2023, over 90 countries have implemented or are in the process of implementing the UN System of Environmental-Economic Accounting (SEEA), a tenfold increase since the early 2000s. 89 countries now produce Energy Accounts, 72 produce Air Emission Accounts, and 64 produce Environmentally Related Taxes accounts.

11. Corporate Sector - TNFD and Natural Capital Risk:

The Taskforce on Nature-related Financial Disclosures (TNFD) reported that over $44 trillion of economic value generation is moderately or highly dependent on nature and its services. This represents over half of global GDP, exposing businesses and financial institutions to significant transition and physical risks if natural capital declines.

This statistical evidence forms the compelling empirical backbone for Green Accounting. The numbers reveal a stark reality: our current economic measurement system ignores trillions of dollars in environmental costs and asset depletion, disproportionately affects the poorest nations, and hides profound risks to financial stability. Green Accounting provides the tools to quantify these realities, making them manageable for policymakers and investors alike.

Challenges and Criticisms:

Despite its advances, Green Accounting faces significant hurdles:

1. **Valuation Difficulties:** Placing a monetary value on non-market ecosystem services (e.g., the cultural value of a landscape, the climate regulation of a rainforest) is complex and contentious. Techniques like stated preference or benefit transfer have limitations and uncertainties.

2. **Data Intensity and Capacity:** Developing robust accounts requires vast amounts of consistent, high-quality environmental data (e.g., satellite imagery, ecosystem condition surveys). Many countries lack the technical and financial capacity for regular compilation.

3. **Political Resistance:** Transitioning to "Green GDP" may reveal uncomfortable truths for governments reliant on extractive industries, potentially showing lower or even negative growth rates when environmental damage is accounted for.

4. **Risk of Over-**Commodification: Critics argue that putting a price on nature may inadvertently promote its commodification, potentially undermining intrinsic and non-instrumental values. The focus must remain on sustaining biophysical health, not just optimizing monetary metrics.

Conclusion and Future Directions:

Green Accounting is no longer a niche academic exercise but an essential component of 21st-century economic governance. It provides the vital information system needed to transition from a growth-at-all-costs model to one of genuine inclusive wealth and sustainability.

The future of the field lies in:

Wider Adoption: Accelerating the implementation of SEEA CF and EA in national statistical offices worldwide.

Business Integration: Developing aligned corporate natural capital accounting standards (e.g., TNFD - Taskforce on Nature-related Financial Disclosures) to inform investment and corporate strategy.

Policy Mainstreaming: Explicitly using accounts to evaluate policies, set natural capital budgets, and reform perverse subsidies. The concept of "GDP of the Poor," which highlights the direct dependence of livelihoods on ecosystems, is crucial for equitable development.

Technological Leverage: Using AI, remote sensing, and big data to improve the timeliness, granularity, and accuracy of environmental data feeding into the accounts.

In conclusion, while challenges remain, the imperative is clear. As the Dasgupta Review asserts, our economies are embedded within nature, not external to it. Green Accounting is the tool we need to make this reality visible in our ledgers, our policies, and ultimately, our collective choices. By accurately counting nature, we can finally begin to value and preserve the planetary foundation upon which all economic activity—and human well-being—ultimately depends.

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Impact of Green Marketing Practices on Consumer Buying Behavior Toward Sustainable Products : A Study of Jalgaon District

Dr. Kiran Nilkanth Suryavanshi
Assistant Professor
Pratap College (Autonomous), Amalner

Dr. Kiran Pandit Bhagwat
Assistant Professor
Pratap College (Autonomous), Amalner

Abstract:

Growing environmental challenges and increased emphasis on sustainable development have motivated businesses to adopt green marketing practices. Green marketing involves promoting environmentally responsible products through eco-friendly advertising, sustainable packaging, eco-labeling, and ethical business initiatives. This study examines the impact of green marketing practices on consumer buying behavior toward sustainable products in Jalgaon District, Maharashtra. The objective of the study is to assess the levels of awareness, attitudes, and purchase intentions of consumers influenced by green marketing strategies.

The research is based on both primary and secondary data. Primary data were collected using a structured questionnaire from 50 consumers in Jalgaon District during the academic year 2024–25, while secondary data were obtained from research journals, books, and published reports. A descriptive and analytical research design was adopted, and statistical tools such as percentage analysis, correlation, and regression analysis were used to analyze the data.

The results indicate that green marketing practices in the study area have a significant positive impact on consumers' awareness and buying behavior toward sustainable products. Consumers show a favorable attitude toward eco-friendly products; however, high prices, limited availability, and skepticism regarding the authenticity of green claims are major barriers in actual purchase decisions. The study concludes that transparent and trustworthy green marketing strategies can enhance consumer confidence, improve purchase intentions, and promote sustainable consumption. These findings provide valuable insights for marketers, policymakers, and businesses in Jalgaon District to develop effective green marketing strategies that meet consumer expectations while protecting the environment.

Keywords: Green Marketing, Consumer Buying Behavior, Sustainable Products, Environmental Awareness, Purchase Intention

Introduction:

Environmental degradation, climate change, and overuse of natural resources have emerged as major global challenges, prompting governments, businesses, and consumers to focus on sustainable development. In response to these challenges, organizations across various industries are rapidly adopting green marketing practices as a strategic approach to promote environmentally responsible products and services. Green marketing involves planning, pricing, promoting, and distributing products in a way that meets consumer needs while minimizing negative environmental impact.

In recent years, consumers have become more aware of environmental issues such as pollution, waste management, and resource scarcity. This increased awareness has influenced consumer preferences, driving demand for sustainable products that are eco-friendly, recyclable, energy-efficient, and ethically produced. Businesses use green advertising, eco-labels, sustainable packaging, and corporate environmental responsibility initiatives to demonstrate their commitment to environmental protection and influence consumer behavior.

However, despite positive attitudes toward sustainability, actual purchase behavior does not always align with environmental concerns. High prices, limited availability of green products, and doubts about the authenticity of green claims often prevent consumers from

making environmentally responsible purchases. This gap between awareness and actual buying behavior necessitates empirical research to examine the impact of green marketing practices.

Jalgaon District features a mix of urban and small-town consumers whose consumption patterns are changing, and awareness of green marketing initiatives is increasing. Studying consumer responses to green marketing in this district provides insights into local buying behavior and sustainability practices. Therefore, this study aims to analyze the impact of green marketing practices on consumer buying behavior toward sustainable products in Jalgaon District, focusing on awareness, attitudes, and purchase intentions.

Problem Statement:

Environmental sustainability has become a major concern globally, leading to increased emphasis on environmentally responsible production and consumption practices. In response, many organizations have adopted green marketing to promote sustainable products and communicate their environmental commitment. Despite the growing presence of green marketing, its actual impact on consumer buying behavior remains uncertain, especially at the regional and district level.

Consumers often exhibit positive attitudes toward environmental protection and sustainable development, but these attitudes do not always translate into actual purchasing behavior. Factors such as high prices, limited availability, lack of credible information, and skepticism about corporate green claims often deter consumers from buying sustainable products. This gap highlights the need to investigate the effectiveness of green marketing practices.

In Jalgaon District, urbanization, education, and media exposure are gradually increasing consumer awareness of environmental issues. However, limited empirical research has been conducted to examine how green marketing practices influence sustainable product purchases in this region. Without localized studies, businesses and policymakers face challenges in designing effective marketing strategies and sustainability initiatives that align with local consumer behavior.

This study aims to determine the extent to which green marketing practices influence consumer buying behavior for sustainable products in Jalgaon District and identify key factors that encourage or hinder environmentally responsible purchasing decisions.

Literature Review:

Growing environmental concerns and demand for sustainable products have made green marketing a strategic practice, attracting academic interest. Numerous studies indicate that green marketing practices significantly influence consumer behavior by raising awareness and shaping attitudes toward eco-friendly purchases. Research shows that companies adopting green marketing strategies are more successful in attracting environmentally conscious consumers who prefer products with eco-labels, recyclable packaging, and energy-efficient features.

Verma's research on consumer attitudes and purchase intentions revealed that environmental knowledge, trust in green claims, and perceived product value play crucial roles in promoting sustainable consumption behavior. Consumers with positive perceptions of green marketing are more likely to intend to purchase such products. Additionally, literature reviews by Huang and Yu highlight the use of the Theory of Planned Behavior to explain how green marketing affects green buying behavior, emphasizing that strategic green practices can reduce the gap between environmental awareness and actual purchasing behavior.

Other studies highlight that consumer preferences for sustainable products depend on factors such as environmental awareness, price sensitivity, social influence, and product labeling. Research shows that while environmental awareness positively affects green product choice, high prices and limited availability often act as barriers to actual purchase. Furthermore, analysis of green marketing trends confirms that sustainable marketing efforts are positively linked to brand trust and loyalty, particularly when companies communicate their green initiatives transparently.

Empirical research also suggests that consumer attitudes and behavior vary across product types and markets. For example, studies in India indicate that green marketing significantly influences consumer behavior in personal care and FMCG sectors, where environmentally conscious consumers prefer eco-friendly alternatives over traditional products. Challenges such as greenwashing, where exaggerated or misleading environmental claims erode consumer trust, also reduce the effectiveness of green marketing strategies. This indicates that authenticity and credible communication are essential for the success of sustainable marketing.

Overall, existing literature establishes a clear link between green marketing practices and consumer buying behavior. However, the magnitude and nature of this impact depend on awareness levels, product features, and credibility of environmental claims. These insights provide a theoretical foundation for examining the effect of green marketing on consumer behavior in Jalgaon District.

Objectives of the Study:
1. To understand the concept and significance of green marketing practices in the context of sustainable products.
2. To assess the level of consumer awareness regarding green marketing practices in Jalgaon District.
3. To analyze consumer attitudes toward sustainable products promoted through green marketing strategies.
4. To evaluate the impact of green marketing practices on consumer buying behavior for sustainable products in Jalgaon District.
5. To provide recommendations to businesses and policymakers for developing effective green marketing strategies that promote sustainable consumption in Jalgaon District.

Hypotheses:
Primary Hypothesis:
- **H_{01} (Null Hypothesis):**
  Green marketing practices do not have a significant impact on consumer buying behavior toward sustainable products in Jalgaon District.

- **H_{11} (Alternative Hypothesis):**
  Green marketing practices have a significant impact on consumer buying behavior toward sustainable products in Jalgaon District.

Secondary Hypotheses:
- **H_{02} (Null Hypothesis):**
  Consumer awareness of green marketing practices does not significantly influence purchase intentions toward sustainable products in Jalgaon District.

- **H_{12}: (Alternative Hypothesis):**
  Consumer awareness of green marketing practices significantly influences purchase intentions toward sustainable products in Jalgaon District.

Variables for SPSS Analysis:

- Independent Variables: Green Marketing Practices, Consumer Awareness, Consumer Attitude
- Dependent Variable: Consumer Buying Behavior / Purchase Intention

Research Methodology:

The research methodology outlines a systematic approach to examine the impact of green marketing practices on consumer buying behavior for sustainable products in Jalgaon District. This study is empirical and follows a structured research design to ensure reliability and validity.

- **Research Design:** Descriptive and analytical design to assess awareness, attitude, and the effect on buying behavior.
- **Data Sources:** Primary data from structured questionnaires; secondary data from books, journals, articles, reports, and credible online sources.
- **Study Area:** Limited to urban and semi-urban consumers in Jalgaon District, Maharashtra.
- **Sample Size & Technique:** 50 consumers selected through convenience sampling, representing diverse ages, income levels, and educational backgrounds.
- **Data Collection Tool:** Structured questionnaire on a five-point Likert scale, measuring awareness, attitude, purchase intentions, and perceived barriers.
- **Statistical Tools:** Percentage analysis, mean and standard deviation, correlation analysis, regression analysis.
- **Study Duration:** Academic year 2024–25.
- **Ethical Considerations:** Respondents were informed about the study's purpose; participation was voluntary, and responses were confidential.

Scope of the Study:

The study focuses on analyzing the impact of green marketing practices on consumer buying behavior for sustainable products in Jalgaon District. It examines consumer awareness, attitudes, and purchase intentions related to eco-friendly advertising, sustainable packaging, eco-labels, and corporate environmental responsibility. Consumers from urban and smaller towns, across various age groups, income levels, and educational backgrounds, were included. The study mainly considers FMCG, personal care, and household products. Results provide insights for marketers, businesses, and policymakers to design region-specific green marketing strategies.

Limitations of the Study:

- Limited to Jalgaon District; results may not be generalizable to other regions.
- Sample size of 50 may not fully represent the district population.
- Primary data collected through questionnaires may include respondent bias or inaccuracies.
- Time and resource constraints limited the study to one academic year (2024–25).
- Focuses only on selected green marketing practices; not all aspects of sustainability and environmental marketing are covered.

Data Analysis, Interpretation and Hypothesis Testing:

This study analyzes the impact of green marketing practices on consumer buying behavior toward sustainable products using data collected from 50 respondents in Jalgaon District. The findings indicate that consumers possess a moderate to high level of awareness regarding green marketing concepts and eco-friendly products. Mean score analysis reveals that

green advertisements, eco-labels, and sustainable packaging have a positive influence on consumers' attitudes and perceptions.

Correlation analysis shows a positive and statistically significant relationship between green marketing practices, consumer awareness, and purchase intention. This indicates that greater exposure to green marketing initiatives increases consumers' willingness to purchase sustainable products. Consumers who demonstrate higher levels of environmental awareness are more inclined toward environmentally responsible buying behavior.

Regression analysis further confirms that green marketing practices significantly predict consumers' purchase intentions. Variables such as green advertising, eco-labeling, and corporate environmental initiatives exert a strong positive impact on buying behavior. However, the analysis also identifies high price sensitivity, limited availability of sustainable products, and skepticism toward green marketing claims as major barriers that negatively affect actual purchasing decisions.

Based on the findings, the null hypothesis is rejected and the alternative hypothesis is accepted, confirming that green marketing practices and consumer awareness significantly influence buying behavior toward sustainable products. The study concludes that transparent communication, affordable pricing, and credible green claims are essential to bridge the gap between environmental awareness and actual consumer purchasing behavior.

Conclusion and Suggestions:

The study concludes that green marketing practices significantly influence consumer buying behavior toward sustainable products in Jalgaon district. The results indicate that consumers have a moderate to high level of awareness about green marketing concepts and eco-friendly products. Green advertising, eco-labeling, sustainable packaging, and corporate environmental initiatives positively affect consumers' attitudes and purchase intentions. Correlation and regression analyses confirm that greater awareness of green marketing practices strengthens consumers' willingness to buy sustainable products. However, despite positive attitudes, actual purchasing behavior is often limited due to higher prices, limited availability of sustainable products, and doubts about the credibility of green marketing claims. These challenges create a gap between environmental awareness and actual buying behavior.

Based on the findings, it is suggested that companies adopt transparent and trustworthy green marketing strategies to build consumer confidence. Improving affordability, product availability, clear eco-labeling, standardized certifications, and awareness programs can further promote informed and environmentally responsible purchase decisions.

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Colorimetric Chemosensors for Cu (II) Ion : A Review

Jayshri S. Patil1, Atul S. Patil1, Gunvant H. Sonawane1*
1. KVPS's Kisan Arts, Commerce and Science College, Parola, Jalgaon.
Email: drgunvantsonawane@gmail.com

Abstract:

    Colorimetric chemosensors are designed to detect specific analytes like biomolecules, heavy metal ions, anions, etc. Colorimetric chemosensors shows distinct colour changes visible to naked eyes, also these offers detection by simple, rapid, low cost, convenient detection. Copper is one of most vital metal ions in biological systems, because it functions as an important cofactor by taking an active part in a large variety of enzymes. However, with excessive loading, copper ion can cause several diseases including Alzheimer's, Parkinson's and Wilson diseases

Introduction:

    The development of selective and sensitive chemosensors for the detection of metal ions and anions has received considerable attention because of their important roles in medicine, living systems and ecosystems. Among the different types of chemosensors, sensors based on colorimetric determination of anions and metal ions have many advantages because of their convenience, low cost, and rapid tracking of analytes. Therefore, colorimetric sensors are recently getting popular due to their capability to detect analytes by the naked eye without utilizing any expensive instruments [1].

    The design and development of chemosensors have expanded substantially in last few decades. Design and synthesis of new chemosensors for d-metal ions i.e. transition metals including heavy metal ions have been of great interest for chemists in recent years as they play important roles in the areas of chemical [2], biological [3,4], and environmental systems [5,6].

    Copper is the third most abundant element and essential in numerous primary metabolic processes [7-9]. Among all the essential elements in biological processes, Cu(II) also possess vital role in different metallo-enzymes as a catalytic cofactor [10]. However, the higher concentration of copper than the required, create several problems in cellular processes by disproportion and takes part in the formation of reactive oxygen species, that causes several diseases such as Wilson's disease, Parkinson's , Alzheimer's disease, Menkes and amyotrophic lateral sclerosis [11-17]. It is essential to detect the concentration of heavy metal ion present in ecosystem which can cause several effect in the environmental and human health. Level of copper in human beings is very low but it is also integral part of metal pollutant in nature [18-20]. The acceptable level of Cu(II) in drinking water is 2×10^{-5} M as per U. S. Environmental protection agency [21] but nowadays the concentration of copper increases due to excess use of copper containing pesticides in the form of complexes, which dissociate finally in to Cu(II) in biological system [21]. Numerous methods and technique are available to determine the concentration of copper, however chemosensors work efficiently.

Current review focuses mainly on design, development and evaluation of chemosensors for Cu(II) ions.

Colorimetric chemosensors for Cu (II) ions:

    Jung and co-workers have reported a new Schiff base **1** chemosensor for Cu (II) ions in a near-perfect aqueous solution. It was based on 2-hydrazinyl-4- (trifluoromethyl) pyrimidine and the pyridine moieties. The Job's plot analysis showed 1:1 (host/guest) stoichiometric ratio. The experimental results also showed that color of the Cu (II) - sensor changes to yellow in the range

of pH 4.0-12.0. This gives strong confirmation that sensor could be used a colorimetric chemosensor for pH monitoring [22].
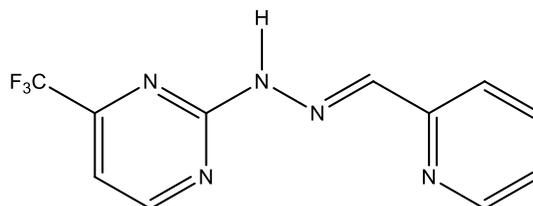
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A colorimetric chemosensor **2** bearing acylthiosemicarbazole moiety as binding site and nitrophenyl moiety as signal group was prepared and synthesized by Lin et al. Chemosensor was developed for the selective and sensitive detection of Cu (II) ions over the other transition metal ions in DMSO/H_2O binary solution. Due to the shackle of strong hydrogen bonds N-H, O=C and N-H, O=C, the coumarin C=O and acyl C=O did not coordinate with Cu (II). Therefore, the sensor chelated with Cu (II) only through C=S and form a stable 2:1 (host/guest) complex [23].
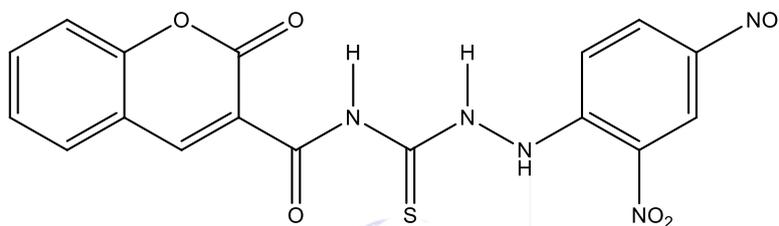
2

Wang et al. prepared and characterized a novel cyclometalated iridium (III) complex bearing a rhodamine-linked N-N ligand **3** for the rapid, selective and sensitive detection of Cu (II) ions. The experimental studies show that the rhodamine moiety is known to be highly selective for Cu (II) ions over other common metal ions. Furthermore, rhodamine based sensor can be utilized for the monitoring of Cu ions in tap water or natural river water [24].
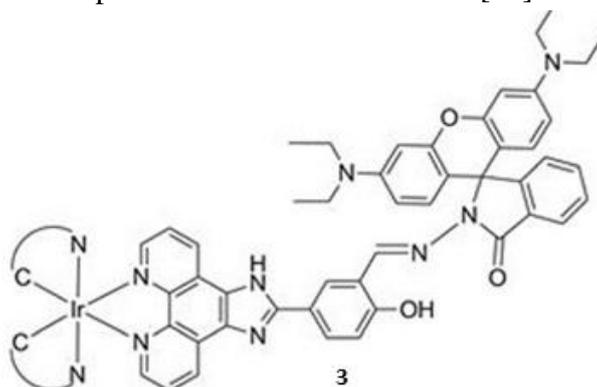
3

By intramolecular charge transfer (ICT) and ligand-to-metal charge transfer (LMCT) mechanisms, Kim and co-workers have established a simple, easy-to-make and highly selective colorimetric chemosensor **4** based on julolidine moiety for the detection of Cu (II) ions. The studies of Job's plot revealed a 1:1 stoichiometric ratio between compound Cu (II) coordination complex. Chemosensor induced an obvious colour change in the presence of Cu (II) ion and the bathochromic shift was explained by the change of ICT band [25].

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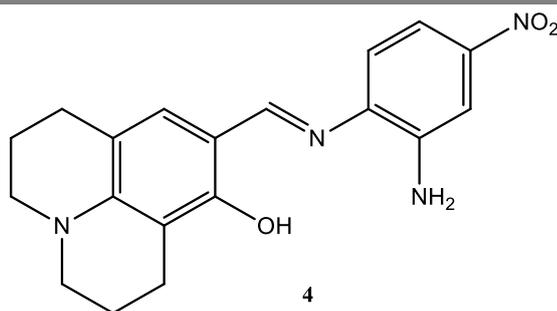
Lee et al. synthesized a simple and easy-to-make colorimetric chemosensor **5** for the detection of Cu (II) ions. It was designed by combining hydroxynaphthalene-2-carbaldehyde and diaminomaleonitrile. The Job's plot exhibited a stable 1:1 (host/ guest) complex. The bathochromic shift with color change from pale yellow to orange was explained through the internal chargetransfer character (ICT) of the molecule. The low detection limit is 2.4 mM which makes it an excellent chemosensor for the detection of copper in drinking water [26]. A colorimetric chemosensor was synthesized by Sadaphal et al. The sensor **6** is based on a pyridyl-thiourea derivative for the detection of copper in the presence of other metal ions. The derivative contains multiple donor atoms (N and S) as coordinating sites for Cu (II). On interaction with Cu (II), 1:1 (host/guest) stable complex was formed. On the addition of Cu (II), the adsorption changes were clearly visible to the naked eye. The applications of the sensor will be utilized for the detection of copper from alloys and natural river water [27].

6
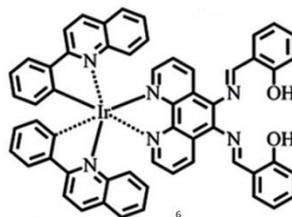
Kim et al. was developed new and simple colorimetric chemosensor **7** for the sequential detection of Cu (II) and glutathione (GSH) in aqueous solution. The chemosensor detected Cu (II) ions by changing its colour from colourless to yellow, the resulting Ligand–Cu (II) complex could sequentially sense GSH [28].

7
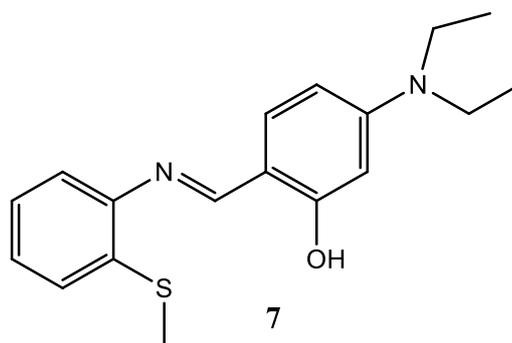
Wang et al. was developed a novel reversible colorimetric chemosensor **8** for rapid naked-eye detection of Cu (II) in pure aqueous solution. A water-soluble polymer P(NIPAM-co-RhBBA) containing pendant rhodamine B-based dyes was successfully synthesized via reversible addition-fragmentation chain transfer (RAFT) polymerization. P(NIPAM-co-RhBBA) in pure aqueous solution exhibits highly sensitive and selective detection of Cu (II) ions accompanied with a remarkable color change from colorless to purple within 20 s, which can be monitored directly by naked eyes. Furthermore, the low-cost test strips are fabricated using

P(NIPAM-co-RhBBA) for convenient and efficient detection of practical Cu (II) ions in real water samples [29].

A highly selective colorimetric chemosensor **9** for copper(II) based on N -phenyl- N '-(pyridin-2-yl)thiourea(HPyPT) was reported by Sadaphal and Gholap. The chemosensor was prepared quantitatively by the solvent free reaction of 2-aminopyridine and phenyl isothiocynate at room temperature in 92% yield. It was showed excellent sensitivity and selectivity for copper over a series of other metal ions under investigation [30].

9
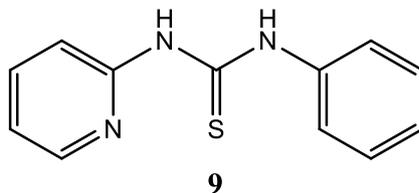
KulathuIyer et al. was reported a quinoline isophorone-based isophorone chemoreceptor for reversible Cu (II) ion recognition. All the colorimetric findings showed an excellent selectivity of chemosensor to Cu (II), in the presence of different metal ions, even at higher concentrations [31]. Alidoosti et a. was reported highly selective colorimetric chemosensor for detection of Cu (II) and F− ions based on Salicylaldehyde Schiff base containing pyridine-2-carboxyamidine moiety [32].

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The Role of Finance and Investment in Promoting Sustainable Development of Grape Farming in Nashik District, Maharashtra

Yogesh Bhausaheb Aher,
Research Scholar
KBCNM University, Jalgaon

Hitesh Gulab Pawar,
Associate Professor
KBCNM University, Jalgaon

Abstract

This research paper examines the crucial role of financial mechanisms and investment strategies in transforming the Nashik district's grape farming sector towards sustainable development. Employing a mixed-methods approach, the study examines the accessibility, adequacy, and effectiveness of existing financial instruments while identifying barriers to adopting sustainable practices. Findings indicate significant gaps between available finance and the capital requirements for sustainability investments, with structural issues in credit delivery, insurance, and risk mitigation. The paper concludes by proposing an integrated financial framework combining tailored credit products, blended finance, value-chain investments, and enhanced policy support to build a resilient and sustainable viticulture ecosystem in Nashik.

Keywords: Sustainable Agriculture, Agricultural Finance, Grape Farming, Nashik, Climate Resilience, Value-Chain Investment, Green Credit

1. Introduction:

Nashik district, acclaimed as the 'Wine Capital of India', is the epicentre of grape cultivation in Maharashtra, contributing over 80% of the state's production and a significant share of national exports (Directorate of Horticulture, Maharashtra, 2023). The sector, however, stands at a critical juncture, facing intertwined challenges of climate vulnerability, water scarcity, soil degradation, and market fluctuations. Sustainable development—encompassing environmentally sound practices, economic viability, and social equity—is imperative for the sector's long-term survival. This transition is inherently capital-intensive, requiring investments in micro-irrigation, organic inputs, climate-resilient infrastructure, and post-harvest management. Despite numerous government schemes and institutional credit channels, a persistent finance gap hinders widespread adoption. This paper analyses the current financial ecosystem, evaluates its alignment with sustainability goals, and proposes a restructured finance and investment model to catalyse sustainable grape farming in the Nashik district.

2. Objectives:

This study aims to achieve the following specific objectives:

1. To map and assess the current landscape of formal and informal financial sources available to grape farmers in the Nashik district.
2. To identify and analyse the financial and non-financial barriers limiting investment in sustainable agricultural practices (SAPs).
3. To evaluate the performance and outreach of existing government subsidies and credit schemes in promoting sustainability.
4. To examine the potential of innovative finance models (e.g., blended finance, value-chain finance, green instruments) in bridging the identified investment gaps.
5. To formulate evidence-based policy and institutional recommendations for creating an enabling financial environment for sustainable viticulture.

3. Review of Literature:

The intersection of finance and sustainable agriculture has garnered substantial scholarly attention. **Meyer (2021)** conceptualises 'sustainable agricultural finance' as capital flows intentionally structured to generate positive environmental and social outcomes alongside financial returns. Globally, blended finance models have emerged as pivotal in de-risking private sector investment in green agri-projects, particularly in developing economies (OECD, 2022).

In the Indian context, studies highlight systemic issues. **Sharma & Desai (2020)** note that institutional credit, while expansive, remains largely input-centric and short-term, failing to address the long-gestation, asset-building needs of sustainable farming. **NABARD (2022)** reports highlight the success of Farmer-Producer Organisations (FPOs) in improving credit access but point to limited capital for infrastructure. Research specific to horticulture and grapes reveals unique challenges. **Patil et al. (2021)** identify the high upfront cost of drip irrigation and protected cultivation as the primary deterrent for smallholders in Maharashtra, despite state subsidies. **The Associated Chambers of Commerce and Industry of India (ASSOCHAM, 2022)** underscores the critical role of post-harvest infrastructure financing in reducing waste and improving value realisation for grape farmers.

A significant gap exists in the literature that comprehensively links financial instrument design with the specific sustainability transition pathways for high-value crops like grapes in a defined agro-climatic region like Nashik. This study seeks to fill this gap by providing a granular analysis of finance as a lever for systemic change in Nashik's viticulture.

4. Methodology:

4.1 Research Design: A convergent parallel mixed-methods design was employed, allowing for the simultaneous collection and integration of quantitative and qualitative data to provide a holistic understanding.

4.2 Study Area and Sampling: The study was conducted across five major grape-growing talukas of Nashik district: Nashik, Dindori, Niphad, Sinnar, and Igatpuri. A multi-stage stratified random sampling technique was used.

- **Primary Respondents:** 350 grape farmers stratified by landholding size: Marginal (<1 ha), Small (1-2 ha), Medium (2-4 ha), and Large (>4 ha).
- **Key Informants:** 40 stakeholders, including bank managers (10), officials from District Cooperative Banks (5), members of grape growers' cooperatives/FPOs (10), government agriculture officers (10), and agro-processors/exporters (5).

4.3 Data Collection:

- **Primary Data:** Collected through (i) A pre-tested, structured schedule for farmers covering socio-economic profile, financial access, SAP adoption, and constraints; (ii) Semi-structured interviews with key informants; (iii) Four Focus Group Discussions (FGDs).
- **Secondary Data:** Sourced from NABARD reports, RBI publications, Maharashtra Horticulture Department statistics, annual reports of major banks, and academic journals.

4.4 Data Analysis:

- **Quantitative Analysis:** Employed SPSS v.26. Descriptive statistics (frequencies, means), inferential tests (Chi-square for association, ANOVA for mean differences), and binary logistic regression to identify factors influencing SAP adoption.
- **Qualitative Analysis:** Thematic analysis was conducted on interview and FGD transcripts to identify recurring patterns, perceptions, and institutional challenges.

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- **Gap Analysis:** Financial gaps were calculated by comparing the reported cost of adopting a full suite of SAPs with the average credit accessible to farmers.

5. Results and Data Analysis:

5.1 Socio-economic Profile and Financial Access:

- 62% of sampled farmers were small or marginal holders. Average annual investment per acre for grape cultivation ranged from ₹1.2 lakhs (conventional) to ₹2.1 lakhs (sustainable model).

- **Formal Credit Penetration:**70% had access to formal credit, primarily via Kisan Credit Cards (KCC). However, 55% reported that the sanctioned limit was insufficient to cover sustainability upgrades.

- **Informal Reliance:** Approximately 35% of marginal farmers still depended on moneylenders for 30-40% of their capital needs, citing procedural hurdles and urgency.

5.2 Adoption of Sustainable Practices and Financial Correlates:

Adoption rates were strongly correlated with landholding size and access to tailored credit.

Table 1: Adoption of Sustainable Practices (%)

Drip Irrigation	38.2	65.4	88.7	96.5	72.2
Organic Manure/Compost	25.6	41.3	60.5	75.8	50.8
Integrated Pest Mngmt.	18.9	32.1	54.2	70.4	44.1
Soil Health Testing	10.5	22.4	40.3	65.2	34.6

Logistic regression indicated that access to credit specifically for SAPs (Odds Ratio: 3.2, $p<0.01$) and membership in an FPO/cooperative (OR: 2.1, $p<0.05$) were the strongest positive predictors of adoption.

5.3 Assessment of Government Schemes:

- **Awareness vs. Access:** While 75% were aware of PMKSY for drip irrigation, only 48% had successfully availed the subsidy. Major bottlenecks cited were bureaucratic delays (avg. 9 months), complex paperwork, and the requirement for upfront farmer investment.

- **Incomplete Support:** Schemes often fund hardware (drip lines) but not complementary assets like fertigation units or water harvesting structures.

5.4 Identified Financial Gaps and Barriers:

- **Credit Gap:** The average shortfall for financing a full sustainable package (drip, organic inputs, soil health management) was estimated at ₹1.65 lakhs per hectare for small farmers.

- **Tenure Mismatch:** Most loans were for 12-18 months, incompatible with the 3-5 year payoff period for organic conversion or orchard rejuvenation.

- **Collateral Constraints:**60% of marginal farmers lacked acceptable collateral, limiting loan size.

- **Risk Perception:** Banks perceived sustainable farming as "experimental" and risky, leading to conservative lending.

5.5 Stakeholder Insights:

- Bankers emphasised the need for credit guarantees to lend for sustainability projects.

- **FPO** Leaders advocated for collective collateral and block lending to reduce transaction costs.

- Exporters expressed willingness to provide advance finance but demanded consistent quality and certification, which farmers found costly to obtain.

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6. Discussion:

The results underscore a systemic failure of the current financial architecture to meet the distinctive needs of sustainable transition. The strong correlation between finance access and SAP adoption validates finance as a critical enabling factor. The prevalent one-size-fits-all loan product is ill-suited for the multi-year, phased investments that sustainability requires. The heavy reliance on subsidy-driven models is unsustainable and often fails to reach the most vulnerable.

The study identifies a promising avenue **in value-chain-linked finance**, where processors or exporters provide forward financing against purchase agreements, reducing bank risk. Similarly, **FPO-operated revolving** funds can address smallholder liquidity crunches for organic inputs. The success of pilot projects **in green warehousing receipts**, where farmers storing produce in certified green warehouses get lower-interest loans, points to another scalable model (NABARD, 2023).

The findings align **with Satyasai and Kumar's (2022)** argument for 'patient capital' in agriculture but extend it by proposing specific, contextual mechanisms for the grape value chain.

7. Conclusion and Recommendations:

Finance is not merely an input but the critical lever for pivoting Nashik's grape farming from a resource-intensive to a sustainable, climate-resilient system. The transition is hampered by inadequate loan sizes, inappropriate tenures, high perceived risks, and fragmented support.

Recommendations:

A. For Financial Institutions (Banks, NBFCs, NABARD):

1. Develop **'Sustainable Grape Farming Loan'** products with longer moratoriums (2-3 years), graduated repayment schedules, and sustainability-linked interest rate discounts.
2. Promote **collateral** alternatives using warehouse receipts, future crop liens, and FPO guarantees.
3. Establish **a Green Credit Guarantee** Fund with state support to cover a portion of default risk on loans for verified SAPs.

B. For Government:

1. **Streamline and** digitise subsidy disbursement under PMKSY and PKVY to reduce delays and leakages.
2. **Provide viability gap** funding or interest subsidies to catalyse private investment in cold chains, packhouses, and renewable energy for FPOs.
3. Mandate and **support sustainability-linked crop** insurance products that cover risks specific to organic or precision farming.

C. For the Ecosystem:

1. **Strengthen FPOs and** Cooperatives as aggregators for input finance, bulk purchasing, and market linkage.
2. Foster ' **blended finance'** consortia involving development agencies, commercial banks, and CSR funds to finance large-scale watershed or soil health projects in grape clusters.
3. **Integrate financial literacy and sustainable practice** training into extension services to improve creditworthiness and project success rates.

By implementing this multi-pronged financial strategy, Nashik can secure the triple wins of enhanced farmer livelihoods, environmental conservation, and long-term economic viability for its iconic grape and wine industry.

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Native Language Identification Using Deep Learning Models

Dr. Prasad A. Joshi

Associate Professor, Department of Computer Science & I.T.,
JET's Zulal Bhilajirao Patil College, Dhule, Maharashtra, India

Abstract:

Native Language Identification (NLI) focuses on predicting an author's native language based on texts written in a second language. This work explores deep learning approaches for NLI using syntactic and distributional textual features extracted from an established learner corpus. Multiple neural architectures—including a Feedforward Neural Network (FNN), Convolutional Neural Network (CNN), Recurrent Neural Network (RNN), and Long Short-Term Memory (LSTM)—are trained and evaluated. Performance is assessed using accuracy, F1-score, and confusion matrix analysis. Experimental results demonstrate that LSTM and CNN models outperform traditional neural networks due to their ability to capture sequential and contextual dependencies.

Keywords: Native Language Identification, Feedforward Neural Network, Convolutional Neural Network, Recurrent Neural Network (RNN), Long Short-Term Memory (LSTM), etc.

1. Introduction:

Native Language Identification (NLI) is a key research problem in computational linguistics and second language acquisition. The fundamental assumption behind NLI is language transfer, where structural, syntactic, and stylistic patterns from a speaker's native language influence second-language writing [1].

With advancements in deep learning, neural architectures have become capable of automatically learning discriminative representations without extensive manual feature engineering. This paper investigates the effectiveness of deep learning models for NLI using learner-generated English text.

The contributions of this work are:

- Use of a publicly available NLI dataset
- Extensive preprocessing and feature extraction
- Comparative analysis of multiple deep learning models
- Evaluation using accuracy, F1-score, and confusion matrices

2. Dataset Description:

This study uses a publicly available Native Language Identification learner corpus, such as the TOEFL11 [2] dataset. The dataset has Essays written in English (L2), Writers belong to different native language (L1) groups and Uniform prompts were selected to minimize topic bias. The native languages (L2) used in the dataset are Arabic, Chinese, Spanish, Hindi and French while writers belonging to English language the details are in Table 1.

Table 1: Dataset Statistics

Attributes	Value
Total essays	12000
Number of L1 classes	11
Avg. words per essay	350
Language	English

3. Data Preprocessing:

Preprocessing is critical to remove noise and standardize input for neural models. We have categorized these phase into two parts - Preprocessing Steps and Text Representation Preparation.

3.1 Preprocessing Steps:

Preprocessing is a crucial stage in Native Language Identification as raw learner-generated text often contains noise, inconsistencies, and variations that negatively impact model performance. The following steps were applied sequentially:

- **Lowercasing:** All characters in the text are converted to lowercase to ensure uniformity. This prevents the same word appearing in different cases (e.g., Language vs language) from being treated as separate features.

- **Tokenization:** The text is segmented into individual units called tokens, typically words. Tokenization enables the model to process text at the word level [3] and is essential for building vocabularies and embeddings [3].

- **Removal of Punctuation and Digits:** Punctuation marks and numerical values are removed as they usually do not contribute to native language patterns and may introduce unnecessary noise into the learning process

- **Stopword Removal:** Commonly occurring words such as the, is, and and are removed. These words carry minimal discriminatory power for NLI since they are used similarly across native language groups.

- **Lemmatization:** Words are reduced to their base or dictionary form (e.g., running → run). Lemmatization reduces sparsity and groups morphologically similar words [4].

- **Padding and Truncation:** Since neural networks require fixed-length input, text sequences are either truncated or padded with special tokens to achieve uniform length across samples.

3.2 Text Representation Preparation

After preprocessing, textual data must be converted into numerical form suitable for deep learning models. A vocabulary is constructed using the most frequent tokens in the corpus. Each word is mapped to a unique integer index. Sentences are then transformed into sequences of integers corresponding to word indices.

To handle variable-length essays - Shorter sequences are padded with zero values and Longer sequences are truncated to a predefined maximum length. This representation preserves word order, which is critical for sequence-based neural models such as RNNs and LSTMs.

4. Feature Extraction Techniques:

Unlike traditional NLI approaches relying heavily on handcrafted features, deep learning enables automatic feature learning.

4.1 Word Embeddings:

Word embeddings are dense vector representations that encode semantic and syntactic properties of words in continuous space. In this study we have used Pretrained embeddings (e.g., GloVe or Word2Vec) and Each word is represented as a fixed-dimensional vector (e.g., 100 or 300 dimensions) [5].

The advantages of Word Embeddings are it capture semantic similarity between words, reduces feature sparsity compared to one-hot encoding, enables the transfer learning from large corpora, and improves generalization in low-resource NLI settings. For example, words such as

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student and learner have similar embeddings, allowing the model to learn generalized patterns rather than memorizing exact words.

4.2 Syntactic Information:

POS-tag sequences are optionally embedded to incorporate syntactic structure. These representations help capture grammatical preferences influenced by native language.

4.3 Sequence-Based Input:

Sequence-based input treats text as an ordered sequence of tokens rather than an unordered set of features. This approach allows models to learn - word order, grammatical structure and long-distance dependencies. Sequence modeling is essential for NLI because native language influence often affects syntactic ordering, such as subject–verb agreement or modifier placement, which cannot be captured by bag-of-words models [6].

5. Deep Learning Models:

Deep learning (DL) represents a huge step forward for machine learning. DL is based on the way the human brain processes information and learns. It has kept breaking barriers during the last years in the state-of-the-art of many predictive tasks. There is still no clear theoretical foundation that explains why Deep Neural Networks (DNN) are so effective. For experimentation we have used FNN, CNN, RNN and LSTM.

5.1 Feedforward Neural Network (FNN)

A Feedforward Neural Network is the simplest form of neural architecture. The characteristics of FNN are no memory of word order, it treats text as a static vector and serves as a baseline deep learning model. We have used input layer (flattened embeddings), one or more fully connected hidden layers and Output layer with softmax activation. Although FNNs are computationally efficient [7], their inability to model sequential patterns limits their effectiveness for NLI.

5.2 Convolutional Neural Network (CNN)

CNNs apply convolutional filters over word embeddings to capture local linguistic patterns. The CNN can detect local syntactic patterns, effectively for stylistic cues influenced by native language and robust to position variation. The CNN filters slide over embedding sequences [8], captures n-gram-like features and Max-pooling selects the most salient features.

5.3 Recurrent Neural Network (RNN)

RNNs process text sequentially, maintaining a hidden state that captures information from previous words. It is suitable for variable-length input and it models sequential dependencies. The major drawback of RNN are vanishes gradient problem and difficult in learning long-term dependencies [9]. Despite these limitations, RNNs outperform feedforward networks for NLI.

5.4 Long Short-Term Memory (LSTM)

LSTM is an advanced RNN architecture designed to overcome vanishing gradients. LSTM is Effective for NLI because it captures long-range syntactic patterns, retains important grammatical cues and models native language transfer effects more accurately [10]. The architecture has input gate, forget gate and output gate.

6. Experimental Setup:

We have split dataset into 80% as training set and 20% testing. For all neural networks all the hyperparameters set as per given here - embedding dimension=300, Optimizer as Adam,

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Loss function as categorical Cross-Entropy, epochs as 20 and batch size as 64 and validation strategy as a 10-fold cross-validation.

7. Evaluation Metrics:

For evaluation purpose the several metrics such as accuracy, f1-score and confusion matrix were used.

7.1 Accuracy

Accuracy measures the proportion of correctly classified instances. It is measured using the following formula.

$$Accuracy = \frac{TP + TN}{TP + TN + FP + FN}$$

While intuitive, accuracy alone may be misleading for imbalanced datasets.

7.2 F1-score

The F1-score balances precision and recall and is particularly suitable for multiclass NLI.

$$F1 = 2 X \frac{Precision\ X\ Recall}{Precision + Recall}$$

7.3 Confusion Matrix

A confusion matrix provides class-wise performance and reveals patterns of misclassification among native language groups.

$$Precision = \frac{TP}{TP + FP}$$

$$Recall = \frac{TP}{TP + FN}$$

8. Results:

From Table 2 it is very evident that LSTM performs far better in terms of accuracy and F1-score in comparison with the other deep learning models. We also observed that LSTM achieved the best performance due to its ability to model long-range dependencies, CNN effectively captured local syntactic cues and FNN performed weakest due to lack of sequence modelling.

Table 2: Performance comparison of Deep Learning models

Model	Accuracy	F1-Score
FNN	0.74	0.73
CNN	0.81	0.80
RNN	0.78	0.77
LSTM	**0.84**	**0.83**

The confusion matrix is shown in Table 3 for the LSTM model shows strong diagonal dominance, indicating accurate predictions for most native language classes. It shows high diagonal values indicate strong classification accuracy, confusion occurs mainly between linguistically similar languages

Table 3: Confusion Matrix by LSTM Model

Actual \Predicted	L1-A	L1-B	L1-C
L1-A	118	7	5
L1-B	9	114	7
L1-C	6	8	116

9. Conclusion:

Results confirm that deep learning models outperform shallow neural networks for NLI. LSTM achieved the best performance due to its ability to model long-range syntactic dependencies. CNNs also performed strongly by capturing local grammatical patterns. The challenges include – data imbalance, high computational cost and interpretability of learned features.

This paper presented a deep learning–based approach to Native Language Identification using learner-generated English text. By leveraging word embeddings and sequence-based neural architectures, the system achieved strong predictive performance. LSTM emerged as the most effective model, highlighting the importance of sequential modeling for capturing native language transfer effects. In future work we may explore transformer-based architectures and multilingual embeddings.

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Humanity and Environment : Integrating Energy Awareness and Renewable Alternatives for Sustainable Development

Dr. Bhagwat C. Patil

Associate Professor, Department of English,

J.D.M.V. Co.Op. Samaj's Arts, Commerce & Science College,

Yawal, Dist.- Jalgaon.

Email: bcpatil77@gmail.com

Mobile: +91 9764131818

Abstract:

The relationship between humanity and the environment has emerged as one of the most critical concerns of the contemporary world. Rapid industrialization, population growth, and excessive dependence on fossil fuels have resulted in climate change, biodiversity loss, and severe ecological imbalance. This paper examines the urgent need for environmental protection through energy awareness and sustainable practices, emphasizing the interconnectedness of human activity and natural systems. It discusses major environmental challenges such as global warming, ocean acidification, deforestation, and rising sea levels, highlighting their socio-economic and ecological impacts. The study further explores renewable and alternative energy sources—including solar, wind, geothermal, and electric mobility—as viable solutions for sustainable development. By adopting decentralized energy systems and promoting clean technologies, humanity can mitigate environmental degradation while meeting developmental needs. The paper argues that sustainable development requires collective global responsibility, policy commitment, and ethical environmental stewardship to ensure the well-being of present and future generations.

Keywords: Humanity; Environment; Sustainable Development; Energy Awareness; Climate Change; Renewable Energy

Introduction:

In the contemporary era, the term *environment* has become so widely used that it hardly requires definition. The environment encompasses air, land, and water, forming the life-support system on which all living beings depend. Human civilization has always relied on natural resources for survival and progress; however, the manner and scale of resource exploitation in recent decades have posed unprecedented threats to ecological balance. Protecting and conserving natural resources has therefore become a global priority, not to prohibit their use but to ensure their availability for future generations.

Sustainable development seeks to harmonize human needs with environmental preservation. The increasing demand for energy, driven by population growth and industrial expansion, has intensified pressure on natural systems. Fossil fuels, which have long powered economic development, are now recognized as major contributors to environmental degradation and climate change. Consequently, energy awareness and responsible consumption have emerged as essential components of environmental sustainability.

This paper explores the complex relationship between humanity and the environment through a multidisciplinary lens. It examines the causes and consequences of environmental degradation, with particular attention to energy use, climate change, and ecological imbalance.

Furthermore, it highlights renewable and alternative energy solutions as pathways toward sustainable development, emphasizing the ethical responsibility of humanity to safeguard the planet.

Human Activity and Environmental Degradation:

The concentration of carbon dioxide in the atmosphere has increased significantly since the beginning of industrialization. This rise is primarily attributed to the growing use of fossil fuels, deforestation, and other anthropogenic activities. Elevated levels of greenhouse gases have led to global climate change, manifested not only through rising average temperatures but also through an increase in the frequency and intensity of extreme weather events such as floods, droughts, heat waves, and irregular precipitation patterns.

A substantial portion of atmospheric carbon dioxide is absorbed by the oceans, where it reacts with seawater to form carbonic acid. This process has resulted in ocean acidification, altering the chemical balance of marine ecosystems. Many marine organisms, particularly those with calcium carbonate shells such as clams, mussels, and corals, struggle to survive in increasingly acidic conditions. These changes threaten marine biodiversity and disrupt food chains that support human livelihoods.

Human negligence further exacerbates environmental damage through the disposal of waste into oceans and other ecosystems. Pollutants such as plastic, sewage, and toxic substances often cause harm that remains invisible until revealed through scientific analysis. The long-term effects of such pollution underscore the need for responsible waste management and environmental awareness.

Climate Change and Its Global Impact:

Climate change poses a serious threat to agriculture, biodiversity, and human settlements. Rising temperatures and changing rainfall patterns affect crop productivity, food security, and rural livelihoods. Many species face extinction due to habitat loss and shifting climatic conditions, leading to irreversible ecological consequences.

One of the most alarming outcomes of climate change is sea-level rise. Thermal expansion of ocean water, combined with the melting of glaciers and ice sheets, has caused sea levels to rise steadily over the past several decades. Low-lying coastal regions and small island nations are particularly vulnerable, facing increased risks of flooding, erosion, and displacement of populations. Regions such as the Sundarbans and parts of Bangladesh exemplify the human cost of environmental neglect.

Deforestation further accelerates climate change by reducing the planet's capacity to absorb carbon dioxide. Forests play a crucial role in regulating climate, conserving biodiversity, and supporting indigenous communities. Their destruction undermines both environmental stability and social well-being.

Energy Awareness and Sustainable Development:

Energy awareness has become an urgent necessity in the modern world. Sustainable development cannot be achieved without rethinking current energy systems and consumption patterns. Shifting toward greater efficiency in energy use and expanding the adoption of renewable energy sources are essential steps, particularly for developing countries striving for economic growth.

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A decentralized energy system offers a promising alternative to conventional centralized models. By locating affordable and accessible sources of power near points of use, decentralized systems reduce transmission losses and enhance energy security. Such systems can integrate multiple renewable technologies suited to local conditions, thereby promoting inclusive and sustainable development.

International cooperation is equally vital. Climate change transcends national boundaries, and its impacts are shared globally. Collaborative efforts in clean technology transfer, research, and policy implementation are necessary to address environmental challenges effectively. Shared responsibility, rather than the assignment of blame, should guide global environmental governance.

Renewable and Alternative Energy Solutions:

Renewable energy technologies present viable solutions to the environmental challenges associated with fossil fuels. Solar energy, wind power, geothermal energy, and hydropower are abundant resources that can significantly reduce greenhouse gas emissions.

Solar energy research has advanced toward improving efficiency and affordability. Innovative techniques involving reflective materials and nanotechnology aim to enhance the absorption of sunlight, making solar power increasingly competitive with conventional energy sources. Wind energy, widely available and renewable, has been successfully harnessed through modern turbine designs that efficiently convert kinetic energy into electricity.

Geothermal energy utilizes the heat stored beneath the Earth's surface and offers a reliable and sustainable energy source in regions with suitable geological conditions. Similarly, electric vehicles represent a cleaner alternative to gasoline-powered transportation, reducing emissions and dependence on fossil fuels.

Other emerging alternatives, such as biomass energy, ocean power, and magnetic levitation transportation systems, further expand the portfolio of sustainable energy solutions. While each technology has limitations, their combined adoption can contribute significantly to environmental conservation and energy security.

Social and Ethical Dimensions of Environmental Responsibility:

Environmental sustainability is not solely a scientific or technological issue; it is also a social and ethical concern. Human attitudes toward nature influence consumption patterns, policy decisions, and collective action. Ethical environmental stewardship requires recognizing the intrinsic value of nature and the rights of future generations.

Public awareness and education play a crucial role in fostering environmentally responsible behavior. Communities informed about the consequences of environmental degradation are more likely to support sustainable practices and policies. Integrating environmental education across disciplines can empower individuals to participate actively in conservation efforts.

Conclusion:

The relationship between humanity and the environment is at a critical juncture. While scientific and technological advancements have enabled unprecedented development, they have also intensified environmental challenges. Climate change, biodiversity loss, and resource depletion underscore the urgent need for sustainable development strategies grounded in energy awareness and environmental ethics. Renewable energy technologies offer promising pathways

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toward reducing environmental impact, yet their widespread adoption is hindered by economic and infrastructural constraints. Overcoming these barriers requires coordinated global action, policy support, and sustained investment in research and innovation. A decentralized and diversified energy system can enhance resilience while meeting the needs of growing populations. Ultimately, sustainable development depends on humanity's willingness to balance progress with preservation. By embracing environmental responsibility and integrating renewable energy solutions, societies can safeguard the planet for present and future generations, ensuring a harmonious coexistence between humanity and the environment.

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IoT for Future Life : A Survey with Applications, Challenges and Directions

Dr. Girish B. Desale
Associate Professor & Head, Department of Computer Science & I.T.
JET's Z. B. Patil College, Dhule, affiliated to KBCNMU, Jalgaon, Maharashtra.
girishdesale@gmail.com

Abstract:

Internet of Things (IoT) is rapidly becoming a foundational layer of future digital life by enabling ordinary objects—homes, vehicles, medical devices, farms, factories and public infrastructure—to sense, communicate, and act on real‑world conditions. Recent survey shows that IoT adoption is expanding from smart-home conveniences to safety‑critical domains such as healthcare monitoring, mobility, smart grids and smart cities. Building on that context, this survey synthesizes the role of IoT in future life through three lenses: (i) enabling technologies (sensing, connectivity, edge/cloud computing and AI), (ii) real‑life application ecosystems (smart living, health, agriculture, industry and governance), and (iii) cross‑cutting challenges (security, privacy, interoperability, reliability, ethics and sustainability). The paper also presents an evidence‑based market view using recent device‑connection forecasts and proposes a practical architecture stack for future‑life services. Unlike implementation‑oriented articles, this work provides a structured overview to guide students, researchers and practitioners in understanding IoT's societal impact and the design considerations required to make IoT safe, resilient and inclusive. The discussion concludes with future directions including edge‑AI, digital twins, low‑power networking and regulation‑ready security baselines.

Keywords: Internet of Things (IoT), Smart Life, Edge Computing, 5G, AIoT, Smart Cities, Security, Privacy, Sustainability.

1. Introduction:

The Internet of Things (IoT) describes an ecosystem in which physical objects are equipped with identifiers, sensors, actuators, and networking capabilities so that they can collect data, exchange information, and support automated decisions. IoT is not a single device or protocol; it is a socio‑technical system spanning hardware, connectivity, platforms, analytics, and human governance. The study emphasizes IoT as a vision where everything becomes network‑accessible and services are built around real‑world context—particularly in smart homes and smart cities.

IoT's role in future life is best understood as a progression from 'connected products' to 'connected services' and finally to 'connected living'. A smart bulb becomes a smart home when lighting is coordinated with energy tariffs, occupancy, security, and comfort settings. A wearable becomes a smart‑health solution when it enables continuous monitoring, alerts, and clinical decision support while respecting privacy.

The importance of IoT is increasing because modern life is increasingly data‑dependent: health decisions, transportation efficiency, energy consumption, and environmental sustainability all benefit from sensing and automation. However, IoT can also amplify risk because it blends cyber systems with the physical world. Therefore, future‑life IoT must be designed with resilience, safety and ethics. This survey presents a structured overview of IoT's role for future life, focusing on enabling building blocks, real‑life applications, challenges, and research directions.

2. Enabling Building Blocks For Future‑Life Iot:

2.1 Sensing and Actuation: IoT begins with perception—capturing physical phenomena such as temperature, motion, vibration, location, heart rate, air quality, or electricity consumption. Actuators then translate decisions into action: switching devices on/off, adjusting valves, controlling motors, or triggering alarms. The reliability of future‑life IoT depends on sensor calibration, drift management, and fault tolerance.

2.2 Connectivity and Addressability: Connectivity options include Wi‑Fi for home and enterprise networks, Bluetooth Low Energy for wearables and short‑range devices, LPWAN (e.g., LoRaWAN/NB‑IoT) for long‑range low‑power sensing, and cellular/5G for high‑reliability mobility services. IPv6 and device identity management support large‑scale addressing and secure onboarding.

2.3 Edge and Cloud Computing: Cloud platforms provide scalable storage, analytics and orchestration, while edge computing processes data near devices to reduce latency, bandwidth and privacy exposure. Future‑life applications (e.g., fall detection, industrial safety, smart traffic) often require edge inference because decisions must occur in milliseconds.

2.4 AIoT: Artificial Intelligence for IoT: AI enhances IoT by converting raw sensor streams into insights: anomaly detection, predictive maintenance, behavior recognition, demand forecasting, and personalized recommendations. The convergence of AI and IoT (AIoT) enables 'context‑aware living' but also requires careful governance to avoid bias and over‑surveillance.

2.5 Interoperability and Standards: IoT ecosystems are heterogeneous. Interoperability depends on protocols (MQTT, CoAP, HTTP), semantic models, and standardized security practices. Without interoperability, future‑life IoT becomes fragmented, expensive to maintain, and unsafe.

3. A Practical Iot Architecture For Future Life:

A useful way to describe IoT services is through a layered architecture: device/perception, network, platform/analytics, and application layers. The study outlines how connected things enable services in smart homes, healthcare and cities; this survey extends that view by emphasizing edge‑AI and governance.

At the device layer, sensors and actuators produce raw data. Gateways may aggregate and translate protocols. At the network layer, connectivity transports data securely. At the platform layer, device management, stream processing, storage, and analytics operate—often split between edge and cloud. Finally, the application layer delivers user value: automation, monitoring dashboards, alerts and optimization. Security and privacy are cross‑cutting requirements across all layers.

4. Role Of Iot In Future Life: Major Application Domains:

4.1 Smart Home and Assisted Living: IoT improves daily life through automated lighting, climate control, energy monitoring, smart appliances and home security. For elderly and differently‑abled users, assistive IoT can enable medication reminders, fall detection, and remote caregiver alerts, increasing independence and quality of life.

4.2 Smart Healthcare and Personalized Well‑Being: Wearables and connected medical devices support continuous monitoring of vital signs, adherence tracking, and telemedicine. Hospital IoT systems can track equipment utilization, monitor cold‑chain storage of vaccines,

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and improve patient safety. The future‑life opportunity is preventive care: early detection of risk patterns before emergencies occur.

4.3 Smart Mobility and Connected Transportation: Connected vehicles, road sensors and intelligent traffic lights can reduce congestion, improve road safety, and enable better public transport scheduling. IoT also supports fleet telematics, predictive maintenance of buses/trucks, and optimized route planning.

4.4 Smart Agriculture and Food Systems: Precision agriculture uses soil‑moisture sensors, weather stations, smart irrigation, and livestock tracking to improve yield and reduce waste. In future life, resilient food systems require IoT to manage water scarcity, optimize fertilizer use, and monitor supply chains.

4.5 Industry 4.0 and Smart Workplaces: Industrial IoT (IIoT) supports predictive maintenance, condition monitoring, quality inspection, and digital twins of machines. In future workplaces, IoT will be central to safety monitoring, energy efficiency, and human‑robot collaboration.

4.6 Smart Cities, Governance and Sustainability: Urban IoT includes smart street lighting, waste management, air‑quality monitoring, water leak detection, and smart grids. Combined with analytics, these systems enable data‑driven governance and sustainability. However, public‑sector IoT requires strong privacy safeguards and transparent accountability.

5. Real‑Life Examples: Iot Services That Already Shape Daily Life:

Table 1 summarizes practical IoT examples that demonstrate how future‑life services are emerging today. These examples are chosen to reflect different sectors and the typical value delivered (safety, comfort, cost reduction, sustainability, or accessibility).

6. Growth Trends And Why Iot Matters For The Next Decade

Industry forecasts consistently indicate strong growth in connected IoT devices. IoT Analytics reports that connected IoT devices reached 18.5 billion in 2024 and are expected to grow to 21.1 billion in 2025, with an estimate of 39 billion by 2030. Such growth implies a future where 'connected sensing' becomes a normal layer of infrastructure.

Why does this matter for future life? First, more devices create richer context for smarter automation. Second, the growth increases cyber‑physical attack surfaces, making security a non‑negotiable requirement. Third, as IoT scales, governance and sustainability become critical: e‑waste, power consumption, and equitable access must be addressed alongside innovation.

7. Key Challenges In Deploying Iot For Future Life:

7.1 Security and Safety: IoT devices often operate in uncontrolled environments and can be difficult to patch. Weak authentication, default credentials, and insecure communication can lead to device takeover or physical harm. Safety‑critical IoT must adopt secure boot, hardware trust anchors, strong identity, and continuous monitoring.

7.2 Privacy and Ethical Use: IoT can create continuous surveillance via cameras, microphones and location data. Future‑life deployments must follow data‑minimization, purpose limitation, and user consent. Transparent policies and privacy‑preserving analytics (e.g., edge processing) reduce risk.

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7.3 Interoperability and Vendor Lock‑in: Fragmented ecosystems raise cost and complexity. Interoperability standards and open APIs are essential for long‑term sustainability.

7.4 Reliability, Resilience and Connectivity Gaps: Many future‑life services rely on stable networks. Rural connectivity gaps, power failures, and harsh environments can reduce IoT reliability. Resilient design includes offline‑first logic, edge autonomy, and redundant communication paths.

7.5 Energy Consumption and Sustainability: Billions of connected devices raise concerns about battery waste and power demand. Low‑power design, energy harvesting, and lifecycle management are key research directions.

7.6 Governance and Regulation: Policy frameworks increasingly require baseline security and transparency. For public deployments, auditability and accountability mechanisms should accompany technical controls.

8. Future Directions:

Future‑life IoT will likely be shaped by: (i) edge‑AI for real‑time decisions, (ii) digital twins for predictive simulation, (iii) low‑power wide‑area connectivity for rural inclusion, (iv) secure‑by‑design device lifecycles, and (v) sector‑specific regulation and certification.

Additionally, human‑centric design will be critical: IoT systems must remain understandable, controllable, and aligned with user values. Research in explainable AI, privacy‑preserving analytics and trustworthy platforms will determine whether IoT improves quality of life without sacrificing rights.

9. Conclusion:

The Internet of Things (IoT) is rapidly evolving into a **core technological backbone of future life**, enabling intelligent interaction between people, environments, and digital services through pervasive sensing, real-time communication, and data-driven intelligence. This survey presented a **comprehensive and forward-looking analysis** of IoT, systematically covering its enabling technologies, architectural frameworks, diverse real-life application domains, key challenges, and emerging research directions.

The study highlights that IoT-driven solutions have the potential to significantly improve **quality of life, operational efficiency, safety, sustainability, and societal well-being** across domains such as smart homes, healthcare, transportation, agriculture, industrial automation, and smart cities. However, despite these transformative benefits, the large-scale deployment of IoT systems continues to face critical challenges related to **security, privacy preservation, interoperability, scalability, energy efficiency, and system resilience**. These challenges are further compounded by ethical concerns, data governance issues, and the lack of unified regulatory standards.

To fully realize the vision of IoT as an enabler of future life, this survey emphasizes the need for a **balanced and integrated approach** that combines technological innovation with robust security mechanisms, standardized architectures, ethical frameworks, and responsible governance. Future research should focus on intelligent IoT systems leveraging AI, edge computing, and secure-by-design principles to ensure trust, transparency, and sustainability. Ultimately, IoT's true impact will be defined not merely by technological advancement, but by its ability to serve as a **human-centric, secure, and sustainable infrastructure**, shaping the foundations of intelligent and connected societies.

Fig 1. A practical IoT architecture stack for future-life services
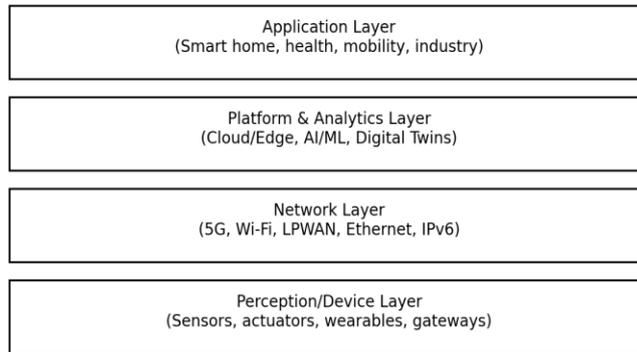
Figure: A practical IoT architecture stack for future-life services

Fig 2. Global connected IoT devices (2021–2030 forecast)
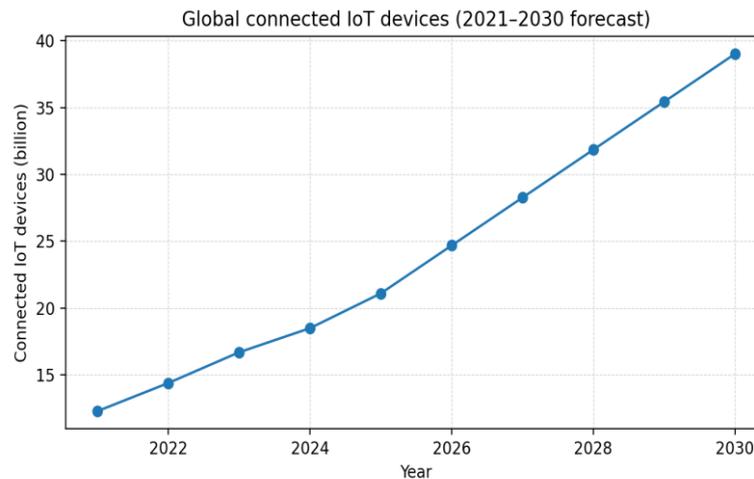
Table 1. Real-life IoT examples and future-life value

Domain	Real-life Example	What IoT Does	Future-life Value
Smart Home	Smart thermostat + smart meter	Learns occupancy, optimizes HVAC, monitors energy	Comfort + lower bills + emissions reduction
Healthcare	Wearable ECG / SpO_2 monitor	Continuous vitals tracking + anomaly alerts	Early risk detection + remote care
Mobility	Connected traffic signals	Adaptive signal timing using flow sensors	Reduced congestion + safer intersections
Agriculture	Soil moisture sensor + smart irrigation	Automates watering based on soil and weather	Water saving + higher yield
Industry	Predictive maintenance sensors	Vibration/temperature monitoring for failures	Reduced downtime + safer operations
Smart City	Smart street lighting	Dimming/brightening based on motion and time	Energy efficiency + public safety
Environment	Air-quality sensor network	Monitors $PM2.5/NO_2$ hotspots in real-time	Public health planning + awareness

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A Study of Power Politics and Revolution in George Orwell's *Animal Farm*

Dr. Bhausaheb S. Desale,

Assistant Professor,

SSVP Sanstha's Bhausaheb N. S. Patil Arts & MFMA Commerce College, Dhule

Email: bhauraj12@gmail.com

Abstract:

George Orwell's Animal Farm is a powerful political allegory that exposes the revolution and the inevitable corruption of power. This research paper examines how revolutionary ideals rooted in equality and justice gradually degenerate into authoritarian power politics. Through a critical reading of the novel, the study explores the transformation of leadership, manipulation of ideology, abuse of language, and systematic exploitation of the working class. The paper employs a political-allegorical and Marxist framework to analyze how Orwell critiques totalitarian regimes, particularly the Soviet Revolution and its aftermath. By focusing on characters such as Napoleon, Snowball, Boxer, and Squealer, the study reveals how power is consolidated, dissent silenced, and history rewritten. The research argues that Animal Farm serves not merely as a satire of a specific political system but as a universal warning against the dangers of unchecked power and failed revolutions. Orwell's narrative ultimately demonstrates that revolutions without moral vigilance and collective awareness inevitably reproduce the very oppression they seek to destroy.

Keywords: Power Politics, Revolution, Political Allegory, Totalitarianism, Marxism, Propaganda, Animal Farm.

Introduction:

George Orwell's *Animal Farm* stands as one of the most influential political allegories of the twentieth century. Written in the form of a beast fable, the novel transcends its apparent simplicity to offer a profound critique of revolutionary politics and authoritarian power. Orwell uses animals on a farm to dramatize the rise and fall of a revolution, mirroring the historical trajectory of the Russian Revolution and the emergence of Stalinist totalitarianism. Revolution, as portrayed in *Animal Farm*, begins with noble intentions—freedom, equality, and justice—but gradually devolves into a system of oppression more brutal than the one it replaced. Orwell highlights how power politics infiltrate revolutionary movements, corrupt leaders, manipulate ideology, and ultimately betray the masses. The pigs, who assume leadership roles after the rebellion, gradually distance themselves from the foundational principles of Animals establishing a hierarchy that benefits only the ruling elite.

The present research paper aims to examine the dynamics of power politics and revolution in *Animal Farm*, focusing on the processes through which power is acquired, legitimized, and abused. In his Politics and the Novel, Irving Howe considers that -
"By a political novel I mean a novel in which political ideas play a dominant role or in which the political milieu is the dominant setting" (Howe, 19).

By analyzing Orwell's depiction of leadership struggles, propaganda, class exploitation, and ideological distortion, the study seeks to demonstrate how revolutions can fail when power becomes centralized and unchecked. The revolution in *Animal Farm* originates from Old Major's visionary speech, which articulates a dream of equality, freedom, and collective ownership. Old Major's ideology combines elements of Marxism and socialism, emphasizing the exploitation of animals by humans and advocating a classless society.

Old Major declares:

"Man is the only creature that consumes without producing."(Orwell 7)

This statement establishes the ideological foundation of the rebellion, framing humans as exploiters and animals as the oppressed proletariat. The revolution succeeds initially because it unites animals under a shared vision. However, Orwell subtly foreshadows the fragility of such unity, as intellectual leadership is immediately monopolized by the pigs. The early success of the revolution symbolizes the optimism of political upheaval. Yet, Orwell suggests that revolutions are inherently vulnerable when power is unevenly distributed and the masses lack critical awareness.

After the rebellion, power politics emerge through the pigs' gradual assumption of authority. Napoleon and Snowball are representing competing models of leadership, struggle for dominance. While Snowball emphasizes collective participation and innovation, Napoleon prioritizes control and force. Napoleon's use of trained dogs to expel Snowball marks the turning point where political rivalry transforms into dictatorship:

"Nine enormous dogs wearing brass-studded collars came bounding into the barn."(Orwell 53)

This moment signifies the replacement of democratic debate with coercion. Orwell demonstrates that power politics thrive on violence, fear, and the elimination of opposition. Napoleon's leadership exemplifies how revolutionary leaders manipulate ideology to consolidate power. Unlike Snowball, Napoleon avoids public debate and operates behind the scenes, rewriting laws and controlling resources. His gradual elevation mirrors the rise of totalitarian dictators who claim revolutionary legitimacy while betraying its principles. Napoleon's transformation underscores Orwell's belief that absolute power corrupts absolutely.

George Orwell's *Animal Farm* functions as a multilayered allegory in which characters, events, and symbols collectively expose the operations of power politics within revolutionary movements. Orwell deliberately employs animals to universalize political experience, allowing the narrative to transcend a specific historical moment and address broader patterns of authoritarian governance. Each animal on the farm symbolizes a social or political class. The pigs represent the intellectual elite who appropriate revolutionary ideology for personal gain. Napoleon symbolizes the authoritarian ruler who consolidates power through fear, while Snowball embodies revolutionary idealism and intellectual debate. Boxer, the loyal cart-horse, symbolizes the working class whose physical labor sustains the state but who remain politically powerless. The farm itself becomes a symbolic microcosm of the state, reflecting how institutions meant to ensure equality are corrupted by power-hungry elites. The windmill, initially presented as a symbol of progress and collective prosperity, transforms into a political tool for manipulation. Napoleon repeatedly alters its significance to suit his agenda, blaming failures on Snowball and using reconstruction as justification for increased labor and control.

Orwell's symbolic framework demonstrates how revolutions are betrayed not by external enemies but by internal corruption. The animals' inability to read, remember, or question authority symbolizes the dangers of political ignorance, reinforcing Orwell's warning that uncritical obedience enables tyranny. One of Orwell's most profound critiques of power politics lies in his treatment of language. Language in Animal Farm does not serve communication or truth; instead, it becomes a weapon of control. The Seven Commandments, initially presented as immutable laws of Animalism, are gradually altered to legitimize the pigs' actions. The commandment "All animals are equal" is eventually transformed into:

"All animals are equal, but some animals are more equal than others."(Orwell 133)
This paradoxical statement depicts the essence of political hypocrisy. Orwell reveals how authoritarian regimes manipulate language to normalize inequality and injustice. By distorting language, those in power reshape reality itself, leaving the oppressed unable to articulate resistance. Squealer plays a crucial role in this linguistic manipulation. As the regime's propagandist, he reframes exploitation as necessity and repression as protection. His speeches exploit fear, misinformation, and pseudo-logic, demonstrating how propaganda sustains political power even in the absence of moral legitimacy. Through this linguistic corruption, Orwell exposes the fragility of truth under authoritarian systems. When language loses its ethical grounding, revolution becomes meaningless, and oppression becomes normalized.

Power politics in *Animal Farm* are sustained through systematic violence and psychological terror. Napoleon's use of dogs as a private militia reflects the transformation of revolutionary defense into state terror. Public executions serve as spectacles of fear, ensuring obedience through intimidation rather than consent. The purge scenes, where animals confess to fabricated crimes and are executed, mirrors totalitarian show trials. Orwell illustrates how regimes fabricate enemies to justify violence and consolidate power. Fear becomes a political instrument that suppresses dissent and fractures collective solidarity. The animals' growing acceptance of brutality reflects the normalization of violence under authoritarian rule. Orwell suggests that prolonged exposure to fear erodes moral judgment, making oppression appear inevitable and resistance futile. This aspect of the novel underscores Orwell's central political insight: revolutions fail not only because leaders abuse power, but because societies gradually adapt to injustice.

Boxer's character embodies the ultimate betrayal inherent in power politics. His unwavering loyalty and physical strength sustain the farm's economy, yet he remains excluded from decision-making processes. His guiding maxims—"I will work harder" and "Napoleon is always right"—reflect the ideological conditioning of the working class. Despite his sacrifices, Boxer is discarded when he becomes physically unproductive. His sale to the knocker exposes the regime's complete moral bankruptcy:

"The van was drawn by a horse and painted dark green."(Orwell 123)
Boxer's fate reveals the exploitative core of authoritarian power. Orwell critiques political systems that glorify labor while dehumanizing laborers. The tragedy of Boxer lies not only in his death but in his inability to recognize his exploitation. Through Boxer, Orwell warns that revolutions that exclude workers from political consciousness inevitably reproduce systems of oppression. Although Animal Farm directly references the Russian Revolution, Orwell's critique extends beyond Soviet history. The novel presents revolution as a cyclical process in which one ruling class replaces another without altering structures of domination. The final scene, where pigs and humans become indistinguishable, encapsulates this cycle:

"The creatures outside looked from pig to man, and from man to pig… but already it was impossible to say which was which."(Orwell 141)

This moment signifies the ultimate failure of revolution. Power politics erase ideological differences, reducing political systems to instruments of exploitation. Orwell implies that revolutions fail when power becomes centralized and accountability disappears. The universality of this message explains the novel's continued relevance. *Animal Farm* remains a political cautionary tale applicable to any society where authority operates without ethical restraint.
Conclusion:

George Orwell's *Animal Farm* presents a study of power politics and revolution, revealing how noble ideals are corrupted through authoritarian ambition. The novel demonstrates that revolutions fail not because equality is impossible, but because power becomes concentrated in the hands of the few. Through allegory, symbolism, and satire, Orwell exposes the mechanisms of political manipulation, the exploitation of the working class, and the erosion of truth. The transformation of Animalism into dictatorship illustrates the dangers of ideological rigidity and uncritical obedience. Ultimately, *Animal Farm* serves as a timeless warning: revolutions without ethical vigilance and collective awareness inevitably reproduce the very systems they seek to overthrow. Orwell's political vision challenges readers to recognize that true revolution lies not merely in overthrowing rulers but in resisting the corrupting influence of power itself.

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The Role of Finance in Sustainable Development : Mobilizing Capital for a just Transition

Mr. Shubham S. Sonar
Ph. D Research Scholar,
KavayitriBahinabai Chaudhari
North Maharashatra University,
Jalgaon, Maharashatra, India

Dr. C. R. Deware
Research Guide,
Associate Professor and Head,
Department of Commerce
Mahatma Gandhi Shikshan Mandalache
Dadasaheb Dr. Suresh G. Patil College
Chopda, Maharashtra, India

Introduction:

Finance as the Great Enabler and Constraint. Finance represents both the circulatory system and nervous system of sustainable developmentchannelling resources while signalling priorities and risks. The ambitious 2030 Agenda for Sustainable Development requires an estimated $5-7 trillion annually in developing countries alone, with current investment falling short by approximately $4.2 trillion. This financing gap underscores finance's pivotal role in either accelerating or constraining progress toward sustainability goals. This paper examines how financial systems are being reimagined and reformed to align capital flows with sustainable development objectives, analyzing theoretical frameworks, empirical evidence, and persistent challenges in mobilizing finance for the triple bottom line of people, planet, and prosperity.

Keywords: Sustainable Development, Financial Systems, Triple Bottom Line etc.

Literature Review: The Evolution of Sustainable Finance:
1. Theoretical Foundations: From Externalities to Integrated Value:

The academic discourse on finance's role in sustainability has evolved through several conceptual stages:

The Externalities Problem (Pigou, 1920; Coase, 1960) established early economic understanding that market prices often fail to account for social and environmental costs. This created the theoretical justification for why purely market-based finance would underinvest in sustainability. Modern applications include carbon pricing mechanisms and biodiversity credits that attempt to internalize these externalities.

Fiduciary Duty and the Friedman Doctrine dominated 20th-century finance literature, asserting that corporate managers' sole responsibility was maximizing shareholder returns. Milton Friedman's 1970 essay famously declared corporate social responsibility "fundamentally subversive." This paradigm is increasingly challenged by legal scholarship showing that long-term value creation requires addressing sustainability risks (Freshfields Report, 2005; UNEP FI, 2019).

Stakeholder Theory (Freeman, 1984) and Integrated Value Creation (Eccles et al., 2014) represent conceptual shifts toward recognizing multiple forms of capital. The Six Capitals Model (IIRC, 2013)—financial, manufactured, intellectual, human, social, and natural—provides a framework for comprehensive value accounting. This theoretical evolution supports the business case for sustainable finance by demonstrating how environmental, social, and governance (ESG) factors affect financial materiality.

2. The Sustainable Finance Spectrum: From Exclusion to Impact:

Literature categorizes sustainable finance approaches along a continuum:

Negative Screening (SRI - Socially Responsible Investing): The oldest approach, excluding sectors like tobacco, weapons, or fossil fuels. Academic debate centers on whether exclusion creates meaningful change versus simply shifting ownership (Hong &Kacperczyk, 2009).

ESG Integration: Incorporating environmental, social, and governance factors into financial analysis. Meta-analyses show mixed but generally positive relationships between ESG performance and financial returns (Friede et al., 2015: 90% of studies show non-negative relationship). Critics argue about measurement inconsistencies and "greenwashing" (Berg et al., 2022).

Thematic Investing: Targeting specific sustainability themes like renewable energy or gender equity. Literature highlights growth areas in climate finance and blue finance (ocean sustainability) but notes challenges in defining boundaries and measuring impact.

Impact Investing: Intentionally generating measurable social/environmental impact alongside financial returns. The literature distinguishes between impact-first versus finance-first approaches and debates additionality requirements (Brest & Born, 2013).

Transition Finance: Emerging literature focuses on financing high-emitting sectors' decarbonization, balancing the tension between exclusion and engagement strategies (Ehlers et al., BIS 2022).

3. Market Frameworks and Regulatory Evolution:

Voluntary Frameworks: The Principles for Responsible Investment (PRI), launched in 2006 with 63 signatories managing $6.5 trillion, now includes over 5,000 signatories managing $120 trillion (2023). Academic analysis questions implementation depth versus symbolic adoption (Arias et al., 2021).

Mandatory Disclosure Regimes: The literature tracks regulatory evolution from voluntary to mandatory sustainability reporting. The EU's Sustainable Finance Disclosure Regulation (SFDR, 2021) and Corporate Sustainability Reporting Directive (CSRD, 2023) represent watershed regulatory developments. Comparative studies examine different jurisdictional approaches (EU's double materiality vs. US's financial materiality focus).

Taxonomy Development: Classification systems defining sustainable activities have proliferated, with the EU Taxonomy (2020) being most comprehensive. Research examines challenges in technical screening criteria development, particularly for transitional activities (Doni et al., 2023).

4. Critical Perspectives and Limitations:

Greenwashing Debates: Extensive literature examines the gap between sustainability claims and actual impact. Research finds only 35% of "sustainable" funds demonstrate significant ESG improvement (Berg et al., 2022). Text analysis of fund prospectuses reveals vague terminology and inconsistent definitions (Drageset et al., 2023).

Financialization of Nature: Critical scholarship warns against reducing ecosystems to financial instruments through mechanisms like biodiversity credits or natural capital accounting, potentially enabling continued exploitation through "offsetting" (Sullivan, 2013).

Justice and Distribution: Emerging literature on climate justice finance examines whether sustainable finance exacerbates or alleviates global inequalities. Research shows only 16% of

climate finance reaches least developed countries (LDCs), with most flowing between developed nations (OECD, 2023).

Statistical Analysis: The State of Sustainable Finance:

1. Market Size and Growth Trajectories:

Overall Sustainable Finance Assets:

- Global sustainable investment reached $35.3 trillion in 2020 (GSIA), representing 35.9% of total managed assets

- Europe leads with $14.1 trillion (42% penetration), followed by US ($12.0 trillion, 33%) and Japan ($2.9 trillion, 24%)

- Projected growth to $50 trillion by 2025 (Bloomberg Intelligence), though recent market volatility has tempered short-term projections

Sustainable Debt Instruments:

- Green bond issuance reached $487 billion in 2022 (Climate Bonds Initiative), cumulative since 2007: $2.4 trillion

- Sustainability-linked bonds (SLBs) grew rapidly to $154 billion in 2022 but face scrutiny over weak Key Performance Indicators (KPIs)

- Social bond issuance: $249 billion in 2022, driven by pandemic response

- Emerging markets represent only 18% of global green bond issuance despite having greatest sustainable infrastructure needs

Climate Finance Flows:

- Annual climate finance reached $1.3 trillion in 2021/2022 (Climate Policy Initiative), but needs are $4.3 trillion annually by 2030

- Public sources: 48%, Private sources: 52%

- Mitigation vs. Adaptation: 91% vs. 9%—adaptation remains severely underfunded

- Only 12% of tracked climate finance incorporates gender considerations

2. Geographical and Sectoral Distribution

Regional Disparities:

- Developing countries received just $38 billion in climate finance from developed countries in 2020, missing the $100 billion annual pledge

- Africa receives only 3% of global climate finance despite high vulnerability

- Small Island Developing States (SIDS) receive 1.5% despite existential threats

Sectoral Allocation:

- Renewable energy: 47% of climate finance

- Sustainable transport: 24%

- Agriculture, forestry, land use: 8% (despite contributing 23% of emissions)

- Water and wastewater: 6%

3. Financial Performance and Materiality

Risk-Adjusted Returns:

- Morningstar analysis (2023): 66% of sustainable funds ranked in top half of performance over 10 years

- During 2022 market downturn, sustainable funds showed 15% less downside capture than conventional peers

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- However, recent fossil fuel outperformance (2022) led to temporary underperformance of ESG funds, highlighting transition risks

Cost of Capital Advantages:

- Green bonds show average 15-20 basis point "greenium" (lower yield) versus conventional bonds (International Finance Corporation)
- Sustainability-linked loans offer interest rate discounts of 5-25 bps for achieving KPIs
- Companies with strong ESG ratings have 10-15% lower cost of capital on average (NYU Stern)

Risk Management Benefits:

- Companies with robust ESG practices experienced 40% lower stock price volatility during COVID-19 market stress (S&P Global)
- Banks with higher ESG scores have 20% lower probability of default (Moody's)
- Insurance companies incorporating climate risk into underwriting have 30% lower catastrophe loss ratios

4. Implementation Gaps and Challenges

Measurement and Reporting Inconsistencies:

- 72% of companies use multiple reporting frameworks, creating confusion (IFAC)
- Only 38% of asset managers comprehensively integrate ESG into investment processes (CFA Institute)
- 45% of institutional investors cite "lack of consistent data" as primary barrier (PwC)

Capacity and Knowledge Gaps:

- 65% of financial institutions report insufficient in-house ESG expertise (Deloitte)
- Emerging markets face particular capacity constraints, with only 12% of African banks having dedicated sustainable finance teams (AfDB)

Market Concentration and Accessibility:

- 70% of sustainable fund assets managed by 10 largest firms (Morningstar)
- Retail investor participation remains limited: only 25% of sustainable fund assets from retail investors in US, versus 50% in Europe

Critical Analysis: Tensions and Transformations:

The Efficiency vs. Transformation Debate:

Sustainable finance literature reveals a fundamental tension between:

- **Incremental approaches:** Optimizing existing systems through better risk pricing and disclosure
- **Transformative approaches:** Reallocating capital to fundamentally reshape economies

Current evidence suggests dominance of incrementalism:

- Only 1% of global financial assets are invested in emerging market sustainable infrastructure
- Fossil fuel financing continues at $742 billion annually (2020-2022 average), barely changed from 2016-2019
- Bank lending to green activities represents just 7% of total lending in EU (ECB)

 The Materiality Paradox

Financial institutions face competing materiality definitions:

- Single materiality: How sustainability affects financial value
- Double materiality: How institutions affect society/environment AND how these impacts create financial risks

Regulatory divergence creates complexity, with EU adopting double materiality while US SEC focuses on financial materiality. This fragmentation increases compliance costs, particularly for multinational corporations facing 34% higher reporting costs.

The Justice Gap in Sustainable Finance

Statistical analysis reveals persistent inequalities:

- Gender lens investing represents only 0.5% of private equity/venture capital (Wharton)
- Racial equity bonds: $8.7 billion issued 2016-2022 versus $2 trillion green bonds
- Only 7% of climate finance targets most vulnerable communities (CPI)

Climate justice literature identifies three deficits:

1. Recognition deficit: Marginalized voices excluded from decision-making
2. Procedural deficit: Lack of transparent, participatory processes
3. Distribution deficit: Benefits and burdens unevenly allocated

- **Innovative Mechanisms and Future Directions**

1. Blended Finance and De-risking Instruments

Blended finance—using public/philanthropic capital to mobilize private investment—has grown but faces challenges:

- Cumulative blended finance deals: $197 billion (Convergence, 2023)
- Average mobilization ratio: $1 public to $5.5 private (OECD)
- However, 65% of blended finance targets middle-income countries, with LDCs receiving only 11%

Innovative instruments showing promise:

- SDG-aligned bonds: Linking returns to specific goal achievement
- Debt-for-nature swaps: $4.3 billion executed 2020-2023, particularly for ocean conservation
- Transition bonds: $15 billion issued for hard-to-abate sectors

2. Central Banks and Financial Regulators

Network for Greening the Financial System (NGFS) growth from 8 to 127 members (2017-2023) shows mainstreaming of climate risk supervision:

- 89% of global GDP now under central banks considering climate risks
- 43 countries have implemented climate risk stress tests
- But only 12% of central banks have explicit sustainability mandates

3. Technological Innovation

- Blockchain for green bonds: Increased transparency, reduced 30% administrative costs in pilots
- AI for ESG analysis: Processing 10,000+ data points per company versus traditional 200-300
- Satellite monitoring: Tracking deforestation with 95% accuracy for sustainable lending compliance

Pathways Forward: Recommendations:

1. Policy and Regulatory Priorities:

- Global baseline standards: Building on ISSB to reduce compliance complexity
- Just Transition requirements: Mandating distributional impact assessments
- Adaptation finance targets: Specific allocations within climate finance commitments

2. Market Innovations Needed

- Scalable blended finance models targeting LDCs and SIDS

- Integrative instruments addressing multiple SDGs simultaneously
- Forward-looking metrics focusing on future alignment rather than past performance

3. Capacity Building Imperatives

- Developing country financial institutions: Technical assistance for sustainable product development
- Regulatory authorities: Resources for effective supervision
- Data infrastructure: Public-private partnerships for emerging market ESG data

Conclusion: Financing the Great Transformation:

Finance stands at a crossroads between reinforcing unsustainable systems or catalysing transformative change. Current statistical evidence reveals impressive market growth but insufficient reallocation toward greatest needs. The $4.2 trillion annual SDG financing gap represents not just a deficit but a profound market failure and moral challenge.

The literature suggests that voluntary measures, while important, require regulatory reinforcement. The evolution from principles to mandatory disclosure represents progress, but enforcement and ambition must intensify. Future research should focus on measuring real-world impact rather than financial flows, developing justice-centred frameworks, and creating innovative mechanisms for adaptation and resilience finance.

Ultimately, sustainable finance's success will be measured not by assets under management but by tangible contributions to emissions reduction, biodiversity protection, poverty eradication, and inequality reduction. As climate scientist Johan Rockström notes, "The financial sector holds the master key to transformation." Whether this key unlocks sustainable futures or continues financing dangerous pathways represents one of the defining questions of our century.

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- UNEP Finance Initiative Studies
- Bloomberg Intelligence Sustainable Finance Market Outlooks

Isolation, Identification and Screening of Common and Dominant Mycoflora Associated with *Chickpea (Cicer arietinum L.)*

S. M. Salunkhe*, S.A. Patil
*Head, Department of Botany,
Dadasaheb Digamber Shankar Patil ASC College, Erandol, Jalgaon, Maharashtra; 425109.
Email: drsopansalunkhe@gmail.com

Abstract:

  Chickpea (Cicer arietinum L.) is one of the most important leguminous oilseed crops, yet its productivity and post-harvest quality are frequently affected by fungal contamination. The present study aimed to screen and document the common and dominant mycoflora associated with soybean samples, with special emphasis on their occurrence and relative abundance. Seed and/or field samples of soybean were collected from representative locations and subjected to standard mycological isolation techniques using appropriate culture media. Fungal mycoflora developing on the media were identified based on macroscopic characters and microscopic features following standard taxonomic keys. The investigation revealed the association of diverse fungal genera, among which Aspergillus, Penicillium, Fusarium, Rhizopus, and Alternaria were frequently encountered. Among these, species of Aspergillus and Fusarium emerged as the dominant mycoflora, indicating their strong adaptability to soybean substrates and prevailing environmental conditions. The presence of such fungi is of concern due to their potential role in seed deterioration, reduced germination, and possible mycotoxin production. The study highlights the need for regular monitoring of soybean-associated mycoflora and adoption of appropriate management practices to minimize fungal infestation, thereby ensuring better crop quality and food safety.

Keywords: *Chickpea (Cicer arietinum L.)*, mycoflora, fungal contamination, dominant fungi, seed health

Introduction and Review of literature:

  The study of mycoflora associated with crop seeds is essential for understanding disease epidemiology, storage losses, and food safety issues. Previous investigations have reported the association of genera such as *Aspergillus*, *Fusarium*, *Penicillium*, *Alternaria*, and *Rhizopus* with soybean seeds. Environmental conditions like temperature, humidity, and storage practices strongly influence fungal colonization and dominance. Multiple studies identify *Aspergillus* and *Fusarium* species as the most frequently occurring fungi on chickpea seeds. Frequently cited as the most dominant, with incidence rates reaching up to 83% in some injured seed samples. It is primarily responsible for reducing carbohydrate content (approx. 26%) during storage. A major storage fungus with high frequency (averaging 54.32% in Kabuli varieties). It is a known producer of aflatoxins and significantly lowers seed germination. The most critical pathogen, causing Fusarium wilt. Incidence rates on seeds harvested from wilted plants can exceed 20-27%. It causes the greatest reduction in seed protein content (nearly 40%). Other Common Species such as *Alternaria alternata* (Blight pathogen), *Rhizopus stolonifer* (Commonly found in storage, incidence up to 100% in certain varieties). *Penicillium spp.* and *Macrophomina phaseolina* (Dry root rot) occurred in storage of *Chickpea.*

  Chickpea, (Cicer arietinum), also called garbanzo bean or Bengal gram, annual plant of the pea family (Fabaceae), widely grown for its nutritious seeds. Chickpeas are an important food plant in India, Africa, and Central and South America. The seeds are high in fibre and protein and are a good source of iron, phosphorus, and folic acid. Similarly, chickpea, a staple crop in arid and semi-arid regions, is vulnerable to fungal infections caused by Ascochyta rabiei, Fusarium oxysporum, and Rhizoctonia solani, resulting in diseases such as Ascochyta blight, Fusarium wilt, and root rot (Walcott et al., 2006).

These diseases can cause significant crop losses, particularly under favourable environmental conditions such as high humidity and soil moisture. Chickpea, a crucial crop in dry regions, also faces threats from fungi like Ascochyta rabiei and Fusarium oxysporum, resulting in diseases such as Ascochyta blight and Fusarium wilt. These diseases can lead to significant losses, especially in wet conditions. Production: Cicer arietinum L. (chickpea) is the second most cultivated leguminous crop with 13.1 million tons per annum production, commonly grown on an estimated 13.5 million hectares of land in tropical, subtropical, temperate and semi-arid areas, worldwide. India is amongst the chief producers of chickpea, having 8.63 mha area under cultivation, 7.85 mt annum -1 production with an average yield of 900 kg per hectare (CIME, 2010; FAOSTAT, 2015; Muehlbauer and Sarker, 2017). Economic importance: It constitutes 20-30% protein, 40-59% carbohydrate, 3% fibre, 3-6% oil, 4% ash, and is a good source of absorbable ions like Ca, P, Mg, Fe, K and essential B vitamins (Ibrikci et al., 2003) Green pods used are used as vegetable. Haulm is used as fodder, Excellent green intensive crop rotations. manure as it is easily decomposed when incorporated (Biomass has 1.5% N), Seed contains 25% protein, 1.15% fat and 62.6% carbohydrate, sprouted seeds which are rich in vitamins are consumed as salad, Flour is used in cakes. Starch is used in making noodles, being short duration fits well in many.

The present investigation was undertaken to screen and document the common and dominant mycoflora associated with soybean, focusing on their frequency and prevalence. Such studies provide baseline information useful for disease management strategies, seed certification programs, and improvement of post-harvest storage practices.

Materials and Methods:

Collection of Soyabean Samples: Seed Varieties used in the present study are Chickpea*(Cicer arientinum L.)* i. *Cicer arientinum* (Chickpea) Vijay ii. *Cicer arientinum* (Chickpea) Jaki-9218 During the course of studies, seed samples were separately collected and stored in pre-sterilized plastic containers without any treatment at laboratory conditions. Chickpea seed samples were collected from representative agricultural fields and storage sources. Care was taken to collect apparently healthy as well as visually infected seeds. The samples were placed in sterile polythene bags, properly labeled, and transported to the laboratory for further analysis.

Surface Sterilization: Seeds were surface sterilized using 0.1% mercuric chloride or 1% sodium hypochlorite solution for a short duration, followed by thorough washing with sterile distilled water to remove any traces of sterilant. The sterilized seeds were dried on sterile blotting paper.

Isolation of Mycoflora: The seed mycoflora was isolated by using different methods such as Standard blotter paper method and Agar plate method as recommended by International Seed Testing Association ISTA (1966), De Tempe (1970), Neergaard (1973) and Agrawal (1976) The isolation of fungal mycoflora was carried out using standard mycological techniques such as the blotter paper method and agar plate method. Sterilized seeds were placed on Potato Dextrose Agar (PDA) and incubated at 25 ± 2 °C for 5–7 days. Regular observations were made for fungal growth(Ellis, 1971; FAO, 2011). Standard blotter paper method and Agar plate method as described by the International Seed Testing Association (ISTA) 1996, was used for the isolation of the seed-borne fungi associated with the seed samples.

Identification of Fungi: Fungal colonies were identified based on macroscopic characters such as colony color, texture, growth pattern, and pigmentation. Microscopic features including hyphal structure, conidiophores, conidia, and spore arrangement were studied using lactophenol

cotton blue staining. Identification was confirmed using standard taxonomic manuals and keys (Neergaard, 1979; Pitt & Hocking, 2009; Raper & Fennell, 1965).

Determination of Frequency and Dominance: The frequency of occurrence of each fungal species was calculated as the percentage of samples in which the fungus appeared. Dominant mycoflora were determined based on their high frequency and consistent occurrence across samples.

Results: The screening of *Chickpea* samples revealed the presence of diverse fungal species belonging to different genera. The commonly isolated genera included *Aspergillus*, *Fusarium*, *Penicillium*, *Alternaria*, and *Rhizopus*. Among these, *Aspergillus* species such as *A. niger* and *A. flavus* showed the highest frequency of occurrence, followed by *Fusarium* species.

Penicillium species were moderately distributed, whereas *Alternaria* and *Rhizopus* occurred less frequently. The dominance of *Aspergillus* and *Fusarium* suggests their strong adaptability to soybean substrates and favorable environmental conditions. The occurrence of these fungi was observed both on field-collected and stored seed samples.

The mycological analysis of soybean seeds revealed a diverse assemblage of fungal genera (Table 1). Among them, *Aspergillus* and *Fusarium* were represented by multiple species and showed the highest frequency of occurrence. The frequency data (Table 2) clearly indicate that *Aspergillus* spp. were the most prevalent fungi, followed by *Fusarium* spp., while *Alternaria* and *Rhizopus* occurred at lower frequencies. Based on relative abundance and consistency across samples, *Aspergillus* and *Fusarium* were categorized as dominant mycoflora (Table 3).

Table 1. List of fungal genera and species isolated from *Chickpea (Cicer arietinum L.*) seeds

Sr. No.	Fungal genus	Identified species	Nature of occurrence
1	*Aspergillus*	*A. niger*	Dominant
2	*Aspergillus*	*A. flavus*	Dominant
3	*Fusarium*	*F. oxysporum*	Dominant
4	*Fusarium*	*F. solani*	Common
5	*Penicillium*	*P. chrysogenum*	Common
6	*Alternaria*	*A. alternata*	Occasional
7	*Rhizopus*	*R. stolonifer*	Occasional

Table 2. Frequency of occurrence of mycoflora associated with *Chickpea* seeds

Sr. No.	Fungal genus	Number of samples infected	Frequency of occurrence (%)
1	*Aspergillus*	38	76
2	*Fusarium*	31	62
3	*Penicillium*	22	44
4	*Alternaria*	15	30
5	*Rhizopus*	12	24

Table 3. Dominance pattern of fungal genera isolated from *Chickpea* seeds

Sr. No.	Fungal genus	Relative abundance	Dominance category
1	*Aspergillus*	Very high	Dominant
2	*Fusarium*	High	Dominant
3	*Penicillium*	Moderate	Common
4	*Alternaria*	Low	Less common
5	*Rhizopus*	Low	Rare

Discussion:

The association of diverse mycoflora with *Chickpea* seeds observed in the present study agrees with earlier reports. Species of *Aspergillus* and *Fusarium* are well known for their ability to colonize oil-rich seeds and survive under a wide range of environmental conditions. Their dominance may be attributed to high moisture content, improper drying, and inadequate storage conditions.

The presence of *Aspergillus flavus* is particularly significant due to its potential to produce aflatoxins, which are highly toxic and carcinogenic. Similarly, *Fusarium* species are responsible for seed rot, seedling blight, and mycotoxin contamination. The detection of *Penicillium* and *Alternaria* further indicates the risk of post-harvest spoilage.

These findings emphasize the importance of routine mycological screening of *Chickpea*seeds. Proper drying, storage under low humidity, and use of fungicidal seed treatments can significantly reduce fungal infestation. Adoption of good agricultural and storage practices is essential to maintain seed health and ensure food safety.

The dominance of *Aspergillus* and *Fusarium* observed in the present investigation corroborates earlier findings on oilseed crops. Their high frequency may be attributed to their rapid growth, enzymatic efficiency, and tolerance to fluctuating moisture conditions. The comparatively lower occurrence of *Alternaria* and *Rhizopus* suggests their secondary role in *Chickpea* seed deterioration.

Conclusion:

The present investigation confirms that *Chickpea* seeds harbor a diverse range of fungal mycoflora, with *Aspergillus* and *Fusarium* emerging as the dominant genera. The occurrence of these fungi poses a serious threat to seed quality, crop productivity, and food safety due to their pathogenic and toxigenic potential. Regular monitoring of soybean-associated mycoflora and implementation of effective management strategies are necessary to minimize fungal contamination and ensure sustainable soybean production.

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Role of Mobile Banking Network Connectivity and effectiveness of banking Correspondence in Rural Area

Priyanka Madhukar Jagtap[1], Dr. Kranti S. Patil[2]

1. Research Scholar, KBHSST's Dr. B.V. Hiray College of Management & Research Centre
Email: priyankajagtap64@gmail.com

2. Assistant Professor, S.S.V.P.S.B.N.S. Arts & M.F.M.A. Commerce College, Dhule
Email: ksp446@gmail.com

Abstract:

Mobile banking and banking correspondents have become central to financial inclusion strategies, especially in rural areas where traditional bank infrastructure is limited. This paper explores the interplay between network connectivity and the effectiveness of banking correspondence systems in enhancing rural banking outcomes. The research assesses how connectivity levels influence the adoption and utility of mobile banking, and how banking correspondents supplement formal banking by bridging gaps in access, trust, and service quality. Drawing on recent studies from India and other rural economies, findings indicate that connectivity quality significantly shapes user engagement and perceived usefulness of mobile banking, while Banking Correspondents play a vital role in delivering financial services.Reliable connectivity and well-supported banking correspondents enhances financial participation, reduces dependence on informal financial systems, and promotes inclusive economic development.The paper concludes to enhance rural connectivity and empowering correspondents to strengthen rural financial ecosystems.

Keywords: Mobile Banking, Network Connectivity, Banking Correspondents, Rural Banking, Financial Inclusion, Digital Literacy.

1. Introduction:

Financial inclusion has emerged as a cornerstone of inclusive economic growth, particularly in developing countries where rural populations often remain underserved by mainstream banking systems. Traditional banks struggle to serve lightly populated or geographically isolated communities due to high operational costs and limited infrastructure. In response, banks and policymakers have promoted mobile banking and banking correspondents (BCs) as alternative access points for rural financial services.

Mobile banking leverages mobile networks to deliver basic financial services such as fund transfers, balance inquiries, and bill payments through mobile phones, even in the absence of physical branch infrastructure. However, for mobile banking to be effective, reliable network connectivity is essential. Connectivity issues including weak signal strength, broken internet access, and low bandwidth pose significant barriers to widespread usage in rural areas. Alongside this, banking correspondent'slocal agents equipped with banking tools act as physical interfaces for customers who lack digital literacy or struggle with digital interfaces, further supporting financial inclusion goals.This paper investigates the dual role of mobile banking network connectivity and banking correspondents in rural areas, examining their effectiveness in enhancing access, trust, and financial engagement among rural populations. This study is based on the interaction between technological infrastructure and human intermediaries in rural banking. Mobile banking network connectivity represents the technological dimension, while banking correspondents represent the human and institutional dimension.

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Mobile Banking Network Connectivity: Includes availability of mobile networks, internet penetration, signal strength, data speed, and service reliability.

Banking Correspondents: Include their accessibility, training, technological competence, trust among customers, and support from parent banks.

Rural Banking Outcomes: Improved access to financial services, increased transaction volume, reduced dependency on cash, and enhanced financial inclusion.

The framework assumes that strong network connectivity enhances the performance of banking correspondents, while effective BCs encourage greater adoption of mobile banking services.

2. Objectives of the Study

- To examine the role of mobile banking network connectivity in rural banking services.
- To evaluate the effectiveness of banking correspondents in delivering banking services in rural areas.
- To analyse the relationship between network connectivity and the performance of banking correspondents.
- To assess the impact of mobile banking and BCs on financial inclusion in rural areas.

3. Literature Review:

Previous studies on rural banking and financial inclusion emphasize the importance of digital channels and agent-based banking models. Researchers have highlighted that mobile banking reduces transaction costs and overcomes geographical barriers, but its success in rural areas is constrained by poor network infrastructure and low digital literacy. Studies on the BC model reveal that banking correspondents play a vital role in last-mile delivery of financial services, particularly for basic savings accounts, allowances, and government benefit transfers.Several researcher note that inadequate training, delayed commissions, and technological issues reduce BC motivation and effectiveness. Others discuss that trust and personal relationships between BCs and rural customers significantly influence adoption of digital banking. The literature indicates a gap in integrated studies that jointly analyse mobile network connectivity and BC effectiveness, which this paper attempts to address.

4. Research Methodology:

This paper adopts a qualitative review methodology, findings from existing academic literature, institutional reports, case studies, and journal articles relevant to mobile banking connectivity and banking correspondents in rural settings. Primary studies from India's rural banking landscape serve as core references, complemented by comparative insights from global research where applicable. The scope of literature spans studies conducted between 2018 and 2025, ensuring that the discussion reflects contemporary developments in mobile connectivity infrastructure, digital adoption trends, and rural financial inclusion policies.

5. Mobile Banking in Rural Area:

Mobile banking has been widely acknowledged as a driver of financial inclusion, especially in contexts with limited physical banking infrastructure. Studies reveal that mobile banking can reduce transaction costs and geographic barriers to financial services, fostering broader access to banking platforms among rural households. However, network connectivity emerges as a recurrent challenge. Poor internet or mobile network quality significantly hampers user experience and acts as a limiting to regular usage. Lack of stable connectivity can reduce transaction success rates, increase delays, and user confidence in digital financial services.

Network Connectivity and Adoption:

Mobile banking adoption in rural settings is heavily dependent on connectivity infrastructure. Research shows that rural communities with better mobile network coverage demonstrate higher adoption rates of mobile banking services, while areas with poor connectivity experience lower engagement and face operational challenges. Beyond connectivity, other factors such as digital literacy, trust, perceived risk, and ease of use significantly affect adoption patterns. These factors often interact with connectivity issues; for instance, users with low digital literacy may struggle more if connectivity issues complicate app usage.

Banking Correspondents and Financial Inclusion:

Where physical bank branches are sparse, banking correspondents serve as extension agents who provide basic financial services on behalf of banks. These correspondents' help customers open accounts, conduct deposits/withdrawals, and update KYC (Know Your Customer) information. Correspondents also serve a critical role in demonstrating trustworthiness and convenience, especially for individuals with low digital literacy towards digital platforms.Empirical evidence suggests that banking correspondents can increase savings rates and access to financial services in rural households, though their effectiveness is moderated by the agents training, incentive structure, and connectivity support.

Role of Mobile Banking Network Connectivity in Rural Areas:

Mobile banking network connectivity is the backbone of digital financial services in rural regions. Reliable connectivity enables real-time transactions, balance inquiries, fund transfers, and access to government welfare schemes. In areas with stable network coverage, mobile banking adoption is significantly higher, leading to reduced dependency on physical bank branches. However, rural areas often suffer from inconsistent network coverage, low bandwidth, and frequent service disruptions. These issues lead to transaction failures, delays, and loss of customer confidence. Poor connectivity also affects the functioning of biometric devices and micro-ATMs used by banking correspondents. Therefore, network quality directly influences both customer experience and service delivery efficiency.

Challenges for Banking Correspondents:

Despite their potential, BCs face multiple challenges low pay, limited technological support, connectivity disruptions at kiosk locations, and occasional hardware/software failures. A recent local media report highlighted resident dissatisfaction with poor internet connectivity and challenges in executing routine transactions because of connectivity failures.

Connectivity as a Core Determinant of Mobile Banking Use:

It shows that mobile banking adoption in rural areas is strongly correlated with the availability and reliability of mobile network connectivity. Where network coverage is patchy or bandwidth is low, users struggle to complete transactions, leading to frustration and abandonment of digital services. Low connectivity also deters bank correspondents from completing online verification or real-time transactions, further reducing service reliability. Although mobile banking services can function on basic mobile phones via USSD platforms such as *99#, there is a growing preference among users for application-based banking, which requires stable and high-quality internet connectivity. While connectivity and BC support are critical, several other barriers persist:Digital Literacy in Rural users often lack the skills to navigate mobile banking apps or interfaces, which reduces uptake even when connectivity is

available also Perceived Risk: Fear of fraud and security concerns deter users from trusting mobile platforms and Infrastructure Gaps Beyond mobile networks, issues like power outages, lack of smartphone penetration, and language barriers further constrain adoption.

Interconnected Role of Connectivity and Correspondents:

The effectiveness of mobile banking in rural environments is not solely dependent on network connectivity. Both connectivity and banking correspondence systems complement each otherwhere connectivity is strong but digital literacy is low, BCs help by guiding users in navigating digital platforms.Where connectivity is weak, BCs and offline mechanisms (like USSD banking) ensure continuity of basic services.Where both connectivity and BC support are robust, rural users demonstrate higher engagement, improved trust, and greater financial activity.This interplay highlights that technological infrastructure alone cannot solve rural financial exclusionhuman intermediaries remain indispensable.

Impact on Financial Inclusion:

The combined impact of mobile banking and effective banking correspondents has significantly improved financial inclusion in rural areas. Increased access to savings accounts, timely receipt of government benefits, reduced travel costs, and improved transparency are key outcomes. Mobile banking also empowers rural customers by providing greater control over their finances.

Yet, digital literacy remains a major challenge. Many rural customers rely entirely on BCs for transactions, limiting independent use of mobile banking applications. Enhancing digital literacy alongside infrastructure development is essential for long-term inclusion.

6. Findings of the Study:

- Mobile banking network connectivity plays a critical role in the success of rural digital banking.
- Banking correspondents are vital for last-mile financial service delivery in rural areas.
- Poor network connectivity significantly reduces the effectiveness of banking correspondents.
- Trust, training, and technological support are key determinants of BC performance.
- The synergy between mobile banking and BCs enhances financial inclusion and rural development.

7. Conclusion:

Financial inclusion in rural areas on the interdependent relationship between mobile banking network connectivity and the effectiveness of banking correspondents. While connectivity enables access to digital channels, correspondents humanize and localize financial services, fostering trust and guiding users through digital landscapes.Improving network infrastructure is necessary but not sufficient investment in capacity building, digital literacy, and incentive structures for banking correspondents is equally important. Such a multifaceted strategy can significantly enhance rural financial participation, contribute to economic development, and reduce exclusion from formal financial systems.

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MXene Two-Dimensional Materials : Recent Synthesis Approaches and Application Perspectives

M. A. Patil
MGMs Dadasaheb Dr. Suresh G. Patil College, Chopda Dist. Jalgaon-425107 (MS)

G. H. Sonawane
KVPs Kisan Arts, Commerce and Science College, Parola Dist. Jalgaon-425111 (MS)

Abstract: -

The New Emergent family of two-dimensional transition metal carbides, nitrides, and carbonitrides, has garnered significant attention due to its unique features include metallic conductivity, hydrophilicity, tunable surface chemistry, and mechanical flexibility. Since their invention, significant efforts have been devoted to developing efficient and scalable synthesis strategies to tailor their structure and properties for diverse applications. This mini-review offers a brief overview of recent advances in MXene synthesis approaches, including selective etching methods, fluoride-free routes, and emerging bottom-up methods, with particular focused on surface functionalization and structural control. Moreover, current advancement in crucial application areas like photocatalytic degradation, H_2 evoalution, CO_2 reduction and N_2 Fixations has critically discussed. Finally, existing obstacles and future research paths are highlighted to guide the rational design and large-scale implementation of MXene-based materials. This review seeks to provide a clear perspective on the developing landscape of MXene research and its potential for next-generation functional materials.

Keywords: - MXenes, two-dimensional materials, synthesis strategies, surface functionalization, Applications

1. Introduction: -

The industrial manufacturing of products involves the use of synthetic raw materials, which are ultimately discharge into the ecosystem due to improper use, inefficient processes, and accidental discharges [1]. The introduction of these pollutants alters the ecological balance through their toxic properties affecting the biotic system. There are a wide variety of pathways involving physical, chemical, and biological separation principles to nullify toxic impurities [2]. For this concern, 2D materials widely employed for environmental remediation. Researcher have attention toward the developed two-dimensional (2D) materials due to their unique structural, chemical and physical properties [3]. The first experimentally discovered two dimensional materials as graphene it was successfully isolated in 2004 by Andre Geim and Konstantin Novoselov at university of Manchester. Before this discovery, two dimensional were considered thermodynamically unstable [4]. The successful isolation of graphene via mechanical exfoliation techniques knows as Scoth tape method [5]. Despite its exceptional properties, graphene addressing several limitations that restrict real-world systems due to its aggregation, stacking, scalable production challenges, zero band gap, stability issue and limited selectivity [6].

MXene, a rapidly expanding family of 2D transitional metal nitride, carbide and corbonitride that were first reported in 2011 [7]. MXene were discovered by Yury Gototsi and his team at Drexel University through the selectively etching of the A elements (mainly group 13 or 14) from layered MAX phases [8]. The discovery of MXene marked as major milestone in the development of 2D materials, resulting thin layer sheet that can be described by the general formula Mn+1XnTx, here M stands for early transition metal, while X is carbon and/or nitrogen, n varies from 1 to 3, determining the number of atomic layers in unit cell and Tx denotes surface terminations such as –O, –OH, and –F. The terminal surface groups are introduced through the

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etching and delamination processes [9]. The composition and surface properties of MXenes various with different experimental etching methods [10]. More than 20 kind of MXene have been successfully obtained. This materials alternative to graphene, possesses an exclusive attribute such as metallic conductivity, tuneable interlayer distance and an abundance of function groups on its surfaces, which tunes excellent hydrophilicity and chemical reactivity [11]. The excellent functionalization ability, easier dispersive in aqueous medium and most astonishing electrochemical properties which make conductive and well utilized for energy storage purposes, its oxidation/reduction reaction that build a pseudocapacitive environment to the electrically connected double layer mechanism of storing charge while led to active component for batteries as well as supercapacitors. MXene has been recognised as negative electrode to establish higher concentration gradients in acidic electrolyte solution, resulted enhancing energy density [12]. In recent years, MXene and MXene based nanomaterials have been used as photocatalysts in environmental remediations and energy applications [13]. However, limited reviews have been published on the synthesis strategies and innovative photocatalyst for environmental remediation [14]. These reviews significantly different from our current reviews, as reviews containing all recent studies and futures outlook, This reviews contains synthesis strategies, catalytic application for degradation, H_2 production, CO_2 reduction, N_2 fixation and reusability. We also briefly report the areas of future research on MXene based catalyst [15].

2. Synthesis Strategies for synthesis of MXenes:-

MXene are typically synthesis through etching for selective etching of A atomic layers of the MAX phases. The synthesis methods for MXene are broadly classified into two major categories: top to bottom and bottom to up route. The top to bottom methods includes HF etching, situ HF etching, fluorine free synthesis method, alkali etching and electrochemical etching methods. On other hand, bottom to up methods includes chemical vapour deposition. Both approaches fundamentally differ in term of precision, scalability, cost, defect control, and structure complexity. The exfoliation methods are followed by delamination with used of various organic intercalants to enhance interlayered spacing between 2D nanosheets. Top to bottom approaches can be broadly subdivided into more recent dry selective extractions and wet chemical methods.

2.1 Wet chemical methods:

Wet chemical methods involve chemical etching, hydrothermal, mechanical and electrochemical exfoliation to selective removal of A layers from MAX phases. The most widely techniques for chemical exfoliation using 50%wt. HF then its followed by intercalation using bulkier organic molecules or cations. Various lower concentration of HF has been used to assure better safety. While other etchants solution containing LiF and HCl for production of HF. For safety concern, fluoride free etchants are gaining large popularity.

2.2 Dry Selective extraction:

Experimentally, quite similar to chemical vapour deposition in which borosilicate glass tube placed in furnace, I_2 vapour passed over the tube containing MAX phase at an elevated temperature $>400^0C$ leads to over etching. At lower temperature, reaction would not be occurred.

2.3 Water free etching:

The process involved fluoride free synthesis, instead of water polycarbonate used as replacement or organic compounds used as etchants It often take more than 7 days and expensive methods, resulting MXene shows excellent performance in Na ion battery.

2.4 Fluoride free etching:

Instead of harsh HF chemical, use of polar organic solvent with ammonium hydrogen fluoride to produce F as terminal function group. These synthesis routes considered as environmentally friendly approach for large surface and robust features of MXene.

2.5 Acid Treatments:

The electrochemical fluoride free synthesis involved low concentration of HCl as a electrolyte. MAX phase as electrode resulting MXene have fluorine free termination surface.

2.6 Hydrothermal alkali etching:

These methods involved concentrate alkali solution as etchant for MAX phase. In mostly reported studies, NaOH widely used and it dissolved into deionised water which is free from dissolve water.

3.0 MXene based Nano composites:

Simple strategies effectively employed for composites with polymer, carbon based materials, transition metal based composites in order to prevent oxidation, degradation of nanoparticles, aggregation, restacking etc. Numerous studies reporting on MXene based Nanocomposites for environmental remediation application such as photocatalytic degradation, CO_2 reduction, H_2 production and N_2 fixation

3.1 photocatalytic degradation of pollutants:

Photocatalytic degradation of organic and inorganic pollutants is an effective strategy for environmental remediation under mild conditions. In recent years, MXenes, a family of two-dimensional transition metal carbides and nitrides with the general formula $M_{n+1}X_nT_x$, have emerged as highly efficient cocatalysts and promoters in photocatalytic pollutant degradation systems. Their metallic conductivity, tunable surface chemistry, and strong interfacial interactions with semiconductors endow MXenes with unique advantages for enhancing photocatalytic activity.

One of the primary roles of MXenes in photocatalytic degradation is to promote efficient charge separation and transfer. When integrated with semiconductor photocatalysts, MXenes readily accept photogenerated electrons owing to their high electrical conductivity and suitable work function. The formation of Schottky or Z-scheme heterojunctions at the MXene–semiconductor interface effectively suppresses electron–hole recombination, thereby increasing the lifetime and availability of reactive charge carriers for redox reactions involved in pollutant degradation.

MXenes also contribute significantly to the generation of reactive oxygen species (ROS), which are key oxidizing agents in photocatalytic degradation processes. The accumulated electrons on MXene surfaces can react with dissolved oxygen to form superoxide radicals ($\bullet O_2^-$), while photogenerated holes in the semiconductor oxidize water or hydroxide ions to produce hydroxyl radicals ($\bullet OH$). These highly reactive species non-selectively attack and mineralize organic pollutants such as dyes, antibiotics, pesticides, and endocrine-disrupting compounds into less harmful products.

In addition, MXenes enhance pollutant adsorption and interfacial contact. Their large specific surface area and abundant surface terminations (–O, –OH, –F) provide favorable adsorption sites for pollutant molecules, increasing local reactant concentration near active sites. This adsorption-assisted mechanism accelerates degradation kinetics and improves overall photocatalytic efficiency.

3.2 CO_2 reduction:

Photocatalytic carbon dioxide reduction (CO_2RR) offers a sustainable pathway for converting CO_2 into value-added fuels and chemicals under mild conditions. In recent years, MXenes, a class of two-dimensional transition metal carbides and nitrides with the general formula $M_{n+1}X_nT_x$, have emerged as highly effective cocatalysts and promoters in photocatalytic CO_2 reduction systems. Their unique combination of metallic conductivity, tunable surface terminations, and strong interfacial interactions with semiconductors makes MXenes particularly attractive for enhancing CO_2RR efficiency and selectivity.

One of the most important roles of MXenes in photocatalytic CO_2 reduction is to facilitate charge separation and transport. When coupled with semiconductor photocatalysts, MXenes readily accept photogenerated electrons due to their favorable work function and high electrical conductivity. The formation of Schottky or Z-scheme heterojunctions at the MXene–semiconductor interface effectively suppresses electron–hole recombination and ensures the accumulation of electrons on the MXene surface, which is essential for driving the multi-electron CO_2 reduction process.

MXenes also play a critical role in CO_2 adsorption and activation. The exposed transition metal atoms on MXene surfaces, together with surface functional groups such as –O, –OH, and –F, provide abundant active sites for CO_2 binding. These sites promote charge transfer from the MXene to adsorbed CO_2 molecules, leading to the formation of activated intermediates (e.g., $*CO_2^-$, *COOH, or *OCHO). Such activation lowers the energy barrier for subsequent proton-coupled electron transfer steps and accelerates CO_2 conversion kinetics.3.3 H_2 production

Upon light irradiation, photogenerated electrons from the semiconductor are rapidly transferred to the MXene due to favorable band alignment and the formation of a Schottky junction at the interface. This interfacial charge transfer effectively suppresses electron–hole recombination, thereby prolonging charge carrier lifetimes and improving photocatalytic efficiency.In addition, MXenes act as active cocatalysts for HER by providing abundant surface-active sites for proton adsorption and reduction. Surface terminations such as –O, –OH, and –F significantly influence the hydrogen adsorption free energy, facilitating proton reduction and H_2 desorption. Certain MXenes, particularly Mo-based carbides, exhibit Pt-like HER activity, making them attractive low-cost alternatives to noble metal cocatalysts. Furthermore, MXenes enhance photocatalytic performance through their strong light absorption in the visible and near-infrared regions. This broad absorption can induce photothermal effects and promote hot-electron generation, which further accelerates HER kinetics under solar irradiation. MXenes also improve the structural stability of photocatalysts by mitigating photocorrosion, especially in sulfide-based systems.

3.4 N_2 fixation

Photocatalytic nitrogen fixation under ambient conditions represents a sustainable alternative to the energy-intensive Haber–Bosch process. Recently, MXenes, a family of two-dimensional transition metal carbides and nitrides with the general formula $M_{n+1}X_nT_x$, have attracted increasing attention as effective cocatalysts and promoters for photocatalytic N_2 fixation due to their unique electronic structure, surface chemistry, and conductivity.A key contribution of MXenes to nitrogen fixation lies in their ability to enhance N_2 adsorption and activation. The exposed transition metal sites on MXene surfaces, together with tunable surface terminations (–O, –OH, –F), facilitate strong interactions with N_2 molecules. These interactions

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weaken the N≡N triple bond, enabling the formation of activated intermediates such as $*N_2^-$ or $*NNH$, which are critical for subsequent proton-coupled electron transfer steps.

MXenes also function as efficient electron reservoirs and transport channels in photocatalytic systems. When coupled with semiconductor photocatalysts, photogenerated electrons are rapidly transferred to the MXene due to its metallic conductivity and favorable work function. This process suppresses charge carrier recombination and ensures the continuous supply of electrons required for the multi-electron nitrogen reduction reaction. The accumulation of electrons on MXene surfaces is particularly beneficial for stabilizing nitrogen-containing intermediates and promoting stepwise hydrogenation pathways.

4.0 Conclusion:-

MXenes have emerged as a versatile and powerful class of two-dimensional materials for enhancing photocatalytic processes, including pollutant degradation, CO_2 reduction, hydrogen production, and nitrogen fixation. Their unique combination of metallic conductivity, tunable surface terminations, large specific surface area, and strong interfacial interactions with semiconductors enables MXenes to function effectively as cocatalysts, electron mediators, and active reaction sites across diverse photocatalytic systems.

In photocatalytic degradation of pollutants, MXenes significantly improve charge separation and facilitate the generation of reactive oxygen species, leading to accelerated degradation kinetics and improved mineralization efficiency. For photocatalytic CO_2 reduction, MXenes promote efficient electron accumulation, CO_2 adsorption, and activation, thereby lowering reaction barriers and enabling tunable product selectivity toward value-added carbon-based fuels and chemicals. In hydrogen production, MXenes act as highly efficient cocatalysts for the hydrogen evolution reaction by providing abundant active sites and rapid electron transfer pathways, offering a promising alternative to noble-metal-based systems. Meanwhile, in photocatalytic nitrogen fixation, MXenes enhance N_2 adsorption and activation, stabilize key reaction intermediates, and suppress competing hydrogen evolution, resulting in improved ammonia yields under ambient conditions.

Despite these remarkable advantages, challenges such as MXene oxidation, restacking, limited intrinsic bandgap, and competition with side reactions still hinder their full potential. Future research should focus on rational interface engineering, surface termination control, compositional tuning, and the development of stable MXene-based heterostructures to further optimize activity, selectivity, and durability. Overall, MXenes represent a highly promising platform for the design of next-generation photocatalysts aimed at sustainable energy conversion and environmental remediation.

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Role of Digital Marketing in Sustainable Development

Dr. Sujata Chandrakant Patil,
Associate Professor (Commerce)
Head, Department of Business Administration,
Appasaheb Raghunathrao Bhaurao Garud Arts, Commerce & Science College,
Shendurni, Tal. Jamner, Dist. Jalgaon MS 424204
Mobile No. 9763946971 Email: patilsujatac1@gmail.com

Abstract:

*In today's interconnected world, **digital marketing** and **sustainable development** have become two major forces shaping global business and society. Digital marketing allows businesses to reach a global audience efficiently and can play a key role in achieving sustainable development goals.*

Role of Digital Marketing in Sustainable Development
1) *Promoting Sustainable Products and Practices*
2) *Reducing Environmental Footprint / **Impact***
3) *Empowering Small and Local Businesses*
4) *Driving Social Awareness and Behaviour Change*
5) ***Encouraging Responsible Consumer Behaviour***
6) ***Supporting Inclusive Economic Growth***
7) *Data-Driven Sustainability*
8) *Using Data for Sustainable Strategy*
9) *Raising Awareness and Education*
10) *Encouraging Responsible Consumer Behaviour **etc.***

Introduction:-

In today's interconnected world, **digital marketing** and **sustainable development** have become two major forces shaping global business and society. Digital marketing focuses on promoting products and services through digital channels, while sustainable development aims to meet current needs without compromising the future. Together, they create opportunities for ethical growth, environmental protection, and social inclusion.

What Is Sustainable Development? Development that meets the needs of the present without compromising the ability of future generations to meet their own needs — **Sustainable development** is built on three main pillars — environmental, social, and economic sustainability. Together, they create a powerful partnership — where businesses can grow responsibly, promote eco-friendly practices, and educate consumers about sustainability.

1. Environmental sustainability (protecting natural resources): protecting natural resources and reducing pollution.
2. Social sustainability (equity, inclusion, community wellbeing): promoting equity, education, and human rights.
3. Economic sustainability (long-term economic growth without harm to society or the environment): ensuring long-term economic growth without creating debt for future generations.

What Is Digital Marketing? Digital marketing uses digital technologies and online platforms to connect with consumers. Common channels include:

- Websites and blogs
- Social media (Instagram, TikTok, LinkedIn, etc.)

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- Search engines (SEO, SEM)
- Email marketing
- Online advertising and analytics tools

Digital marketing allows businesses to reach a global audience efficiently and at a lower cost than traditional marketing. It uses digital channels (social media, search engines, email, websites, etc.) to promote products, services, and brands.

Research Problem:

Digital marketingand Marketing Innovation is always essential for progress of the business firm and sustainable development. And it will be continue in today's competitive market situations. This Research would like to find out the Importance of change and Innovation in marketing for sustainable development. Forprogress of business and to find out the solution for retain it.

Key Words: Digital Marketing, sustainable development.

Objectives Of Study:

1) To know about the Digital Marketing and sustainable development concept
2) To understand role of emerging role of Digital Marketing in sustainable development.
3) To find out finding and solution to retain sustainable development Trends.

Research Methodology:

Research type – This is Descriptive type research. It is based on Secondary Data from different books, Journals, websites, articles etc. to satisfy the objectives of research paper.

Data Collection And Analysis:

For this study researcher used the secondary data such as different books, Journals, websites, articles etc.This study is conceptual in nature through the review ofvaluableliterature,journals,magazines,websourcesandreferringtopublications, qualitative results have been drawn out in theformoffindings&Suggestions.

Description:

The Connection between Digital Marketing and Sustainable Development:-

Digital marketing can play a key role in achieving sustainable development goals by:

1. **Promoting Sustainable Products and Lifestyles**: Brands can use online campaigns to raise awareness about eco-friendly products, recycling, renewable energy, and ethical consumption.
2. **Reducing Environmental Impact:** Digital marketing relies on virtual tools rather than printed materials, saving paper and reducing waste compared to traditional advertising.
3. **Empowering Local and Small Businesses**: Small enterprises can use digital marketing to reach customers globally, supporting inclusive economic growth.
4. **Raising Awareness for Social and Environmental Causes**: Non-profits and green organizations use digital campaigns to advocate for social justice, climate action, and community development.
5. **Data-Driven Sustainability:** Digital analytics help companies measure and improve their sustainability performance and marketing effectiveness.

Key Roles of Digital Marketing in Promoting Sustainable Development: Digital marketing combines marketing strategies with data analytics and technology to create targeted, interactive, and measurable campaigns.

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Main Types of Digital Marketing:

1. **Search Engine Optimization (SEO)**
   - The process of improving website visibility in search engines like Google.
   - Focuses on keywords, content quality, and backlinks.

2. **Content Marketing**
   - Creating and sharing valuable content (blogs, videos, infographics) to attract and retain customers.
   - Builds trust and authority.

3. **Social Media Marketing (SMM)**
   - Using social platforms like Instagram, Facebook, LinkedIn, and TikTok to connect with audiences, increase brand awareness, and drive sales.

4. **Email Marketing**
   - Sending personalized emails to nurture leads, share news, and build loyalty.

5. **Pay-Per-Click Advertising (PPC)**
   - Paid ads on search engines or social media platforms where businesses pay each time a user clicks.

6. **Affiliate Marketing**
   - Partnering with other individuals or companies to promote products and earn commissions for each sale generated.

7. **Influencer Marketing**
   - Collaborating with influencers to reach specific target audiences authentically.

8. **Mobile Marketing**
   - Marketing through smartphones via apps, SMS, or in-app advertising.

How Digital Marketing Supports Sustainable Development – Role of Digital Marketing to Support Sustainable Development:

Digital marketing plays a vital role in promoting and achieving sustainable development by connecting businesses, consumers, and communities in ways that encourage responsible consumption, environmental protection, and inclusive economic growth. Below is an overview of how digital marketing supports sustainability across economic, social, and environmental dimensions. Digital marketing helps to impower sustainable development by promoting sustainable practices, influencing consumer behaviour, and helping companies meet both their business and sustainability goals. It is also useful for raising awareness about environmental and social issues, fostering green consumerism, and enabling transparent communication about a company's commitment to sustainability. The field "sustainable digital marketing" is developing to reduce its own environmental footprint, through strategies like optimizing energy consumption in online ads and choosing eco-friendly suppliers.

1) Digital marketing helps businesses showcase eco-friendly and ethical products to a wide audience.It helps eco-conscious businesses reach target audiences more efficiently and cost-effectively.Brands use digital platforms to educate and influence consumer behaviour toward eco-friendly products, ethical consumption, and waste reduction. Brands can use online campaigns to educate consumers about sustainability. E.g. Companies advertising recyclable packaging or carbon-neutral production online.Campaigns that highlight carbon-neutral delivery or recyclable packaging.Promoting Sustainable Products and Practices includes: Search Engine Optimization (SEO) and paid ads highlight green products and services.E-

commerce platforms can display sustainability certifications and transparent sourcing information.Data-driven targeting ensures minimal waste in advertising resources.

2) Reducing Environmental Footprint/ **Impact**: Unlike traditional marketing (printing flyers, billboards, etc.), digital marketing uses fewer physical materials, reducing paper waste and pollution. Online campaigns also allow for targeted ads, minimizing resource wastage.Compared to traditional marketing (billboards, print, direct mail), digital marketing uses fewer physical resources.Analytics tools help target audiences efficiently, reducing wasted advertising spend and materials.Compared to traditional marketing (e.g., print, TV, billboards), digital marketing significantly reduces the carbon footprint:No need for printed materials, physical distribution, or excessive waste.Online meetings, webinars, and virtual events cut down travel emissions. Analytics tools allow for efficient resource use by tracking and optimizing campaigns.

3) Empowering Small and Local Businesses: Digital marketing provides equal access to global markets for small and medium enterprises (SMEs), fostering inclusive economic growth.Platforms like social media and e-commerce help rural artisans and local producers reach global consumers.

4) Driving Social Awareness and Behaviour Change: **Raising Awareness for Social and Environmental Causes.** Organizations and NGOs use digital marketing to advocate for climate action, gender equality, and social justice — aligning with the **UN Sustainable Development Goals (SDGs)**.Campaigns can raise awareness about climate change, fair trade, and social responsibility. Influencer marketing is used to spread sustainable lifestyle choices.

5) **Encouraging Responsible Consumer Behaviour:** Through storytelling, videos, and social media, marketers can inspire consumers to make sustainable choices — such as buying locally, reducing waste, and conserving energy.

6) **Supporting Inclusive Economic Growth:** Digital platforms enable **small and medium-sized enterprises (SMEs)**, including those in rural or developing regions, to access global markets. This supports **economic sustainability** by creating jobs and reducing inequality.

7) Data-Driven Sustainability: Analytics and AI help companies track the effectiveness of sustainability campaigns, consumer attitudes, and carbon impacts of their digital activities. Digital analytics help companies measure the impact of their sustainability initiatives and track consumer preferences, enabling better decision-making.

8) Using Data for Sustainable Strategy: Digital tools provide valuable analytics and consumer insights that help companies align their strategies with sustainability objectives: Tracking the impact of green campaigns, understanding audience sentiment about environmental issues, Measuring progress toward sustainability KPIs.

9) Raising Awareness and Education: Digital marketing enables organizations to educate audiences about sustainability issues — such as climate change, ethical consumption, and renewable energy — through:Social media campaigns highlighting eco-friendly practices.Content marketing (blogs, videos, infographics) that inform consumers about sustainable lifestyles.Influencer collaborations with advocates for green living.

10) Encouraging Responsible Consumer Behaviour:Digital marketing can influence social norms and consumer choices:Campaigns can frame sustainability as an aspirational lifestyle.Interactive platforms allow brands to engage consumers in sustainability challenges

or reward eco-friendly actions (e.g., recycling programs).Transparent storytelling builds trust and accountability.

11) Empowering Small and Local Businesses: Digital marketing provides equal opportunities for small enterprises and artisans to reach global audiences without large budgets:social media and online marketplaces support inclusive economic growth. Promoting locally made or fair-trade products encourages sustainable production and consumption.

Conclusion –

Digital marketing has revolutionized how businesses communicate and grow. It allows companies to reach the right audience, build meaningful relationships, and achieve measurable success. As technology continues to evolve, digital marketing will remain at the heart of modern business strategies — blending creativity, data, and innovation to shape the future of commerce. Digital marketing plays a **vital role in achieving sustainable development** by promoting awareness, encouraging responsible consumption, and empowering businesses to grow ethically. When used responsibly, it not only benefits companies but also contributes to environmental preservation, social inclusion, and economic resilience.In short, **digital marketing is not just a business tool — it's a catalyst for a more sustainable and equitable world.**

Digital Marketing and Sustainable Development are increasingly interconnected fields in today's economy. They relate and support one another, when guided by sustainable principles, can be a powerful tool for positive change. Digital marketing and sustainable development are deeply connected. When used responsibly, digital marketing can **educate consumers, promote green innovation, and support sustainable economic growth**. Companies that align marketing with sustainability not only protect the planet but also build stronger, more trusted relationships with their customers.

Findings: -

1. In the modern era, **digital marketing** and **sustainable development** have become key drivers of global progress.

2. Digital marketing plays a crucial role in advancing sustainable development by influencing how companies operate and how consumers behave.

3. Digital marketing helps businesses showcase eco-friendly and ethical products to a wide audience.

4. Digital marketing uses fewer physical materials, reducing paper waste and pollution.

5. Digital marketing is not just a business tool — it's a catalyst for a more sustainable and equitable world.

6. Digital Marketing and Sustainable Development are increasingly interconnected fields in today's economy.

Suggestions: -

Businesses must practice **transparent, ethical, and responsible digital communication**. To overcome the issues related to sustainable development, businesses must practice **ethical, transparent, and responsible digital marketing.**

Companies that align marketing with sustainability not only protect the planet but also build stronger, more trusted relationships with their customers.

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Scope of Inclusive Education in the New Education Policy- 2020

Mrunal Bapurao Pawar
Research Student,

Dr. N. H. Desale
Associate Professor,
Kisan Arts, Commerce, and Science College Parola, Dist. Jalgaon.
pawarmrunal5720@gmail.com

Abstract:

The aim of this research paper was to study the scope of Inclusive Education in the National Education Policy-2020. Being descriptive in nature, this research study followed primary and secondary data as source of information. The concept of inclusive education as cited in NEP 2020 provides students with equal opportunities for education, regardless of their birth, background or circumstances, and should put forward the policy of a method through which the holistic development of those students will take place. Inclusive education as expected in NEP-2020 does not only create classroom teaching which includes only the curriculum. It also helps in developing the behavioural, emotional and social skills of special children, so that the child can easily sit with other children and build a good environment for the whole society.

Key words: Inclusive Education, Equity, Social sections, Disabilities, Educational Rights.

Introduction:

With regard to education, Gandhiji meant the all-round and best development of the body, mind and soul of the child and man. Swami Vivekananda used to say that education is the expression of man's inner perfection. It becomes necessary to change the previous education policy and keep it as a new change in some way. Most importantly, in the changing global scenario, there was a need for changes in the existing education system to meet the requirements of the knowledge-based economy. There became a need for a new education policy to improve the quality in the field of education and to promote new techniques of innovation and research. To ensure the global reach of the Indian education system, changes in the education policy were necessary to adopt global standards of education and under this, the implementation of the new education policy. It is considered a historic act of courage and far-sightedness in the field of education. Dr. Ramesh Pokhriyal Nishank is congratulated in this context because he has reiterated the main points related to the education policy and said that there are many road maps for this policy in which inclusive education becomes a separate provision.

In the changing global environment, changes in the education policy were necessary to meet the needs of the knowledge-based economy and to ensure the accessibility of the Indian education system at the global level. This education policy aims to ensure inclusive and equitable quality education for all by 2030 and to promote lifelong education opportunities. The need for change in the education system in India was felt for a long time. However, this feeling became even stronger during the Covid-19 pandemic, when it was seen how students from disadvantaged groups had to face difficulties in getting education due to the online education system. According to the official document of the Government of India, the New Education Policy 2020 addresses several concerns related to primary, secondary, higher and technical education in the country. From removing the rigid divisions between arts and science, vocational and academic streams, it also focuses on improving assessment.

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A civilized society is built by the educated citizens of that country and all people have an important part in it. Getting education is the fundamental right of every child, which is very important for the progress, development and growth of the country. This is a framework for Divyang or children with special needs to go far ahead in the field of education, which is started through this medium. This research paper is an attempt in finding out the scope for Inclusive education in NEP-2020.

Objective of the Study:
1. To understand the concept of Inclusive Education.
2. To study the scope for inclusive education in NEP-2020.

Methodology:

Being descriptive in its nature, this research followed descriptive research design following primary and secondary source of data. The primary source used in this study was the structure of NEP-2020 published by the Government of India, while the secondary sources were published articles, research papers, newspaper articles, interviews, and texts. The data was analyzed by following review system and is interpreted in accordance to the objective of the study.

Meaning of Inclusive Education:

Inclusive education means including children from all sections of society in the mainstream and providing them equal opportunities for education. Thus, inclusion in education means that a normal student, a handicapped student and students of different nature should get the opportunity to receive normal education to fulfill special educational needs. In this, a normal student and a handicapped student receive education together in school. Earlier, inclusive education was conceived only for special students, but at present it is implemented for all students.

Meaning of Inclusive Education Inclusive education means to include children from all sections of society in the mainstream and provide them equal opportunities for education. Thus inclusion in education means to provide opportunities for a normal student, a handicapped student and students of different nature to receive normal education to fulfill special educational needs. In this, a normal student and a handicapped student receive education together in school. Earlier, inclusive education was conceived only for special students, but at present it is implemented for all students.

Standbeck and Standbeck define inclusive education as, 'An integrated school or system can be defined as a place that belongs to all, where everyone is accepted, where everyone contributes and cooperates with his or her school community and classmates to meet his or her educational needs.

According to Michael F, inclusive education refers to a set of values, theories, and practices that emphasize effective and meaningful instruction for all students, whether they are special or not.

Inclusive education is an educational approach that values diversity and promotes the inclusion of all students, regardless of their:
1. Abilities (physical, intellectual, emotional)
2. Disabilities (visible or invisible)
3. Language background

4. Cultural background
5. Socio-economic status
6. Gender identity
7. Sexual orientation

Key principles of inclusive education:
1. Acceptance and valuing of diversity
2. Equal opportunities for all students
3. Supportive learning environment
4. Accommodations and modifications to meet individual needs
5. Active participation and engagement
6. Collaboration among teachers, students, parents, and communities
7. Ongoing assessment and adaptation to meet changing needs.

Inclusive education is not a one-size-fits-all approach, but rather a continuous process of adaptation and growth, ensuring that all students can reach their full potential.

Historical Background of Inclusive Education:

While understanding the historical background of inclusive education, first of all it is very important to know the education system in ancient times. Exclusion method is used in ancient educational system viz. Suppose a person is physically handicapped or has any kind of deficiency, such a person was excluded from the society. That is, it meant that this group was completely isolated from educational and other opportunities or from the community. Therefore, educational policies aimed at bridging this kind of educational, social and psychological gap for all people or special groups especially for their integration to bring them into the mainstream.

The concept of inclusive education is a system of providing opportunities to students with disabilities to study alongside the general student. The concept of inclusive education as its used was actually introduced by the Kothari Commission in 1964-66 which recommended the inclusive education of students with disabilities with the general classes and students. Later this was to some extent reflected in the National Education Policy of 1986. The year 2000 was important for inclusive education in India. In this year, NCERT approved inclusive schooling in the National Curriculum Framework for School Education (2000). The concept of inclusive education and providing equal rights to education to all got strengthened by the Sarva Shiksha Abhiyan 2002. Under the Sarva Shiksha Abhiyan, provision was made to provide compulsory and quality primary education to all children aged 6-14 years by the year 2010. Accordingly, the Right to Compulsory and Free Education Act, 2009 and the Persons with Disabilities Act, 1995 enumerate seven types of disabilities. The Right of Persons with Disabilities Act, 2016 was subsequently introduced in the Lok Sabha to amend the law under the Center and increased the total number of persons with disabilities from seven to 21. The Act came into effect on 19 April 2017 across India. Therefore, due to inclusive education scheme, disabled children with special needs have started getting free admission in normal schools. No student with disabilities will be deprived of education, and if students with disabilities are educated along with normal children, they will not feel inferior and thereby facilitate their adjustment with the society.

In the last two to three decades of the 2020s, comprehensive education programs were developed for disabled children. In this context the Salamanca Conference 1994 proved to be a milestone. In this meeting, it was ensured that punishment for all i.e. children, youth and other

people with special needs should be given under the general punishment system. India was inspired to pass the Persons with Disabilities Act 1995.

Scope for Inclusive Education in NEP-2020:

It is with reference to the Kasturirangan Committee's (2019) recommendations; the National Education Policy-2020 has been brought into effect after 34 years of long span. As it covers all levels of areas of education, the policy is integrated within the four phases. Equitable and Inclusive Education covers school education. The NEP-2020 is in line with the Right of Person with Disabilities Act, 2016. As mentioned earlier that the number of disabilities have been increased to 21 in accordance to this act, NEP-2020 finds pathways in overcoming barriers in discrimination measures.

Education to All Sections:

The New Education Policy 2020 aims to ensure that no child is denied any opportunity to acquire knowledge or learn and excel because of circumstances related to his or her birth or background. According to paragraph 6.2 of the 2020, a number of factors, including poverty, social customs and practices, and language, affect enrolment and retention rates among Scheduled Castess, lack of access to quality schools. Therefore, one of its key features is to bridge these gaps in access, participation and access outcomes for SC children. It also acknowledges the importance of interventions to promote education of children from minority communities, and particularly those from communities that are educationally underrepresented.

Gender Equity:

Many provisions have been made in the new education policy to increase the participation of girls and women in education, due to which a Gender Inclusive Fund has been established in para. 6.8. It is to take girls to social parameters and household work. It has become necessary to identify the problems and obstacles in the way of girls' education through this. Gender Inclusive Fund will be made available to the states, which will help them in implementing such policies, schemes, programs etc. in which women can get a more safe and healthy environment in the school premises, such as setting up women's toilets in the campus, providing other facilities related to cleanliness and sanitation, making special provisions for coming and going to school, giving strong contribution to parents related to economic status so that they are not forced to leave school due to poverty. In this, women's enrollment will increase and women's awareness towards education will increase even more.

Education to Disabilities (Divyangjan):

Ensuring equal participation of disable children has been taken as a priority in the New Education Policy 2020. Divyang children have been enabled to participate in the teaching processes from the elementary level to the higher level. This policy is fully consistent with all the provisions of the Disability Rights Act 2016. While preparing the outline of the National Curriculum, NCERT has also consulted the National Institutes of the Department of Persons with Disabilities. Keeping in mind the integration of Divyang children, provisions have been made for financial assistance to school campuses and it has also been considered necessary to appoint specially trained teachers there. There is a provision to open resource centers for children with severe and more disabilities. To ensure their full participation and inclusion in the classroom, assistive devices, appropriate technology based devices, language, appropriate teaching material,

Braille script and accessible books, large print books are made available in sufficient quantity. Home based education has also been considered as an option for Divyang children.

Inclusive School Environment:

Principles of updating teachers' knowledge and skills through frequent training, opening alternative avenues for recruitment of teachers from educationally under-represented groups or disadvantaged groups have implications for student teacher ratio. This provision in NEP 2020 serves purpose of giving opportunities to teachers as well students who are disadvantaged in both social and educational background. (Para. 6.4)

Conclusion:

An analysis of the scope of inclusive education in the context of paragraphs 6 and 14 of the National Education Policy 2020 shows that the concept of inclusive education implemented by the National Education Policy 2020 envisages a goal through which children from all walks of life should learn and progress and have all learning opportunities must be made available in the real sector. Therefore, the concept of inclusive education as cited in NEP 2020 provides students with equal opportunities for education, regardless of their birth, background or circumstances, and should put forward the policy of a method through which the holistic development of those students will take place.

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An Analytical Study of Workplace Bullying and Harassment in the Education Sector in the Context of Sustainable Human Resource Management

MS. Jayshri Omprakash Verma
Research Scholar,

Dr. Prof. Shyam Jivan Salunkhe
Research Guide,
Department of Commerce and Management,
A. R. B. Garud College Shendurni, Dist. Jalgaon.
Email Id: jayshri.verma@gmail.com, Contact Number:9767447458

Abstract:

Bullying and harassment at work have become serious psychological threats that have an impact on long-term sustainability, organizational effectiveness, and employee well-being. Such damaging workplace practices compromise not only individual dignity but also institutional effectiveness and social sustainability in the education sector, where human capital is the fundamental resource. Sustainable Human Resource Management (SHRM) is a helpful and useful framework for dealing with workplace bullying because it places an emphasis on moral behaviour, long-term organizational development, and employee well-being.The occurrence, kind, and effects of workplace bullying and harassment at educational institutions are investigated analytically in this study, which also assesses the contribution of sustainable HRM practices to the management and prevention of these problems.Bullying and harassment at work have grown to be serious organizational issues, especially in the education sector where human resources are the most valuable resource. These unfavourable workplace practices have a negative impact on long-term sustainability, institutional efficacy, and employee well-being. Sustainable Human Resource Management (SHRM) is a significant framework for dealing with workplace bullying and harassment because it sets a high value emphasis on ethical employment practices, employee dignity, and long-term organizational development.The nature, occurrence, and effects of workplace bullying and harassment at educational institutions are examined analytically in this study, which also looks at how sustainable HRM practices might help prevent and handle these issues. The study emphasizes the important connection between bullying behaviours, employee well-being, and sustainable HR policies using a descriptive and analytical research methodology.

The results highlight the necessity of adopting SHRM concepts to support inclusive, sustainable, and healthy learning environments.

Keywords: Workplace Bullying, Harassment,EmployeeWell-being, Job satisfaction, Sustainable Human Resource Management, Education Sector

Introduction:

Employee well-being is becoming more widely acknowledged in the modern workplace as an essential component in determining company sustainability. In this regard, workplace harassment and bullying have drawn attention as major organizational problems that jeopardize ethical governance and social sustainability. Such difficulties also affect the education sector, which is fundamental to the advancement of society. Excessive workloads, hierarchical pressures, job insecurity, and interpersonal conflicts - which can take the shape in the manner of bullying and harassment - are common experiences for educators.

Social justice, ethical behaviour, and respectable working conditions are key components of sustainable development. By encouraging long-term employee well-being, moral leadership, and just organizational procedures improvement, Sustainable Human Resource Management

(SHRM) is consistent with these ideals. By fostering hostile work environments, raising stress levels, decreasing productivity, and increasing employee turnover, bullying and harassment directly conflict with the goals of SHRM. Therefore, it is both relevant and timely to examine workplace bullying within the context of SHRM, mainly in the district-level education sector.

Review of Literature:

Extensive research identifies workplace bullying as a persistent form of psychological violence characterized by power imbalance and repeated exposure to negative acts (Einarsen et al., 2011). Studies in the education sector reveal that teachers and academic staff are particularly vulnerable to bullying due to hierarchical structures, performance pressures, and job insecurity (Branch, Ramsay & Barker, 2013).

The diverse aspect of harassment - including sexual, verbal, psychological, and discriminatory harassmentis highlighted by research, and it has a negative effect on both organizational commitment and employee well-being. Bullying, according to academics, causes stress, burnout, absenteeism, and decreased teaching efficiency.Sustainable HRM literature emphasizes employee health, ethical leadership, and long-term human resource development (Ehnert, 2009). Kramar (2014) suggests that organizations adopting sustainable HR practices experience lower conflict levels and improved organizational climates. However, limited studies integrate workplace bullying explicitly with Sustainable HRM in the education sector, indicating a significant research gap that this study seeks to address.

Statement of Problem:

Bullying and harassment at work continue to exist at educational institutions despite institutional norms and legal frameworks. Anecdotal information point out that a large number of cases in Jalgaon District are unreported because of weak grievance redressal procedures, ignorance, and fear of reprisals. Employee psychological anguish, decreased job satisfaction, and waning organizational commitment are all consequences of the lack of sustainable HR policies. Thus, under the framework of Sustainable Human Resource Management, workplace bullying and harassment in the Jalgaon District's education sector must be methodically studied.

Objectives of the Study:
1. To find out the types and features of workplace bullying and harassment at work in the education sector.
2. To study how bullying at work affects workers' job satisfaction and general well-being.
3. To look into current HRM procedures for resolving grievances and employee wellbeing.
4. To examine how Sustainable Human Resource Management might help stop harassment and bullying at work.
5. To analyse recommendations on how to encourage ethical and sustainable work environments in educational establishments.

Research Hypotheses:

Null Hypothesis (Ho) and Alternate Hypothesis (H1)
1. Ho: There are no significant types and features of workplace bullying and harassment at work in education sector.
   H1: There are significant types and features of workplace bullying and harassment at work in education sector.
2. Ho:Bullying at work has no significant effects workers' job satisfaction and general well-being.

H1: Bullying at work has significant effects workers' job satisfaction and general well-being.

3. Ho: Current HRM procedures for resolving grievances and employee wellbeing are not effective.

   H1:Current HRM procedures for resolving grievances and employee wellbeing are effective.

4. Ho: Sustainable Human Resource Management is not of help stop harassment and bullying at work.

   H1: Sustainable Human Resource Management is of help stop harassment and bullying at work.

5. Ho: Ethical and sustainable work environments in educational establishments do not significantly reduce workplace bullying and harassment.

   H1: Ethical and sustainable work environments in educational establishments significantly reduce workplace bullying and harassment.

Research Methodology:

1. Research Design

The study applies descriptive and analytical research design to investigate the connections between sustainable HRM practices and workplace bullying.

2. Sources of Data

- **Primary Data:**Interviewsand structured questionnaires and with teaching and non-teaching staff.
- **Secondary Data:** Books, research journals, institutional reports, and policy documents.

3. Sampling:

A stratified sampling technique ensures representation across different categories of educational institutions and employee groups.

4. Tools for Data Analysis

- Percentage analysis
- Mean and standard deviation
- Chi-square test
- Correlation analysis

5. Data Analysis and Discussion:

According to the analysis, bullying and harassment in the workplace can take many different forms, such as verbal abuse, professional isolation from work, intrusive monitoring, and abuse of authority. Workers who are subjected to bullying report feeling more stressed, emotionally burned out, and less satisfied with their jobs. The results reveal that bullying is more common in organizations without sustainable HR practices, such as open grievance procedures and employee assistance programs. Reduced workplace bullying and sustainable HRM practices are significantly correlated, have a strong connection, according to statistical analysis.

6. Findings of the Study

- Bullying and harassment at work have an adverse effect on both psychological well-being and productivity.
- Bullying decreases employee retention, organizational commitment, and job satisfaction.
- Bullying practices continue due to of inadequate HR policies.
- A key component of building secure and moral workplaces is sustainable human resource management.

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7. Suggestions and Recommendations

- Comprehensive anti-bullying and anti-harassment policies should be developed and establish and enforced by educational institutions.
- It is crucial to establish transparent and confidential grievance redressal procedures.
- There should be frequent training sessions, program, workshop, seminars, courses, events, lessons on workplace dignity and ethical leadership.
- adoption of sustainable HRM techniques that prioritize long-term development and employee well-being.
- To guarantee efficacy, HR policies are continuously observed and updated.

Conclusion:

This study concludes that Sustainable Human Resource Management (SHRM) offers a comprehensive framework for addressing these issues by integrating ethical practices, employee welfare, and long-term organizational goals. Promoting sustainable HR practices is essential for building inclusive, healthy, and productive educational institutions. Bullying and harassment at work causesserious obstacles to employee well-being and institutional sustainability in the education sector.

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Infectious Disease COVID-19 and it's Fall out on Families in Dhule City

Dhairyashil V. Ahirrao and Ansari Sana Kausar,
Post Graduated Department of Zoology,
S. S. V. P. S. L. K. Dr. P. R. Ghogrey Science College Dhule, M.S. India.
Email ID :dv2ahirrao@gmail.com

Abstract:

Coronaviruses are a group of enveloped viruses with non-segmented, single-stranded and positive sense RNA genomes. In March 2020 the World Health Organization declared the SARS-Cov-2 virus a global pandemic. The human body is exposed to a variety of infectious microorganisms, such as viruses, bacteria, fungi, protozoa and helminths, which cause tissue damage through different mechanisms. Viruses are unique among these five types of infectious organisms in that they can manipulate the host-cell machinery in a unique way and continuously evolve to survive and prosper in all species.

The present study analyze the impact, spread and control measures of the COVID-19 pandemic in Dhule City (Maharashtra) and to understand the effectiveness of local health responses in managing the outbreak.

Key words: Coronavirus, SARS-Cov-2, Pandemic, Infectious, COVID-19, Dhule etc.

Introduction:

Coronaviridae is a family of viruses with a positive-sense RNA having an outer viral coat that can cause illness from mild common cold to acute respiratory tract infection. Under the electron microscope, a unique corona of peplomer proteins is observed around it (Akdeniz et al 2020; Alinia-Ahandani E and Sheydaei M. 2020). This family of viruses mainly causes respiratory diseases in humans in the form of respiratory infections, common cold/pneumonia and even death. These viruses have potential to infect animals basically (Keni et al, 2020), e.g. two (alpha (α) and beta (β) coronavirus infect mammals while remaining (gamma and delta coronavirus) are reported to cause infection in birds. Furthermore, six categories of coronaviruses are recognized that infect humans.

In 21st century, the appearance of SARS-CoV-2 have marked the introduction of highly pathogenic coronaviruses into the humans for the third time after severe acute respiratory syndrome coronavirus (SARS-CoV) and Middle East respiratory syndrome coronavirus (MERS-CoV) in 2004 and 2018 respectively (Babarinsa et al 2021). Novel coronavirus caused pneumonia, transformed to coronavirus disease 2019 (COVID-19) by WHO on February 11, 2020, a viral pneumonia as a result of extreme acute breathing syndrome coronavirus 2 (SARSCoV-2). Inhalation experience to respiratory droplets by coughing, sneezing[2] or an unsafe touch between the infected and healthy person (Fong et al 2021), can lead to the transmission of coronavirus from a gap of more than a few meters to room scale (Gormley et al 2020). The organ that is the most susceptible to be infected by coronavirus in human body is lung, because the virus has capability to joins up the alveolar cells by ACE2 enzyme using its spikes. Therefore, it is to be understood that the inactivity or reduced activity of ACE2 is considered to be protective.[2] By now it has been spread all over the World due to which it was declared to be a "pandemic" by WHO.[5] At present, the instances of COVID-19 have been determined in lots of nations across the ecosphere.

The present study discusses the impacts of the COVID-19 pandemic on families. It caused financial hardships for many families and increased stress for parents. The pandemic

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disrupted family routines and affected children's education. It also negatively impacted people's health and incomes.

Material and Method:

To study and analyse the impact, spread and control measures of the COVID-19 pandemic in Dhule City (Maharashtra), and to understand the effectiveness of local health responses in managing the outbreak. To assess the impact of covid-19 on social life of people, on health, human Behaviour and human learning, To study the impacts of lockdown on family, Relationship and financial condition of families.

Coronaviruses are members of the family. Coronaviridae order Nidovirales. These enveloped viruses possess genomes in the form of single-stranded RNA molecules of positive sense, that is, the same sense as the messenger RNA (mRNA). At present, four genera are known: Alphacoronavirus, Betacoronavirus,Gammacoronavirus,Deltacoronavirus. Members of the genera Alphacoronavirus and Betacoronavirus are identified to cause human disease, whereas those of the generaGammacoronavirus and Deltacoronavirus are causative agents of animal disease.

Coronavirus Structure

- Spike (S)
- Nucleocapsid (N)
- Membrane (M)
- Envelope (E)
- RNA viral genome
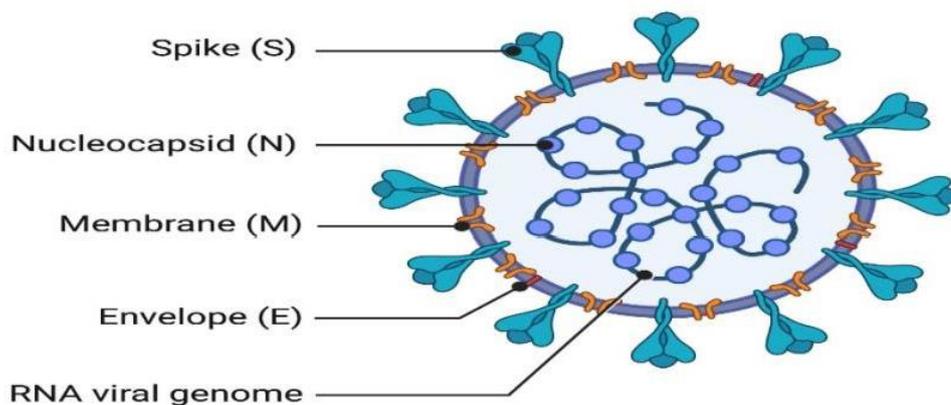
C

OVID-19 symptoms include:

- ▪ Cough
- ▪ Fever or chills
- ▪ Shortness of breath or difficulty breathing
- ▪ Muscle or body aches
- ▪ Sore throat
- ▪ Loss of taste or smell
- ▪ Diarrhea
- ▪ Headache
- ▪ Nausea or vomiting
- ▪ Congestion or runny nose

Some people infected with the coronavirus have mild COVID-19 illness and others have no symptoms at all. In some cases, however, COVID-19 can lead to respiratory failure, lasting lung and heart muscle damage, nervous system problems, kidney failure or death.

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Questionnaires for the survey:

- How do you feel when the first lockdown was announced?
- How COVID-19 affected your Income?
- Did you feel cutoff from your friends or relatives during lockdown?
- What life lesson has COVID-19 taught you?
- Did u lose any one of your near and dear one due to COVID-19?
- How did your daily routine and eating habits change during lockdown?
- Did you take any exercise during lockdown?
- Did you find online education effective for your child?
- What problems did your family face when all of you were combined to your home?
- How did you feel when your nobility outside the home is restricted?

Results and Discussion:

General problems families facing in COVID-19 lockdown:

The noble corona virus impact everyone some more drastically that others. Not only have individuals and family is having dealing with traits to their health from government 19 itself by trying to avoid and survive infection by their so many special meanings for primary for most families which participated in the survey it meant making big change in everyday routine due to financial closure schools and colleges dealing with current time or loss of family members.

In the first wave of covid19 finally social isolation, school/child care closure unemployment in stability are created unpredicted conditions. For families racing children at home shopping with new normal calendar for all. Lock down alters lifestyles and the disrupted enjoyment of living in a society.

For all most families locked on spend that many parents were unable to go to work due to temporary closure of their work places. School closed resulted in children mousing overnight distance learning. Many homestay in 2 over populated multifunctional pages 24/7 with both positive and negative impact on the relationship home is function sandals school office and leaving space parents for finding themselves in a blind.

The children who were act boarding school enjoy their pre-long the stay at home with family with their family members doing gardening and maintenance work around the house and helping young the sibling to manage their some children occasionally become frustrated with other siblings and become frustrated with other siblings and conflicts developed. About the third of the children reported of increase in anxiety and tension in relationship at home.

Psychological Impacts of COVID-19:

In response to COVID-19 pandemic, the first safety measure adopted was lockdown (LD) and quarantine policies (QP), which have caused a psychological distresses and social anxieties aggravating risk factors regarding mental health and psychological stability of almost each group of age. A comparative analysis of major psychological traumas e.g. mental disorders, anxiety, depression, fear, worries, stress, insomnia, reduced physical activity, weight gain and loss, variation in sleep and screening time, food intake and alcohol consumption in leading countries

Impact of COVID-19Lockdown on the Routine of families:

It has also been observed that COVID-19 pandemic influenced family routines, relationship's and technology use (smart phones and tablet computers) among families with school going children. As the pandemic dragged on and the burden of household and

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professional wonk continued to increase, parents were neglecting their normal daily routines. As a result, chidden followed the same haphazard habits and routines.

It had become especially difficult for parents to maintain a strict routine for the children, with fixed times for meals, studying and sleeping.

In the current situation parents were unable to restore Structure and as a result, children lost interest in anything and became aggressive. Yow group income families found it difficult do provide devices to their children for attending online classes. Way a time children failed to attend online classes resulting in learning losses.

Financial problem during COVID-19 pandemic:

Household income in India was drastically impacted due to the coronavirus (COVID-19) lockdown as of April 12, 2020 COVID-19 forced 30% of families into financial hardships and threw them. off their feet, impacting their ability, to pay the rent, buy groceries, pay bills, access needed healthcare services and see their way through a cruses About 30% families had to cut down their expenses as Come family members lost jobs or had their salaries slashed. 20% families forced from their relatives to take loans to borrow money daily for their daily expenditure. It was borrowing time for families living on rent as the landlords wanted went on time and Severed eviction notices to tenants who were unable to pay on time, the poor sections of society were worst it. The low income group, whose monthly income was less that is 15000 suffered the most due to such unplanned expanses as they did not have adequate saving to cope up and this pushed them into further financial crises. It has been observed that 30% of respondents from medium income group lost a job income due to Covid-19. Most of these job or income losses were due to being experiencing reduced work hours.

Conclusion:

The survey highlights that Dhule City effectively managed the COVID-19 crisis through strong community participation, public awareness, and government initiatives.

Despite challenges during the second wave, recovery rates were high, and vaccination drives proved successful. Continued vigilance, healthcare investment, and digital readiness are essential to combat future health emergencies.

The survey of COVID-19 in Dhule city reveals that the city experienced a severe initial outbreak, with a significantly higher fatality rate compared to the state average during the early phase of the pandemic. However, through consistent efforts in testing, containment, and vaccination, Dhule successfully reduced its active cases and eventually became one of the first cities in Maharashtra to be declared "COVID-free."

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Environmental Ethics and Moral Responsibility toward Future Generations

Dr. Datta Uttamrao Kuntewad

Head, Department of Economics,

D. G.Tatkare Arts and Commerce College, Tala, Raigad.

kdudatta@gmail.com

Abstract:

This paper explores the normative foundations of our obligations to future generations within the framework of environmental ethics. It examines the tension between current economic desires and the survival needs of future inhabitants of Earth. By analyzing key philosophical hurdles such as the Non-Identity Problem and the limitations of social contract theory, the paper argues for a transition from anthropocentric exploitation to an ecocentric "trusteeship" model. It concludes that intergenerational justice is a fundamental requirement of any coherent moral system in the Anthropocene.

1. Introduction: The Temporal Expansion of Ethics:

For most of human history, ethical systems were "spatial" and "present-bound." They governed interactions between people living at the same time in the same tribe or city. However, the 21st century has introduced a "crisis of presence." Our technological capacity to alter the climate, deplete aquifers, and leave radioactive waste for millennia has outpaced our traditional moral frameworks.

Environmental ethics asks us to consider "The Other" not just across a border, but across time. This paper argues that the absence of future persons from current political and economic decision-making is not a justification for their exclusion from moral consideration.

Objective of this research paper -

The objective of this research paper is to provide a comprehensive philosophical and ethical justification for the moral obligations that current human generations hold toward future, as-yet-unborn generations in the context of the environment.

Specifically, the paper aims to:

 * **Establish a Moral Framework:** To move beyond "present-bound" ethics by integrating traditional theories—Utilitarianism, Deontology, and Virtue Ethics—into a long-term model of intergenerational justice.

 * **Resolve Philosophical Paradoxes:** To address and provide solutions for complex conceptual hurdles, such as Derek Parfit's Non-Identity Problem and the "Problem of Asymmetry," which often complicate our ability to assign rights to non-existent persons.

 * **Evaluate Sustainability Models:** To distinguish between "Strong" and "Weak" sustainability, arguing that certain natural assets (biodiversity, climate stability) are irreplaceable and cannot be compensated for with man-made capital or technology.

 * **Advocate for a Paradigm Shift:** To propose a transition from Anthropocentrism (viewing nature solely as a resource for humans) to Ecocentrism or a "Trusteeship" model, where humans act as temporary stewards of the Earth's biological integrity.

 * **Bridging Theory and Practice:** To examine how abstract moral responsibilities can be implemented through legal and political mechanisms, such as the Precautionary Principle and the institutionalization of "guardians" for future generations.

In essence, the paper seeks to demonstrate that preserving a functional and diverse ecosystem is not an act of optional charity, but a fundamental requirement of justice and a prerequisite for any coherent moral system in the age of the Anthropocene.

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2. Ethical Theories as Foundations for Responsibility:

2.1 Utilitarianism: Maximizing Long-Term Well-being:

Utilitarianism posits that the right action is the one that maximizes "utility" (happiness or well-being). Total Utilitarianism suggests that if we can foresee that our actions will cause immense suffering to billions of future humans—regardless of when they live—we are morally obligated to prevent that suffering.

However, utilitarians face the challenge of "Social Discounting." Economists often discount the value of future benefits, arguing that a dollar today is worth more than a dollar in 100 years. Ethically, this is indefensible. As philosopher Parfit argues, "distance in time is like distance in space"; just because a person is far away (temporally or geographically) does not mean their suffering matters less.

2.2 Deontology: Duties and Future Rights:

Immanuel Kant's "Categorical Imperative" suggests we should act only according to rules that we would want to become universal laws. If we universalize the law "exhaust all resources for the pleasure of the current generation," the human race would perish. Thus, we have a "perfect duty" to sustain the conditions for human life.

2.3 Virtue Ethics: Becoming "Good Ancestors":

Virtue ethics focuses on the character of the agent. Instead of asking "What is the rule?", it asks "What kind of ancestor do I want to be?" A virtuous person practices temperance and stewardship. Jonas (1984) proposed the "Imperative of Responsibility," suggesting that the first duty of modern man is to ensure that there are "future humans" with a world that allows for authentic human life.

3. The Paradoxes of Future Ethics:

3.1 The Non-Identity Problem:

Perhaps the most significant challenge in environmental philosophy is Derek Parfit's Non-Identity Problem. It suggests that our current environmental policies actually determine which specific individuals will be born in the future.

If we choose a "Depletion Policy" (consuming all resources), the timing of conception for everyone in the future will shift. Consequently, different people will be born than if we had chosen a "Conservation Policy." Since the people born under the Depletion Policy would not have existed otherwise, can they say they were "harmed"?

Ethicists respond to this by moving from "Person-Affecting" ethics to "Impersonal" ethics. We have a duty not to specific "Johns" or "Marys" of the year 2150, but a duty to ensure that whoever exists has a certain standard of environmental quality.

3.2 The Problem of Asymmetry:

We have total power over the future, but they have no power over us. They cannot vote, they cannot boycott our products, and they cannot sue us. This power asymmetry creates a "Tyranny of the Present." Ethics serves as the only mechanism to provide a "voice" for the disenfranchised future.

4. Resource Justice and Sustainability:

4.1 Strong vs. Weak Sustainability:

- Weak Sustainability: Argues that we can deplete natural capital (forests, oil) as long as we replace it with man-made capital (technology, infrastructure).
- Strong Sustainability: Argues that certain natural assets (the ozone layer, biodiversity, stable climate) are irreplaceable. No amount of money can compensate a future generation for a planet that is biologically dead.

4.2 The Common Heritage of Mankind:

This legal and ethical principle suggests that certain global commons—the deep seabed, outer space, and the atmosphere—do not belong to any one generation. We are "usufructuary" tenants; we have the right to use the "fruits" of the earth but an obligation to pass on the "capital" unimpaired.

5. From Anthropocentrism to Ecocentrism:

Traditional ethics is often Anthropocentric (human-centered). We save the bees because they pollinate our crops. However, many argue that this worldview is what caused the crisis.

5.1 Biocentrism and Intrinsic Value:

Paul Taylor argues for "Biocentric Outlook," where every living thing has a "teleological center of life." If we recognize that a species has intrinsic value, our responsibility to future generations includes preserving the biological diversity of the world, not just the utilitarian resources.

5.2 Deep Ecology:

Arne Næss's "Deep Ecology" calls for a total shift in consciousness. It suggests that the "Self" is not just the individual, but the entire biosphere. Protecting the environment for future generations is, therefore, an act of self-preservation in the highest sense.

6. Implementation: Moral Responsibility in Practice:

6.1 The Precautionary Principle:

"In dubio pro natura" (when in doubt, side with nature). Given the complexity of ecosystems, we must assume that our interventions could have catastrophic long-term effects. Moral responsibility requires us to avoid "tipping points" (e.g., permafrost melting) even if the science is not 100% certain.

6.2 Legal Guardianship for the Future:

Some nations are beginning to codify these ethics. For example, the Welsh "Well-being of Future Generations Act" requires public bodies to consider the long-term impact of their decisions. This is the practical manifestation of moral responsibility.

7. Conclusion: The Stewardship Mandate:

Environmental ethics is the ultimate test of human morality. It requires us to care for someone we will never meet, who will never thank us, and whose existence depends on our self-restraint.

Our responsibility toward future generations is a "Trusteeship." We did not inherit the Earth from our ancestors; we borrowed it from our children. A failure to act on climate change and ecological collapse is not just a political failure; it is a fundamental breach of the intergenerational social contract. To be human is to be part of a lineage. To protect the environment is to honor that lineage and ensure that the "Great Chain of Being" remains unbroken.

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A Comprehensive Review on Future Plants for Human Welfare : Prospects for Food, Health, and Environmental Sustainability

Dr. Pradip P. Patil
Associate Professor, Department of Botany,
KVPS Kisan Arts, Commerce and Science College, Parola, Dist. Jalgaon (MS) India.
Email. patilpradip@yahoo.com

Abstract:

   Rapid population growth, climate change, depletion of natural resources, and rising health challenges demand innovative and sustainable solutions for human welfare. Plants have always been central to human survival by providing food, medicine, fiber, fuel, and ecological stability. In the future, certain groups of plants-referred to as future plants—are expected to play a crucial role in addressing food security, nutrition, healthcare, environmental sustainability, and industrial needs. This review highlights potential future plants, their significance, applications, and prospects for enhancing human welfare through scientific and biotechnological advancements.

Keywords: Future plants, human welfare, food security, medicinal plants, climate resilience, sustainability

Introduction:

   Plants have been fundamental to human civilization since prehistoric times, providing food, shelter, medicine, fuel, fiber, and cultural identity. Nearly all aspects of human welfare like nutrition, health, economy, and environmental stability are directly or indirectly dependent on plant resources. However, the twenty-first century is witnessing unprecedented global challenges, including rapid population growth, climate change, biodiversity loss, land degradation, water scarcity, malnutrition, and emerging diseases. These challenges demand a paradigm shift from dependence on a narrow range of conventional crops to the exploration, conservation, and utilization of future plants with high potential to support sustainable human welfare (FAO, 2019).

   Modern agriculture relies heavily on a limited number of species such as rice, wheat, and maize, which contribute the majority of global caloric intake. Such over-reliance increases vulnerability to climate extremes, pests, and diseases. In contrast, future plants include underutilized crops, climate-resilient species, medicinal and nutraceutical plants, halophytes, bioenergy crops, algae, and genetically improved varieties that can thrive under adverse environmental conditions while providing multiple benefits (National Research Council, 1996; Myers et al., 2017). These plants are often rich in nutrients, bioactive compounds, and adaptive traits, making them suitable for addressing food insecurity, hidden hunger, and health-related issues.

   The concept of future plants is closely aligned with sustainable development goals, particularly those related to zero hunger, good health and well-being, climate action, and life on land. Climate-resilient crops such as millets, sorghum and halophytes are gaining global attention due to their ability to grow in marginal environments with minimal inputs (IPCC, 2022). Similarly, medicinal and aromatic plants continue to serve as a backbone of traditional healthcare systems and are increasingly validated by modern pharmacological research (WHO, 2013). Nutraceutical plants bridge the gap between nutrition and medicine, contributing to preventive healthcare and improved quality of life.

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In addition to food and medicine, plants play a critical role in environmental sustainability. Fast-growing trees, grasses and aquatic plants contribute to carbon sequestration, soil conservation, phytoremediation, and ecosystem restoration. Bioenergy and industrial plants provide renewable alternatives to fossil fuels and synthetic materials, supporting a transition toward a bio-based economy (Tilman et al., 2009). Advances in plant biotechnology, including tissue culture, genetic engineering, and genome editing, further enhance the potential of future plants by improving yield, stress tolerance, and production of valuable metabolites.

Therefore, the identification and development of future plants is not only an agricultural concern but also multidisciplinary approach integrating botany, ecology, biotechnology, nutrition, medicine, and socio-economic planning. This review aims to provide a comprehensive overview of future plants for human welfare, highlighting their categories, significance, applications, and prospects in ensuring a sustainable and resilient future for humanity.

2. Criteria for Selection of Future Plants:

The identification and prioritization of future plants for human welfare require a systematic and multidisciplinary approach. These plants must possess attributes that enable them to address present and emerging challenges related to food security, health, environmental sustainability, and economic development (FAO, 2019; IPCC, 2022). The major criteria for selecting future plants are discussed below:

2.1 Nutritional and Health Value:

Future plants should possess high nutritional quality, including balanced proteins, essential amino acids, vitamins, minerals, dietary fiber, and health-promoting phytochemicals. Plants rich in antioxidants, omega fatty acids, micronutrients such as iron, zinc, and calcium are crucial for combating malnutrition and hidden hunger (Myers et al., 2017; Singh et al., 2020). Nutraceutical and functional food potential is therefore a key criterion in plant selection (WHO, 2013).

2.2 Medicinal and Therapeutic Potential:

Plants with potential medicinal value are important contributors for future use. Species producing secondary metabolites such as alkaloids, flavonoids, terpenoids, and phenolic compounds are valuable for pharmaceutical, herbal, and traditional medicine industries (WHO, 2013). Scientific validation of ethnobotanical knowledge further strengthens the selection of such plants (Fabricant & Farnsworth, 2001).

2.3 Climate Resilience and Stress Tolerance:

A crucial criterion for future plants is their ability to tolerate abiotic stresses such as drought, salinity, heat, cold, and flooding. Climate-resilient crops ensure stable productivity under changing climatic conditions and reduce the risk of crop failure (IPCC, 2022). Traits such as deep root systems, efficient water use efficiency, salt tolerance, and adaptive metabolism are highly desirable (Lobell et al., 2011).

2.4 Low Input Requirement and Resource Efficiency:

Future plants should require minimal inputs of water, fertilizers, and pesticides. Plants capable of growing under rainfed conditions, fixing atmospheric nitrogen, or utilizing poor soils are especially valuable for sustainable agriculture (Tilman et al., 2009). Resource-efficient crops help reduce environmental degradation and cultivation costs.

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2.5 Adaptability to Marginal and Degraded Lands:

Plants capable of growing on marginal, degraded, saline, alkaline or wastelands are essential for sustainable land use planning. Such plants enable productive utilization of unexploited lands and contribute to land restoration and rural livelihoods (National Research Council, 1996; FAO, 2019).

2.6 Multipurpose Utility:

An important feature of future plants is their multipurpose nature. A single plant species may serve as a source of food, fodder, medicine, fuel, fiber, timber, bioenergy, or industrial raw material. Multipurpose plants increase farming system resilience and economic returns (Singh et al., 2020).

2.7 Environmental and Ecological Benefits:

Future plants should provide ecosystem services such as carbon sequestration, soil conservation, nutrient cycling, biodiversity conservation, and phytoremediation. Plants contributing to climate change mitigation and ecological restoration are highly valuable for long-term human welfare (Tilman et al., 2009; IPCC, 2022).

2.8 Potential for Genetic Improvement and Biotechnology:

Plants that show potential for genetic enhancement through conventional breeding, tissue culture, genetic engineering, and genome editing are strong candidates for future development. Availability of genetic diversity, ease of propagation, and responsiveness to biotechnological tools are key considerations (FAO, 2019; Singh et al., 2020).

2.9 Socio-economic and Cultural Acceptability;:

The successful adoption of future plants depends on socio-economic feasibility and cultural acceptance. Ease of cultivation, traditional familiarity, market demand, value addition potential, and contribution to rural employment are essential criteria (National Research Council, 1996).

2.10 Conservation Status and Sustainability:

Future plants should be selected with due consideration to biodiversity conservation and sustainable use. Domestication of underutilized species, conservation of wild relatives, and sustainable harvesting practices ensure long-term availability without ecological damage (FAO, 2019; IPBES, 2019).

Collectively, these criteria ensure that future plants are biologically promising, environmentally sustainable, economically viable, and socially acceptable, thereby maximizing their contribution to human welfare.

3. Future Food Plants for Nutritional Security:

Ensuring nutritional security for the rapidly growing global population is one of the most critical challenges of the present century. Future food plants are those crop species that possess high nutritional value, adaptability to changing climatic conditions, and the ability to grow with limited inputs. These plants are essential for addressing food insecurity, malnutrition, and micronutrient deficiencies, particularly in developing countries (FAO, 2019; Myers et al., 2017).

3.1 Millets and Pseudo-cereals:

Millets are increasingly recognized as future food crops due to their exceptional nutritional profile and climate resilience. Crops such as finger millet (*Eleusine coracana*), pearl millet (*Pennisetum glaucum*), foxtail millet (*Setaria italica*), and little millet (*Panicum sumatrense*) are rich in dietary fiber, calcium, iron, zinc, and antioxidants. Finger millet contains

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significantly higher calcium levels than rice and wheat, making it valuable for bone health and prevention of osteoporosis (Saleh et al., 2013).

Pseudo-cereals like amaranth (*Amaranthus spp.*) are gluten-free and possess balanced amino acid profiles, including lysine, which is deficient in most cereals. These crops are gaining global importance due to their high protein content, adaptability to marginal environments, and potential to combat protein-energy malnutrition (Vega-Galvez et al., 2010; National Research Council, 1996).

3.2 Legumes and Protein-rich Plants:

Legumes play a vital role in future food systems as affordable and sustainable sources of plant-based protein. Pulses such as chickpea (*Cicer arietinum*), lentil (*Lens culinaris*), pigeon pea (*Cajanus cajan*), and mung bean (*Vigna radiata*) are rich in proteins, essential amino acids, dietary fiber, and micronutrients. In addition to their nutritional benefits, legumes improve soil fertility through biological nitrogen fixation, thereby enhancing sustainability of cropping systems (FAO, 2016).

Underutilized legumes like winged bean (*Psophocarpus tetragonolobus*) are particularly promising future crops, as almost all plant parts like seeds, pods, leaves, and tubers are edible and nutritionally rich. Such multipurpose protein crops are important for achieving sustainable nutrition security (Singh et al., 2020).

3.3 Biofortified and Functional Food Crops:

Biofortification is an effective strategy for improving the nutritional quality of staple crops through conventional breeding and biotechnology. Biofortified varieties of rice, wheat, maize, and millets enriched with iron, zinc, and provitamin A have shown significant potential in reducing micronutrient deficiencies, commonly referred to as hidden hunger (Bouis & Saltzman, 2017). Functional food crops containing health-promoting phytochemicals further contribute to disease prevention and improved public health.

3.4 Leafy Vegetables and Underutilized Greens:

Green leafy vegetables such as spinach (*Spinacia oleracea*), moringa (*Moringa oleifera*) and traditional leafy vegetables are rich sources of vitamins, minerals, antioxidants, and dietary fiber. Many indigenous leafy vegetables are climate-resilient, fast-growing, and require minimal inputs, making them ideal future foods for nutritional security (WHO, 2013).

3.5 Future Oilseed and Fat-rich Food Plants:

Oilseed crops with health-promoting fatty acid profiles are important future food plants. Crops such as camelina (*Camelina sativa*), perilla (*Perilla frutescens*), flaxseed (*Linum usitatissimum*), and moringa provide oils which rich in omega-3 and omega-6 fatty acids and which are beneficial for cardiovascular health. Diversification of oilseed sources enhances nutritional quality and reduces dependence on conventional oil crops (FAO, 2019).

Overall, future food plants for nutritional security emphasize dietary diversity, resilience, and sustainability. Integrating millets, pseudo-cereals, legumes, biofortified crops, leafy vegetables, and novel oilseeds into food systems can significantly improve human nutrition while ensuring environmental sustainability.

4. Medicinal and Nutraceutical Plants:

Medicinal plants have been integral to traditional healthcare systems and are increasingly important in modern medicine. Future medicinal plants include:

- *Withania somnifera* (Ashwagandha) – adaptogenic and immunomodulatory

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- *Curcuma longa* (Turmeric) – anti-inflammatory and antioxidant
- *Ocimum sanctum* (Tulsi) – antimicrobial and stress-relieving
- *Aloe vera* – wound healing and cosmetic applications

Advances in phytochemistry, biotechnology, and tissue culture are enhancing the production of bioactive compounds from these plants.

5. Climate-resilient and Stress-tolerant Plants:

5.1 Halophytes:

Halophytes such as *Salicornia*, *Atriplex*, and *Suaeda* can grow in saline soils and coastal areas, making them future crops for saline agriculture. They have applications in food, fodder, biofuel, and environmental restoration.

5.2 Drought-tolerant Plants:

Plants like sorghum, pearl millet, agave, and cactus pear (*Opuntia ficus-indica*) are important for dryland agriculture and water-scarce regions.

6. Plants for Environmental Sustainability:

6.1 Carbon Sequestration and Climate Mitigation:

Fast-growing trees and grasses such as bamboo and switchgrass (*Panicum virgatum*) contribute to carbon sequestration, soil conservation, and ecosystem restoration.

6.2 Phytoremediation Plants:

Plants like sunflower and mustard have the ability to absorb heavy metals and pollutants, offering eco-friendly solutions for environmental cleanup.

7. Bioenergy and Industrial Plants:

Bioenergy crops such as jatropha (*Jatropha curcas*), pongamia (*Pongamia pinnata*), sugarcane and algae are promising renewable energy sources. Industrial plants providing fibers, gums, resins, and biodegradable materials will reduce dependence on fossil fuels and synthetic products.

8. Role of Biotechnology in Developing Future Plants:

Plant biotechnology plays a pivotal role in the development of future plants by:

- Genetic improvement for yield and stress tolerance
- Tissue culture for rapid multiplication
- Metabolic engineering for enhanced secondary metabolites
- Genome editing for precise trait development

These approaches accelerate the domestication and improvement of underutilized plants.

Challenges and Future Prospects:

Despite the immense potential of future plants in enhancing human welfare, their large-scale adoption and integration into mainstream agriculture, healthcare, and industry face several scientific, socio-economic, and policy-related challenges. At the same time, emerging technologies, global awareness, and sustainability-driven policies offer promising future prospects.

9.1 Challenges:

9.1.1 Limited Research and Scientific Validation:

Many future plants, particularly underutilized and wild species, suffer from inadequate scientific research regarding their agronomy, genetics, nutritional composition, and medicinal

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efficacy. Lack of standardized data limits their acceptance in formal agricultural and healthcare systems (National Research Council, 1996; Singh et al., 2020).

9.1.2 Lack of Awareness and Acceptance:

Farmers and consumers often lack awareness about the nutritional, economic, and ecological benefits of future plants. Cultural preferences, dietary habits, and market-driven monoculture farming systems restrict diversification toward novel or traditional crops (FAO, 2019).

9.1.3 Market and Value Chain Constraints:

Poor market infrastructure, absence of assured procurement, limited processing facilities, and weak value chains discourage farmers from cultivating future crops. Many nutritionally rich crops such as millets and indigenous vegetables face price volatility and low commercial demand (FAO, 2016).

9.1.4 Policy and Institutional Gaps:

Agricultural policies and subsidy systems in many countries favor major staple crops, leaving future plants neglected. Insufficient policy support for research funding, seed systems insurance and minimum support prices acts as a major barrier to adoption (IPBES, 2019).

9.1.5 Conservation and Biodiversity Loss:

Several potential future plants are threatened by habitat destruction, overexploitation, and climate change. Loss of genetic diversity and wild relatives reduces options for future crop improvement and resilience (IPCC, 2022).

9.1.6 Technological and Biotechnological Limitations:

While biotechnology offers powerful tools, their application in underutilized crops is often limited due to lack of genomic resources, skilled manpower, and regulatory challenges associated with genetically modified organisms (FAO, 2019).

9.2 Future Prospects

9.2.1 Strengthening Research and Development:

Expanding multidisciplinary research involving botany, biotechnology, nutrition, pharmacology, and environmental science will unlock the full potential of future plants. Genomic studies, metabolomics, and agronomic trials can accelerate domestication and improvement (Singh et al., 2020).

9.2.2 Integration of Biotechnology and Genome Editing:

Advance biotechnological tools such as tissue culture, marker-assisted breeding and genome editing offers immense scope for improving yield, stress tolerance and nutritional quality of future plants while reducing breeding time (FAO, 2019).

9.2.3 Promotion of Climate-smart and Sustainable Agriculture:

Future plants are integral to climate-smart agriculture due to their resilience and low-input requirements. Integration of millets, legumes, halophytes, and agroforestry species can enhance farm sustainability and climate adaptation (IPCC, 2022).

9.2.4 Policy Support and Institutional Frameworks:

Supportive policies, including incentives for crop diversification, inclusion in public distribution systems, nutrition programs, and minimum support prices, can significantly enhance adoption. Global initiatives promoting sustainable diets and biodiversity-friendly agriculture further strengthen prospects (FAO, 2019; IPBES, 2019).

9.2.5 Value Addition, Processing, and Market Development:

Development of value-added products such as ready-to-eat foods, nutraceuticals, herbal medicines, and bio-based industrial products can enhance economic viability and consumer acceptance of future plants (FAO, 2016).

9.2.6 Conservation and Sustainable Utilization:

In situ and *ex situ* conservation of genetic resources, coupled with sustainable harvesting and domestication strategies, will ensure long-term availability of future plants. Community participation and integration of traditional knowledge are vital for conservation success (National Research Council, 1996).

Overall, addressing existing challenges through scientific innovation, policy support, market development, and public awareness will enable future plants to play a transformative role in ensuring food and nutritional security, environmental sustainability, and holistic human welfare.

10. Conclusion:

Plants have always been central to human survival and progress, and their importance is expected to increase manifold in the face of growing global challenges such as population explosion, climate change, environmental degradation, nutritional insecurity and emerging health concerns. This review highlights that future plants-including underutilized food crops, medicinal and nutraceutical plants, climate-resilient species, bioenergy crops, and environmentally beneficial plants hold immense promise for ensuring holistic human welfare.

Future food plants such as millets, pseudo-cereals, legumes, leafy vegetables, and biofortified crops can play a decisive role in achieving food and nutritional security by providing balanced nutrition while requiring fewer resources and exhibiting greater resilience to climatic stresses. Similarly, medicinal and nutraceutical plants bridge traditional knowledge and modern healthcare, offering affordable, plant-based solutions for disease prevention and management. Climate-resilient plants, halophytes, and drought-tolerant species expand agricultural possibilities in marginal and degraded lands, thereby promoting sustainable land use and rural livelihoods.

Beyond food and health, future plants contribute significantly to environmental sustainability through carbon sequestration, soil conservation, phytoremediation, and biodiversity conservation. Bioenergy and industrial plants further support the transition toward a green and bio-based economy by reducing dependence on fossil fuels and non-renewable resources. Importantly, advances in plant biotechnology, tissue culture, molecular breeding and genome editing have opened new avenues for rapid improvement, domestication, and large-scale utilization of future plants.

However, the successful integration of future plants into mainstream systems requires a concerted effort to overcome existing challenges related to research gaps, policy support, market development, conservation, and public awareness. Multidisciplinary research, supportive institutional frameworks, farmer participation, value-chain development, and integration of traditional knowledge with modern science are essential to realize their full potential.

In conclusion, future plants represent a sustainable pathway toward food security, improved health, environmental resilience, and socio-economic development. Strategic identification, conservation, and utilization of these plant resources will be critical in achieving the goals of sustainable development and ensuring a resilient and prosperous future for humanity.

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Mahatma Gandhi's Thought and Sustainable Business Practices with Corporate Environmental Responsibility

Dr. Gaurav Ganesh Mahajan
Assistant Professor, Department of Commerce,
PRHS's Arts Commerce and Science College, Dharangaon Dist. Jalgaon

Abstract:

Environmental degradation caused by industrial and corporate activities has emerged as a major global concern. While businesses increasingly adopt sustainability frameworks, ethical grounding remains weak in many corporate strategies. Mahatma Gandhi's philosophy, though articulated in a pre-industrial context, offers enduring ethical principles relevant to sustainable business and corporate environmental responsibility (CER). His ideas of truth, non-violence, simplicity, trusteeship, and swadeshi, provide an ethical foundation for sustainable business practices and Corporate Environmental Responsibility (CER). It connects Gandhian thought with modern corporate sustainability frameworks and demonstrates its relevance in guiding ethical, eco-friendly, and socially responsible business conduct.

Keywords: Gandhian thought, sustainable business, corporate environmental responsibility, trusteeship, environmental ethics

Introduction:

The rapid pace of industrialization and globalization has intensified environmental challenges such as climate change, pollution, depletion of natural resources, and loss of biodiversity. Corporations, as major economic actors, significantly influence environmental outcomes through their production processes, supply chains, and consumption patterns. In response, concepts such as Corporate Social Responsibility (CSR) and Corporate Environmental Responsibility (CER) have gained prominence. However, many corporate sustainability initiatives remain compliance-driven rather than ethically motivated.

Mahatma Gandhi emphasized that economic activity must be guided by moral values and social responsibility. He criticized unchecked industrial growth and materialism, arguing that development without ethics leads to social injustice and ecological imbalance. This research explores the relevance and application of Gandhian thought in shaping sustainable business practices and Corporate Environmental Responsibility (CER).

Conceptual Introduction:
A Philosophical Overview of Mahatma Gandhi:

Mahatma Gandhi's philosophy focused on: Truth (Satya), Non-violence (Ahimsa), Simplicity, Trusteeship, Swadeshi (Self-reliance).These principles emphasized ethical living, equality, welfare of all beings, and minimal exploitation of nature.

Sustainable Business Practices:

Sustainable business refers to business strategies that integrate economic growth with environmental preservation and social well-being. It aligns with the Triple Bottom Line (TBL) approach Profit, People, and Planet.

Corporate Environmental Responsibility (CER):

CER is a subset of Corporate Social Responsibility (CSR), focusing specifically on environmental stewardship. It involves companies proactively reducing environmental impacts through policies, practices, and technologies that protect natural resources and ecosystems.

Review of Literature:

Prabhu & Rao, (1996) stated the Gandhian Philosophy and Economic Thought in their study that Gandhi's economic ideas were grounded in ethics, simplicity, and social welfare. In *Hind Swaraj*, he critiqued modern industrial civilization for promoting excessive consumption and alienating humans from nature. Scholars have emphasized Gandhi's belief that wealth and resources should be used for the collective good rather than individual accumulation.

Elkington, (1997) focuses on **Sustainable Business Practices** and ethical governance in the study. Sustainable business practices focus on balancing economic growth with environmental protection and social well-being. Elkington's Triple Bottom Line framework People, Planet, and Profit has been widely used to evaluate corporate sustainability. Studies highlight that long-term business success increasingly depends on environmental stewardship and ethical governance.

Carroll, (1999) studied **Corporate Environmental Responsibility** (CER). CER refers to corporate accountability for minimizing environmental harm and promoting sustainable use of natural resources. Research indicates that firms integrating environmental responsibility into core strategies perform better in risk management and stakeholder trust.

Joseph, (2006) studied on **Gandhian Thought and Environmental Ethics** and stated that Environmental philosophers argue that Gandhi's principle of Ahimsa extends to ecological systems, emphasizing non-exploitation and coexistence with nature. His advocacy of simplicity and restraint aligns with contemporary sustainability discourse.

Research Methodology:

Research Design:

The study adopts a **qualitative and conceptual research design**, focusing on interpretative analysis of philosophical and academic literature.
Sources of Data

The research work Secondary Sources:

Selected writings and speeches of Mahatma Gandhi and Books, peer-reviewed journals, and research articles on sustainable business, environmental ethics, and corporate responsibility. Method of Analysis

A **descriptive analysis** approach is used to identify key Gandhian principles and examine their relevance to sustainable business practices and corporate environmental responsibility.

Objectives of the Study:
1. To analyze Mahatma Gandhi's philosophical ideas.
2. To examine the relationship between Gandhian thought and sustainable business practices.
3. To explore the applicability of Gandhian principles in strengthening corporate environmental responsibility.

Discussions:

Gandhian Principles and Sustainability

1. **Truth (Satya) and Corporate Transparency**

   Satya (Truth) is one of the fundamental principles of Mahatma Gandhi's philosophy and serves as the moral foundation of ethical conduct. When applied to the corporate context, the principle of Satya translates directly into **corporate transparency and ethical governance.** Corporate transparency involves open, accurate, and timely disclosure of information related

to a company's operations, financial performance, environmental impact, and social responsibilities. Truthful reporting of environmental performance is a core part of CER.

2. Non-violence (Ahimsa) and Environmental Protection

Ahimsa, or non-violence, forms the ethical foundation of Gandhian thought. Environmental degradation caused by corporate activities can be interpreted as indirect violence against ecosystems. Businesses guided by Ahimsa would prioritize pollution control, reduction of carbon emissions, and adoption of environmentally friendly technologies. In business, this translates to reducing pollution, sustainable sourcing and protection of biodiversity by avoiding harm to the environment.

3. Simplicity and Resource Efficiency

Gandhi's advocacy for simple living encourages businesses to adopt resource-efficient production, reduce waste, and minimize ecological footprints. Gandhi's emphasis on simple living and self-restraint challenges the modern consumerist model. Sustainable businesses inspired by this principle would focus on efficient resource utilization, waste minimization, and production of environmentally sustainable goods rather than promoting excessive consumption.

4. Trusteeship and Ethical Wealth Distribution

Gandhi's trusteeship model holds that wealth and natural resources should be used for the welfare of all. The concept of trusteeship is central to Gandhi's economic philosophy. Applied to modern corporations, trusteeship implies responsible management of natural resources, transparency, and accountability toward present and future generations. This principle directly supports the objectives of corporate environmental responsibility.

5. Swadeshi and Local Sustainability

Emphasizing local production and self-reliance, the Swadeshi principle encourages local sourcing. Swadeshi encourages the growth of **community-based and small-scale enterprises** that are closely connected to local ecosystems. This fosters ecological sensitivity, conservation of natural resources, and preservation of traditional knowledge and skills.

Sustainable Business Practices Inspired by Gandhian Thought:

1. Green Supply Chain Management:

Green supply chain management emphasizes the use of eco-friendly raw materials, ethical sourcing, and energy-efficient transportation. This approach reflects Gandhian values of **Ahimsa and trusteeship**, as it minimizes environmental harm and ensures responsible use of resources.

2. Circular Economy Models

Circular economy models focus on **reduce, reuse, and recycle**, which align closely with Gandhi's ideals of **simplicity and non-wasteful living**. This model promotes sustainable production and respects nature's limits.

3. Eco-Innovation and Green Technology

Eco-innovation involves developing products and processes that lower environmental impact through renewable energy, biodegradable materials, and clean manufacturing. This reflects Gandhi's vision of development that serves society without harming nature.

4. Environmental Management Systems (EMS)

Environmental Management Systems such as **ISO 14001** provide a structured framework to monitor, control, and improve environmental performance. These systems support Gandhian

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principles of **responsibility and transparency** by ensuring accountability in environmental practices.

Corporate Environmental Responsibility (CER): Gandhian Alignment:

1. Pollution Control and Carbon Management:

Pollution control and carbon management reflect Gandhi's principle of **Ahimsa (non-violence)** toward nature. Companies practicing CER invest in cleaner production processes, emission reduction strategies, and pollution abatement technologies to minimize environmental harm.

2. Resource Conservation:

Resource conservation is rooted in Gandhi's deep respect for nature and his emphasis on restraint. Businesses practicing CER work to reduce water consumption, improve energy efficiency, and manage waste sustainably.

3. Biodiversity and Ecosystem Protection:

Protection of biodiversity and ecosystems aligns with Gandhian values of non-violence and **trusteeship**. Initiatives such as habitat restoration, afforestation, and protection of flora and fauna reflect corporate responsibility toward preserving ecological balance.

4. Environmental Reporting and Accountability:

Environmental reporting and accountability embody Gandhi's principle of **Satya (truthfulness)**. Honest and transparent disclosure of environmental performance through sustainability reports builds stakeholder trust and ensures corporate accountability.

Challenges in Implementing Gandhian Sustainability:

➤ **Profit vs. Sustainability Trade-offs:** Modern businesses often focus on short-term profit maximization, which may conflict with Gandhian ideals of long-term environmental and social responsibility. Sustainable practices usually require higher initial investment and slower returns. This makes ethical sustainability less attractive in competitive markets.

➤ **Policy and Regulatory Gaps:** Inconsistent environmental policies and weak enforcement mechanisms hinder the adoption of Gandhian sustainability. Without strong regulatory support and incentives, corporations may treat sustainability as optional rather than essential. This limits widespread implementation of CER.

➤ **Low Consumer Awareness and Demand:** Limited awareness about sustainable products reduces consumer demand for environmentally responsible goods. Many consumers prioritize low cost over ethical considerations. As a result, businesses lack market-driven motivation to adopt Gandhian sustainability practices.

➤ **Globalized and Large-Scale Business Models:** Gandhian sustainability emphasizes simplicity, decentralization, and local self-reliance, which are difficult to implement in large, global corporations. Complex supply chains and mass production systems make ethical and localized sustainability challenging to achieve.

Policy and Managerial Implications:

1. Government Policies:

Governments play a crucial role in promoting Gandhian sustainability by offering **incentives for green technologies**, such as tax benefits and subsidies, which encourage businesses to adopt eco-friendly innovations. Strong **environmental regulations and standards** ensure corporate accountability and discourage environmentally harmful practices. Additionally, targeted **support for Small and Medium Enterprises (SMEs)**—through finance, training, and

technology access—helps them implement sustainable practices without compromising competitiveness.

2. Corporate Strategies:

Corporations must embed sustainability into their **core business strategy** rather than treating it as a peripheral activity. Conducting **regular environmental audits** enables firms to monitor environmental performance and identify areas for improvement. Active **stakeholder engagement**, including employees, customers, suppliers, and communities, fosters shared environmental goals and aligns business operations with Gandhian values of trusteeship and responsibility.

3. Educational Initiatives:

Educational institutions play a vital role by **integrating Gandhian philosophy and sustainability concepts into business education**, shaping ethically conscious future leaders. Teaching sustainability alongside ethics helps students understand the moral dimensions of business decisions. Such initiatives contribute to building a **cultural ethic of environmental responsibility**, encouraging long-term commitment to sustainable and value-driven business practices.

Conclusion:

Mahatma Gandhi's philosophical principles offer a rich ethical foundation for sustainable business practices and Corporate Environmental Responsibility (CER). By embracing non-violence, truth, simplicity, trusteeship, and Swadeshi, modern enterprises can enhance environmental stewardship, promote social equity, and achieve long-term economic success. Integrating Gandhian thought in corporate strategies not only supports sustainability but also encourages a more human and responsible form of capitalism.

In an era of escalating ecological crises, Gandhian philosophy remains highly relevant and can inspire businesses to adopt environmentally responsible practices that promote long-term social and ecological well-being.

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Contemporary Relevance of Vedic and Upanishadic Thoughts in Environmental Education for Sustainable Development

Dr. Vaishali Jagannath Korde

Asst. Professor,

Gangamai College of Education, Nagaon, Dhule

Email - vaishali.shirule@gmail.com

Abstract :

Environmental sustainability emphasizes natural resource conservation, biodiversity protection, and climate change mitigation. It is critical to maintaining ecological balance and ensuring the earth's regenerative capacity. This is one of the Pillars / Dimensions of Sustainable Development. Likewise to achieve the SDGs the principles of our Indian Knowledge System - Vedas and Upanishads offer profound ethical, spiritual, and ecological perspectives that remain highly relevant for contemporary environmental education. Environmental Education is the basic need for attaining the sustainable development. This paper explores Vedic and Upanishadic foundations for environmental ethics, need for sustainable development, Linking Ancient Wisdom with Contemporary Environmental Education, and Contemporary Applications and Global Relevance.

Key words : Environmental Sustainability, Environmental Education, Sustainable Development, Indian Knowledge System, Vedas, Upanishads, Contemporary Relevance

Introduction :

In the face of mounting ecological crises such as climate change, biodiversity loss, and pollution, environmental education has become essential to fostering sustainable development worldwide. While modern scientific frameworks provide tools for understanding and mitigating environmental decline, ancient Indian philosophical traditions—especially those found in the Vedas and Upanishads—offer profound ethical, spiritual, and ecological perspectives that remain highly relevant for contemporary environmental education. These texts emphasize the interconnectedness of life and nature, promoting values that align closely with sustainable development goals (SDGs), particularly those focused on quality education (SDG 4 - Quality Education – Ensure inclusive and equitable quality education and promote lifelong learning opportunities for all), climate action (SDG 13 - Climate Action – Take urgent action to combat climate change and its impacts), and life on land and water (SDG 14 - Life Below Water – Conserve and sustainably use the oceans, seas, and marine resources & SDG 15 - Life on Land – Protect, restore, and promote sustainable use of terrestrial ecosystems and biodiversity).

Objectives :

1. To search the Vedic and Upanishadic foundations for environmental ethics from IKS.
2. To study the need for sustainable development.
3. To find the relation between the ancient wisdom with contemporary environmental education.
4. To suggest the contemporary applications and global relevance.

Vedic Worldview: Nature as Sacred and Interconnected :

The Vedic literature, dating back several millennia, presents nature not merely as a resource, but as sacred and integrally connected to human life. Core concepts such as ṛta (cosmic order) reflect a worldview in which ecological balance is fundamental to universal harmony.

Natural elements like Earth (Pṛthivī), Water (Aap), Fire (Agni), Wind (Vāyu), and Sky (Aakash) are often personified as deities, underscoring their intrinsic value and agency.

A well-known Vedic sentiment that resonates with environmental reverence is:

"**माता भूमिः पुत्रो अहं पृथिव्याःl**" - Mātā Bhūmiḥ Putro Ahaṃ Pṛthivyāḥ

("The Earth is my mother; I am her son.")

This metaphor fosters deep ethical responsibility toward the planet, encouraging learners to view environmental protection as a moral duty rather than merely a scientific problem to solve.

Upanishadic Foundations for Environmental Ethics :

The Upanishads, philosophical treatises forming the culmination of Vedic thought, further deepen this ecological worldview by articulating the unity of all existence. Rather than seeing humans as separate from nature, they describe a cosmos where every being shares the same underlying reality (Brahman). This non-dualistic perspective supports a systems-oriented mindset—a key component of modern environmental education that emphasizes interdependence and ecological integrity.

A quintessential Upanishadic aphorism from the Maha Upanishad expresses a holistic vision of the world:

"**अयं निजः परो वेत्ति गणना लघुचेतसाम् ।**

उदारचरितानां तु वसुधैव कुटुम्बकम्॥"

- ayaṃ nijaḥ paro vetti gaṇanā laghucetasām

udāra-caritānāṃ tu vasudhaiva kuṭumbakam

("This is mine, that is another's—such discrimination is narrow-minded; for the magnanimous, the whole earth is one family.")

This concept of Vasudhaiva Kutumbakam encourages learners to cultivate global ecological consciousness, transcending narrow self-interest and fostering collaborative stewardship of the planet.

Another Upanishadic idea relevant to sustainability is found in the Isha Upanishad:

"**ईशा वास्यमिदं सर्वम्।**" - Iśā vāsyam idaṃ sarvam

("All this—whatever exists in this changing universe—should be covered by the Lord.")

This verse points to a reverential relationship with all existence, implicitly advocating a non-exploitative and respectful approach to nature—a foundation for lifelong environmental ethics.

Need for Sustainable Development :

Sustainable development is essential to ensure balanced progress that meets human needs while preserving the environment for future generations. Rapid industrialization, population growth, and excessive exploitation of natural resources have created serious ecological, economic, and social challenges. Sustainable development provides a long-term solution to these problems.

1. Conservation of Natural Resources - Natural resources such as water, forests, fossil fuels, and minerals are limited. Unsustainable use leads to depletion and scarcity. Sustainable development ensures responsible use and conservation of these resources so they remain available for future generations.

2. Environmental Protection - Uncontrolled development has resulted in pollution, deforestation, biodiversity loss, and climate change. Sustainable development promotes eco-

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friendly practices, renewable energy, and pollution control to protect ecosystems and maintain environmental balance.

3. Addressing Climate Change - Climate change poses a serious threat to human survival. Sustainable development encourages reduction of greenhouse gas emissions, adoption of clean energy, and climate-resilient practices to mitigate and adapt to climate change impacts.

4. Economic Stability and Long-Term Growth - Short-term economic gains often lead to long-term losses due to environmental damage. Sustainable development supports stable economic growth by promoting green industries, efficient technologies, and sustainable livelihoods.

5. Social Equity and Justice - Development should benefit all sections of society. Sustainable development emphasizes poverty reduction, gender equality, education, healthcare, and inclusive growth, ensuring fair distribution of resources and opportunities.

6. Improving Quality of Life - Access to clean air, safe water, nutritious food, and healthy living conditions enhances human well-being. Sustainable development improves quality of life while safeguarding health and safety.

7. Inter-generational Responsibility - The present generation has a moral responsibility to protect the environment and resources for future generations. Sustainable development ensures that today's progress does not become tomorrow's crisis.

8. Global Peace and Stability - Resource scarcity and environmental degradation can lead to conflicts and displacement. Sustainable development reduces such risks by promoting cooperation, resilience, and balanced growth.

The need for sustainable development arises from the urgent requirement to balance economic growth, environmental protection, and social well-being. It is the foundation for a secure, equitable, and prosperous future. Without sustainable development, progress becomes short-lived and destructive. Therefore, adopting sustainable development is not optional—it is essential for human survival and global harmony.

Linking Ancient Wisdom with Contemporary Environmental Education :
Environmental education today seeks not only to impart knowledge about ecological systems but also to instill values and attitudes that promote sustainability.
Vedic and Upanishadic perspectives contribute to this goal in several ways:
i. Ethical Grounding: Viewing the Earth as a mother and all beings as part of one family builds empathy and responsibility toward the environment, which can motivate sustainable behavior beyond compliance with laws or rules.
ii. Holistic Understanding: The Upanishadic emphasis on unity encourages learners to perceive ecological problems as interconnected, fostering systems thinking essential for addressing complex environmental challenges.
iii. Cultural Relevance: Integrating ancient ecological wisdom into contemporary curricula—such as Sanskrit course offerings on environment at universities—can bridge traditional knowledge with modern science, enriching students' worldview and promoting culturally grounded sustainability.
iv. Behavioral Change: The reverence for natural elements—seen in Vedic hymns honoring rivers and trees—aligns with modern conservation initiatives and supports behavior change toward protection of ecosystems and biodiversity.

Contemporary Applications and Global Relevance :
Today, Vedic and Upanishadic principles have found resonance beyond academia, influencing policy discourse and public education, especially in India. Leaders and educators increasingly reference ancient spiritual and ecological ideas—such as the ritualistic respect for

earth, water, sky, and biodiversity—to emphasize environmental stewardship in contemporary contexts.

Furthermore, core ideas like Vasudhaiva Kutumbakam have been invoked in international forums and educational programs to promote global solidarity toward sustainability, reflecting their universal applicability.

Conclusion :

The Vedic and Upanishadic worldview—rooted in sacred ecology, philosophical unity, and ethical responsibility—offers timeless insights for environmental education and sustainable development. By integrating this ancient wisdom with contemporary scientific knowledge, educators can foster a generation that not only understands ecological systems but also values and nurtures the natural world. Such integration enriches the ethical foundation of sustainability education and inspires action toward a just, resilient, and thriving planet.

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Stability Studies of Extemporaneous Preparation of Omeprazole Oral Solution

Mr. Harshad S. Deshpande

Department of Chemistry JET's Z.B. Patil College,
Dhule (Maharashtra) – Dhule-424002.

Dr. V.B. Jadhav

Department of Chemistry JET's Z.B. Patil College,
Dhule (Maharashtra) – Dhule-424002.

Abstract:

For the treatment of acidity related to gastrointestinal disorder proton pump inhibitor are widely prescribed. Where this disorder is due to various causes such as, overweight or obese, delayed emptying of the stomach, diseases of connective tissue, diet, lifestyle and certain medications. Due to all this reasons, it is used for all age patient. The PPI is available in the dosage forms like tablets, capsules, injections and novel dosage forms. Due to its significant instability, it is very less stable in liquid dosage form. As the world population is getting older, as well as considering the child. Requirement of the Oral suspension are getting increased, considering difficulty in swallowing. This is most suitable dosage form for hospitalised patient those are dependant on nasogastric tube for food administration. Liquide dosage form can be used to achieve various dose proportionate easily and will save wastage of drug to enhance greener chemistry. The most used gold standard drug is Omeprazole due to its very few side effects. This review is to evaluate various study conducted to demonstrate chemical stability of PPI in the liquid dosage form. Its degradation pathway, stabilisation technique and study methods used for omeprazole drug are discussed,to provide comprehensive understanding.

Keywords: Proton pump inhibitor, Liquid dosage form, Omeprazole, green chemistry, chemical stability.Oral suspension.

Introduction :

'Omeprazole' is well accepted proton pump inhibitor having huge demand in the market to treat GRED (Gastroesophageal reflux disease), gastric and duodenal ulcers, erosive esophagitis (1). Omeprazole is week base and due to its pKa value it will selectively accumulate in acidic which is essential for pharmacological action (2). But due to this property it becomes most unstable this drug in acidic and neutral condition and it will be degraded very fast before reaching to the site of absorption (3). Due to instability only its therapeutic effect was not reduced but it will form non harmful degradation product which is the major concern in the pharmaceutical chemistry (4).

Children represent a vulnerable group for whose treatment many medicines are not available in appropriate dosage form commercially.(5).Considoring difference in the pharmacokinetic data in the adult drug usage and paediatric drug usage data (6,7,8,9,10),paediatric dose can't be obtained by direct dividing of adult drug. While dividing adult oral dosage form such as tablet or capsule there are always a chance of inappropriate dose quantity. As children's & elderly person are unable to swallow a whole tablets or capsules, correct dose adjustment is difficult. Hence it is more suitable or convenient to use liquid oral dosage form such as solution or suspension.(11,12). However, when oral liquids are not available in that case, available oral dosage such as tablets or capsules are used to prepare oral suspension. Tablets are crushed in mortar by using pestle & obtained powder is dissolved in suitable liquid such as water or juice. Similarly capsules are opened and granules are dissolved.Study on different suspension formulation stability is performed by scientist, to evaluate safe usage period

Chemical Structure and stability characteristic of Omeprazole:

- IUPAC name: 6-methoxy-2-[(4-methoxy-3,5-dimethylpyridin-2-yl) methylsulfinyl]-1H-benzimidazole
- Molecular formula: $C_{17}H_{19}N_3O_3S$
- Molecular weight: 345.41606 g/mol
- Description: It is a crystalline powder with white to off-white color
- Solubility: Very slightly soluble in water, slightly soluble in isopropanol and acetone, while freely soluble in methanol and ethanol
- Category: Proton pump inhibitor.
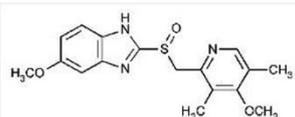
Figure 1: Chemical structure of Omeprazole

Omeprazole structure framework consist of benzimidazole ring linked to a pyridine moiety via a sulfoxide functional group (13). In this structure linkage of sulfoxide is more prone to chemical degradation (14).

The reactive groups such as pyridine nitrogen and sulfoxide group will give therapeutic effect due to intramolecular rearrangement and acted in vivo for enzyme inhibition. In acidic environment it will be degraded irreversibly during storage and formulation (15).

The stability of omeprazole is strongly interfered by the functional group reactivity and nature (16). Sulfoxide group is strongly susceptible to oxidative and reductive action to form the sulphide and or sulphone derivative (14). Imidazole is highly sensitive to acidic conditions and forms degradation which is irreversible intramolecular reaction which is result of protonation (17).

	R_1	R_2	R_3	R_4
Omeprazole/ esomeprazole	CH_3O	CH_3	CH_3O	CH_3
Lansoprazole	H	CH_3	CF_3CH_2O	H
Pantoprazole	CF_2HO	CH_3O	CH_3O	H
Rabeprazole	H	CH_3	$CH_3O(CH_2)_3O$	H

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Figure 2 : Mechanism of Activation and Irreversible Inhibition of Gastric H^+/K^+-ATPase by Proton Pump Inhibitors: Chemical Transformation, Intracellular Accumulation, and Enzyme Binding Pathway (18)

From the figure 1 it can be easily understood the chemical mechanism for the inhibition of gastric H^+/K^+-ATPase enzyme by all PPI including omeprazole. The figure is also useful in understanding hepatic metabolism, pharmacological efficacy, covalent binding and chemical changeability which les to chemical instability or degradation (18).

Factors Affecting stability:

pH: Considering highly sensitive to acidic environment omeprazole is stable in alkaline or neutral environment. In the acidic or even in neutral environment it will form irreversible degradation due to proton catalytic rection initiation (19).

Moisture: Hydrolytic reaction due to moisture resulted in degradation and proton pump mobility will be enhanced (20). Water accelerates the hydrolytic reaction hence stability of suspension will be hampered in suspension when water is used as vehicle.
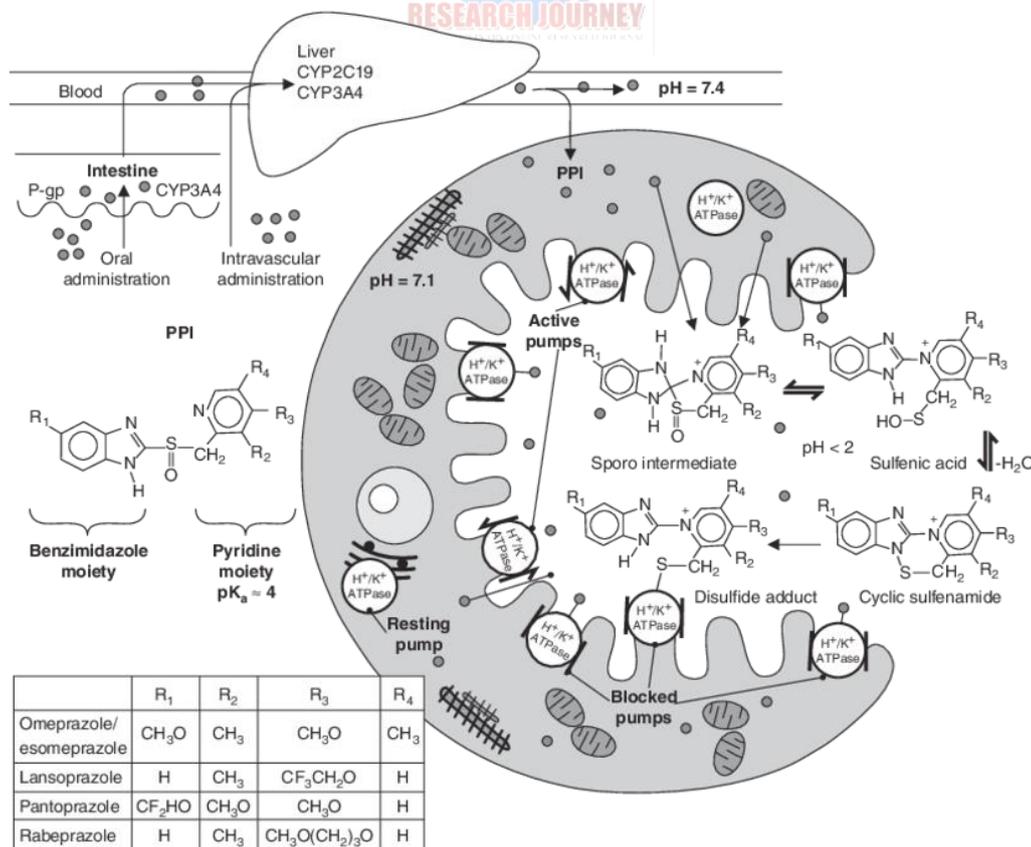
Temperature: Chemical reaction rate will be directly proportional to temperature, as temperature increases the reaction rate according to Arrhenius equation (21)

Need of suspension & its stability: Suspension stability is not evaluated by manufacturer as it isprepared in different formulations such as tablets & capsule for which stability study is conducted. But study in the suspension is not conducted by manufacturer. The dispersed drug in the vehicle will change its stability where drug & excipient will interact with vehicle and will be oxidised, degraded or there is increase in microbial load.

Chemical stability study:

During Stability study stability indicating test was verified for the prepared suspension inline to ICH Q1 A (R2) Stability testing of new drug substances and products. ICH Q1C Stability dosage for new dosage form.

The suspension is stored in two different temperature as 2-8°C Refrigerated condition & at 25°C as controlled room temperature. Testing is performed for the stability indicating parameter as Appearance, pH, viscosity and assay.The result wared reported and stability is determined.

In the Shelf life study of extemporaneously prepared omeprazole oral suspension' (5) Suspension is prepared as below

The 2 mg/ml suspension was prepared by emptying 10 capsules of omeprazole (20 mg) in mortar and grinding with 1 g of methyl cellulose and then stirring with sodium bicarbonate solution (8.4%) and making the volume up to 100 ml with the same solution.

This suspension is filled in two separate container. One container is stored in normal room condition (25±5°C) and another stored in refrigerator. 2°C to 8°C. Study was performed for 4 week period with the interval of 0, 7, 14, 21 & 28 days. Testing is performed for 2 parameters as appearance & % of omeprazole. % of omeprazole was determined by UV absorbance as λ_{max}at 301 nm.

The shelf life was estimated by extrapolating the graph up to the time when drug concentration will be reduced to 90% under different conditions of storage. Appearance is studied as physical properties as caking, re-dispersion behaviour, color change, or general appearance during the period of study. Problem of caking of suspension is resolved by including methyl cellulose in the formula(22)

The study concluded that The stability studies show that the preparation undergoes degradation when stored at room temperature and also in refrigerated condition. However, the data indicate that the preparation maintains the stability; up to 90% of initial value of drug content is available under both the storage conditions during the period of study. The rate of decomposition is slow in refrigerator as compared to room temperature, and therefore, it is recommended that these extemporaneous preparations should be stored in cool place at 2°C–8°C and can be safely used for up to one month even when stored at room temperature. Formulation and Stability Study of Omeprazole Oral Liquid Suspension for Pediatric Patients (23) Two formulation was prepared as below

Oral liquid suspensions of omeprazole were prepared at 2 mg/mL using crushed omeprazole pellets (formulation A) and pure omeprazole (formulation B) with a complete vehicle including humectant (Sorbitol 70 % & glycerin), suspending agent (Sodium carboxymethyl cellulose), sweetening (Sodium saccharin), antioxidant (Sodium bisulfite), and flavoring agents (Mint essence) Vehicle is used as Sodium bicarbonate solution 8.4% which also act as Ph regulator.

Both formulation (Formulation A & formulation B) is stored in amber glass vial at two different storage condition as 25°C & refrigerated 4°C. The formulation is tested at interval of 0, 3, 7, 14, 30, 60, 90, 120 & 150 days for appearance, test, pH, suspensibility, viscosity and content of omeprazole. Microbiological studies were conducted according to the United Stated Pharmacopeia (USP).

After studies result is concluded as Formulation A and formulation B can be stored for at least 150 and 90 days, respectively, at refrigerated conditions. Formulation A can be stored at room temperature for 14 days. Both formulations are perfectly suitable for pediatric patients who are usually notable to swallow solid oral formulations.
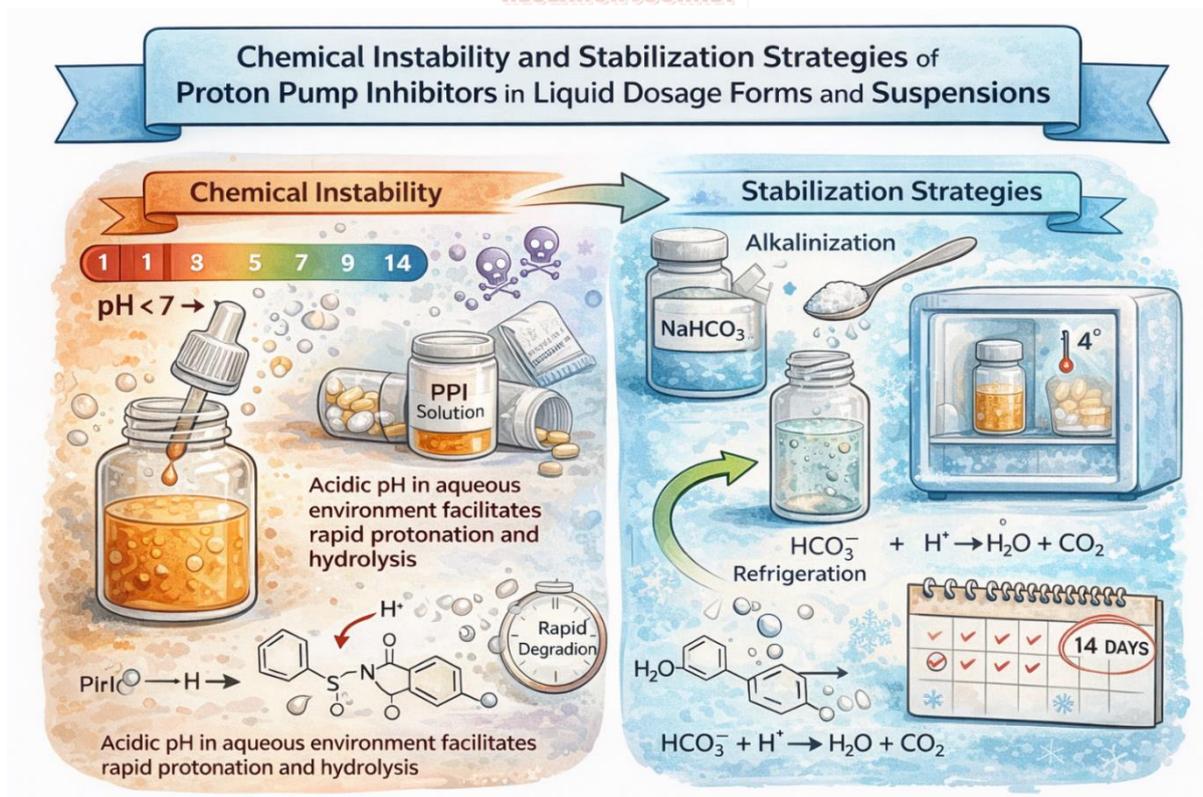

Chemical Instability and Stabilization Strategies of Proton Pump Inhibitors in Liquid Dosage Forms and Suspensions

Figure 3: Chemical stabilisation of Omeprazole in suspension by different additives and incising pH of suspension

Conclusion:

The Chemical stability ofomeprazole is mostly depends on the environmental factors such as pH, moisture and temperature. The high requirement of liquid suspension is due its dose proportionate flexibility, avoiding wastage and availability to target patient such as elderly people, children's and hospitalised patient who has difficulty in swallowing. Liquid dosage form has poor stability due to its hydrolytic and acidic nature. The shelf life of suspension can be increased by using process such as refrigeration, alkalisation and protection from light.

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Portrayal of Human Values in Dr. Deepak Chaudhari's Short Stories Collection 'The Right Hand and Other Stories'

Mr. Pramod Prakash Patil

Research Student,

(KBCNorth Maharashtra University, Jalgaon)

Centre: SSVPS's NS Patil Arts and MFMA Com. College, Dhule.

Contact: 7201876384.   Email:pramod2009.1987@gmail.com

Introduction:

Dr. Deepak S. Chaudhari is an emerging English authorof Khandesh, (North Maharashtra), India, working as Professor and Head Department of English in well reputed college SSVPS Arts & Com. College Dhule. He has published his 7th short story book '***The Right And Other Stories'***in May, 2023. Simple and regional style of narrative, picturisation of common man, genuine projection of country side etc. are the characteristics of his stories. One can observe the real life experiences in his stories. Mr. Chaudhari has observed the rural area and common life style of Maharashtrian life.This period was very life taking for everyone who has witnessed how everyone was suffering for basic needs.Dr. Chaudhari has observed the life of common man of his surrounding and presented in his books. Present short story volume gives us an idea about the rural life, their believes and how they people are trapped into the blind beliefs of society.There are so many blind beliefs in our society, still after the development of medical and scientific research.Many of the people in villages are believing on the witches, ghost, and other supernatural elements. The present research paper aims to focus on the Portrayal of Human values in Dr. Deepak Chaudhari's Short Stories collection 'The Right Hand and Other Stories'

His first story ***Shevantha*** talks about the same issue. The present story deals with the superstitious nature of the villagers. Akka, the young married village girl was suffering from the infection of the poison of the poisonous snake. She touched the bowl unknowingly which was stung by the poisonous snake. It made her the wound at the right thumb. Akka's in-laws sent her to her parent's house for the treatment. But her relatives assured that she was haunted by the spirit of her neighbouring woman Shewanta at her parent's house as she was invited for the Manes' Feast at Shewanta's house soon after her marriage. Instead of the medicinal treatment, Akka's parents were applying the home remedies as they were told and suggested by their neighbours. Akka's mother worshipped and prayed the idol of Shewanta which was placed under the huge, old tamarind tree on the bank of the brook and begged mercy for her daughter's welfare. After worshipping the idol, Akka got relief from her pain. Her mother repented over for delaying of worshipping Shewanta.

The Right Hand is the story of the poor and helpless college student Manish who was trapped into the addiction of masturbating his friends for earning money. It was a good income source for Manish when he was living in Pune. He was living in Pune for his education due to the healing poverty; he couldn't demand money from his parents, so he turned towards such a unnatural deed. He was pursued for such deed by his friend Nachiket for earning money. Manish was getting his charges for this work. Due to the continuous exertion, his right hand was aching and turned workless. Manish didn't earn more than lakhs rupees, but he has to spend more than lakhs for the operation of his workless right hand.

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Shri Swami Samarth is the story of the middle aged couple Shankar and Ashwini who were deprived of having a child after 23 years of their marriage. After spending more than 20 lakhs for the treatment for conceiving a child, triplets (three children) entered their house. Ashwini was of the view that it was only the grace of Lord Shri Swami Samarth whom she ardently worshipped since her childhood. Though the children were born due to the Test Tube Baby treatment spending a lot, Ashwini's mother-in-law also agreed that Lord Shri Swami Samarth entered their house in the form of the newly entered triplets. Shankar wasn't ready to accept the truth as he had spent lakhs of rupees, but he accepted the truth for the devotion of his wife and mother.

His third story **The Beggars Never Marry!** deals with the healing and pathetic love story of the beggar Dinya and a college girl Sonali. The beggar was the billionaire, has earned a lot from begging. He was in love with Sonali, spent a lot on her. Offered her the heavy, costly gold necklace and various delicious gifts also. Sonali also loved him, but when the beggar proposed her for marriage; she refused him thinking of his residence and his profession. She grasped the gold necklace given by the beggar. The beggar promised her to offer his entire saving which he had saved in the bank if she marries him, but Sonali's parents didn't allow her to marry with the beggar, as the society is of the view that the beggars never marry due to their unpredictable residence. She preferred the poor fellow for marriage rejecting the billionaire beggar.

A *Gift of God is* the comic story of the old, village fellow, Dhondiba, who was an intensive tea taker, he was of the view that he takes only a cup of tea in a day, but he was taking it as per his demand, it turned into five to six cups or sometimes more than it, in a day. Few years later, it caused him diabetes and suffered with gangrene in the wound at his left leg. The doctor warned him to cut off his leg for preventing the gangrene. Dhondiba was helpless in front of his addiction and desired to have a cup of tea. Dhondiba stands for the every village folk who are unaware of the approaching calamity due to the addiction of a cup of tea. Though Dhondiba was suffering of it, it made no difference for him. He ordered his wife to prepare a cup of tea.

The present story **I Should have More Hair!** deals with the workless young fellow Ravya, who got the new earning source by selling the waste, useless and scattered hair. Ravya was lonely young fellow to earn for the family, but he expected the service with more salary or the work with heavy wage, so he was avoiding for going the work. His wife Seeta and mother were working in the farm, whereas, he was passing time and sleeping in the house the entire day. He got the new idea of selling the hair and started collecting the hair from the surrounding villages. Colleting the hair near the saloons, shaved hair of the head shave ceremonies near the wells, brooks, rivers and under the trees of his own and the surrounding villages as well as cities has turned his routine. He was washing and selling the same hair in the city and getting his earning.

His another story **The Gold Ring** is about the suffering of the poor village fellow Chandu Anna for the survival of his family and the torturing of the demand of ten *tolas* gold ring from the in-laws of his elder daughter Reeta. Chandu Anna doesn't have any work. He was searching gold in the graveyards and in the open drainages out of the city. Many a times, he has to return with empty handed as due the growing rate of the gold, people used to give golden ornament less than a gram or half of a gram, or sometimes, less than it. Reeta was blaming her father for not completing the wish of her in-laws and her long stay at her parent's house. She was well acquainted with the healing poverty and helplessness of her father of getting gold in the grave, but she was also helpless in front of the demand of her in-laws. It caused the long stay of Reeta

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at her parent's house. Her father was unable to give the gold ring of ten tolas to his daughter's in-laws.

An Ambulance Man is very heart touching story of an old man.The present story is based upon the need of the organs donation as well as the mindset of the village folks about it. The old fellow Atmaram Dajbhao decided to donate his body to the government hospital as he was well aware of the need of the organs donation. He prepared his 'Will' before few months ago of his death discussing with his lonely, educated, engineer son, Raavsaheb. But, the villagers accused Raavsaheb that being an engineer; he did it for saving the excess expenses for the rituals of his father. Poor Raavsaheb! He was most flawless and tried a lot to convince the people that he did it only for his father's 'Will', but the villagers gave him the blot as 'An Ambulance Man' which turned his identity for decades. He was known as 'An Ambulance Man', not only in the entire village and surrounding villages, but amongst his relatives also.

Mangal, a story deals with the superstitious nature of the well educated family who ruined the life of their well educated and clever daughter Mangal. Her father Kalu Aba was so greedy, that he wanted to earn money from the marriage of Mangal from the groom's family which caused the delay in her marriage. After crossing her thirty five, Mangal married, but due to the ever ending demands of her father from her husband, she was discarded by her in-laws very soon after her marriage. She got the notice from her in-laws for divorce after the waiting of five years. The clever and well educated Mangal got divorce from her in-laws due the greedy and obstinate nature of her father, but the innocent and flawless planet Lord Mangal (Mars) was accused for it. As Lord Mangal (Mars) is blamed for delaying the marriage of the young folks in Indian culture, as usual, it was also accused for the mishap with unfortunate, simple, innocent and well educated Mangal.

Conclusion:-

Dr. Chaudhari has closely observed the human problems in the society and wrotehisstories with theobservation. Every story is highest expression of human inner feeling. His narrative technic is more effective. His every word Directly connect to his readers. In fact the way he has touched the issues of our society is really appreciable. All the stories are very fine to read and give social message. He also has focused how human values are degrading from our so called modern society. It the need of human being and society to make it improve and establish a better social circumstanced for our future generations.

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Technology-Enabled Hospital Management Approaches for Enhancing Administrative Decision-Making and Financial Performance

Shriraj Bhanudas Dere[1]
Research Student
Sandip University, Nashik
shriraj.mns@gmail.com

Dr. Samadhan Bundhe[2]
Research Guide
Sandip University, Nashik
samadhan.bundhe@sandipuniversity.edu.in

Abstract :

The rapid digital transformation of healthcare organizations has significantly reshaped hospital management practices, particularly in administrative decision-making and financial performance.

The objectives of the study were to examine the extent to which digital technologies such as electronic health records, analytics platforms, and decision support systems have been adopted and integrated into hospital management processes, and to analyse their combined influence on administrative decision-making effectiveness. The study also aimed to assess the impact of technology-enabled hospital management approaches on financial performance in terms of cost efficiency, revenue management, and resource optimization. In addition, it sought to evaluate the economic and managerial value of technology investments by examining cost–benefit outcomes and strategic returns across different hospital settings. Finally, the research aimed to identify organisational, technological, and system integration challenges that influence the effective use of digital technologies and their implications for long-term managerial effectiveness and financial sustainability. A quantitative research design was employed using descriptive and exploratory approaches. Primary data were collected through a structured questionnaire administered to 300 hospital management professionals across public, private, trust-based, and corporate hospitals. The findings indicated that hospitals had substantially progressed in adopting digital management systems, which positively influenced decision quality, timeliness, coordination, and managerial efficiency. The study also revealed that technology-enabled management approaches contributed to improved cost efficiency, revenue management, and resource utilization, thereby enhancing financial sustainability. Organizational readiness emerged as a critical factor affecting the successful utilization of digital systems. Overall, the results supported the hypothesis that technology-enabled hospital management approaches have a significant positive impact on administrative decision-making effectiveness and financial performance. The study contributes to the existing literature by providing an integrated managerial and financial perspective on digital transformation in hospital management and offers practical implications for hospital administrators and policymakers.

Keywords: Technology-enabled hospital management, Administrative decision-making, Financial performance; Digital transformation, Organizational readiness

1. Introduction

The increasing adoption of digital technologies in hospitals has generated measurable changes in administrative efficiency and financial performance, making technology-enabled hospital management a critical area of realistic investigation. Hospitals operate under growing pressure to control costs, improve service delivery, and ensure regulatory compliance, all of which demand data-driven managerial decision-making. Hospital information systems, integrated digital platforms, and analytics tools significantly enhance administrators' ability to monitor operational indicators such as patient flow, resource utilization, and revenue cycles (Malhan et al., 2024).

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Quantitative evidence further suggests that digital transformation initiatives improve cost performance by reducing process redundancies and enabling real-time financial oversight (Stoumpos et al., 2023). Hospitals with higher levels of technology integration report better coordination between administrative and clinical units, leading to improved financial sustainability and operational outcomes (Boonstra & Broekhuis, 2010). Despite these documented benefits, variations in implementation effectiveness highlight the need for empirical studies that examine how technology-enabled management practices influence administrative decision-making quality and financial performance in hospital settings.

Technological Transformation in Hospital Management:

The healthcare sector is undergoing rapid transformation driven by advancements in digital technologies and increasing pressure to deliver high-quality care while maintaining financial sustainability. Hospitals today operate in complex environments characterized by rising operational costs, regulatory compliance demands, and growing patient expectations. To address these challenges, healthcare organizations are increasingly adopting technology-enabled management systems to improve administrative efficiency and strategic decision-making. The internet, digital technology, and their relationship to novel treatments and best practices for improved health management procedures are all part of the digital transformation of healthcare. Both lowering service costs and enhancing patient well-being can be achieved through quality management of vast amounts of data. Medical education will be impacted by digital technologies, and professionals will devise new methods of instruction (Stoumpos, A. I., Kitsios, F., & Talias, M. A., 2023).

The Figure 1 shows key trends in digital transformation in healthcare. Telemedicine has the highest adoption, highlighting the growing importance of remote healthcare services. Artificial intelligence is widely used to support diagnostics and decision-making. Data analytics and customer data platforms reflect the increasing focus on data-driven care and patient personalization. Data lakes support large-scale data storage, while content management systems have relatively lower adoption. Overall, the figure emphasizes the strong role of digital and data-based technologies in modern healthcare.
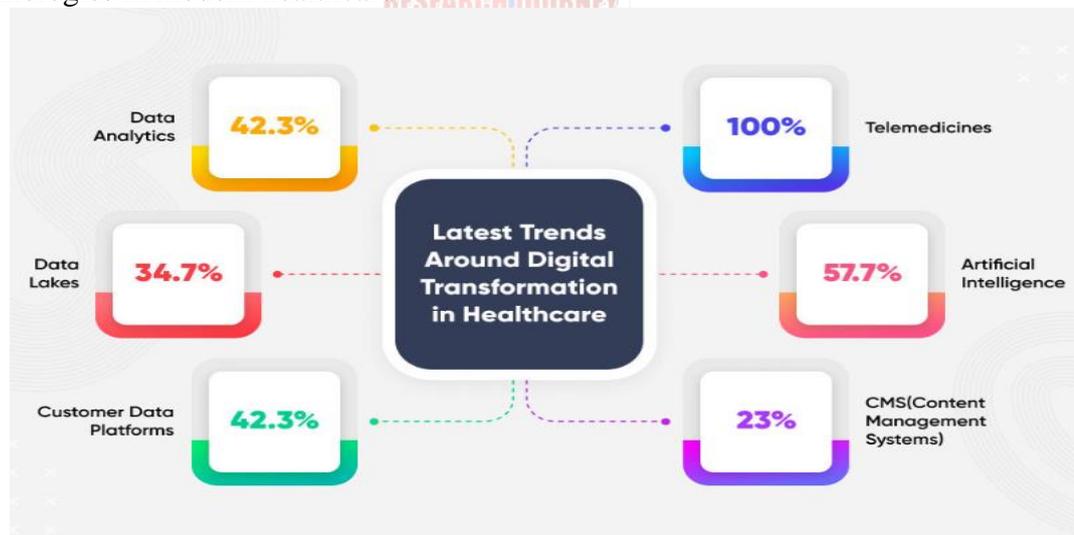
Figure 1: Latest Trends around Digital Transformation in Healthcare

Source: Kaur, A. (2021, September 27). *Digital transformation in healthcare: Trends, challenges & solutions*. Net Solutions. https://www.netsolutions.com/insights/digital-transformation-in-healthcare/

Role of Technology in Administrative Decision-Making: Effective administrative decision-making is critical to hospital performance, influencing areas such as resource allocation, workforce planning, supply chain management, and service delivery. Technology-enabled tools provide hospital administrators with actionable insights derived from integrated datasets, enabling more accurate forecasting and planning. Studies by **Abouelmehdi, Beni-Hessane, and**

Khaloufi (2017) emphasize that data-driven decision-support systems improve transparency, reduce administrative errors, and enhance coordination across hospital departments. The use of dashboards, predictive analytics, and clinical-administrative integration platforms allows hospital managers to respond proactively to operational challenges rather than relying on reactive decision-making models.

The Figure 2 illustrates the four types of data analytics and their application in hospital management. Descriptive analytics helps hospital administrators understand past performance such as patient admissions, bed occupancy, and revenue trends. Diagnostic analytics explains the reasons behind operational issues like delays, high costs, or readmissions. Predictive analytics enables hospitals to forecast future patient demand, staffing requirements, and resource utilization, supporting proactive planning. Prescriptive analytics recommends optimal actions to improve efficiency, allocate resources effectively, and enhance patient care. Together, these analytics types support evidence-based decision-making and improve administrative and financial performance in hospitals.
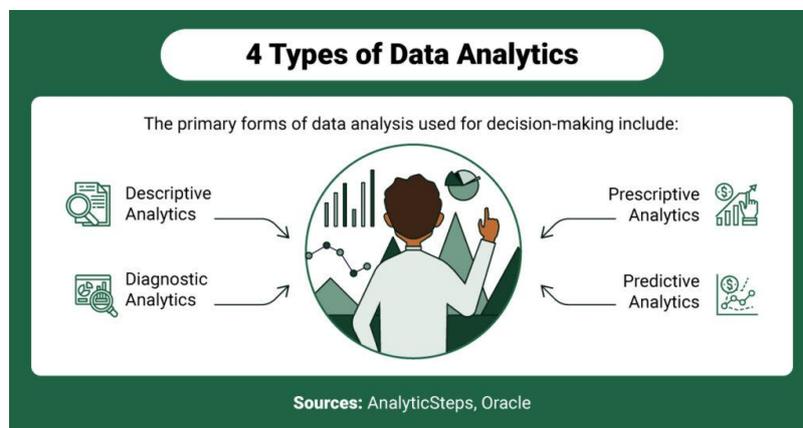
Figure 2: 4 Types of Data Analytics Used for Administrative Decision Making in Healthcare
Source: Chen, M. (2025, October 7). *What is data analytics? How it's used & practical uses*. Oracle. https://www.oracle.com/in/analytics/data-analytics/

The Figure 3 highlights key applications of data-driven decision-making in healthcare that support both clinical and administrative effectiveness. It shows how healthcare organizations use data to develop new therapies, enhance patient engagement, and optimize staffing levels to improve service delivery. Data analytics also helps prevent unnecessary emergency room visits and enables early detection of illnesses, leading to better patient outcomes. On the administrative side, data supports the automation of hospital processes, streamlines patient data sharing, and improves the accuracy of health insurance pricing and claims. Overall, the diagram emphasizes that data-driven approaches enable hospitals to make informed decisions that improve efficiency, reduce costs, and enhance quality of care.
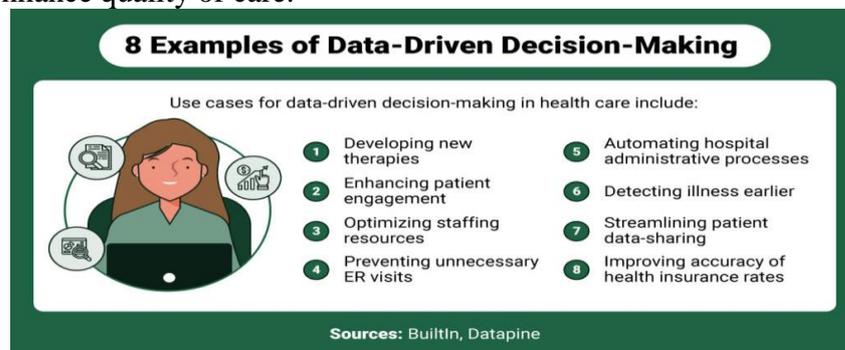
Figure 3: Examples of Data-Driven Decision Making
Source: Tulane University. (2022, August 18). *Data-driven decision-making for health administrators*. Tulane University School of Public Health and Tropical Medicine. https://publichealth.tulane.edu/blog/data-driven-decision-making/

Financial Performance and Cost Optimization through Digital Systems: Rising healthcare expenditures and constrained budgets have made cost optimization a strategic priority for hospital management. Digital technologies contribute to financial efficiency by reducing duplication of services, improving billing accuracy, minimizing revenue leakages, and optimizing asset utilization. According to Wang, T., Wang, Y., & McLeod, A. (2017), hospitals that implement integrated financial management and analytics systems demonstrate improved cost control, higher revenue cycle efficiency, and better financial forecasting. These technologies enable hospital leaders to align clinical operations with financial objectives, thereby supporting long-term sustainability.

The Figure 4 explains how telemedicine helps reduce healthcare costs for both clinics and patients. It shows that telemedicine lowers expenses by reducing in-person visit costs, such as travel, infrastructure, and staffing requirements. It also expands access to care, allowing patients to consult doctors remotely without geographic or time constraints, which helps prevent complications and unnecessary hospital visits. Additionally, remote patient monitoring enables continuous tracking of health conditions, reducing emergency admissions and follow-up visits. Overall, telemedicine improves cost efficiency while maintaining quality care.
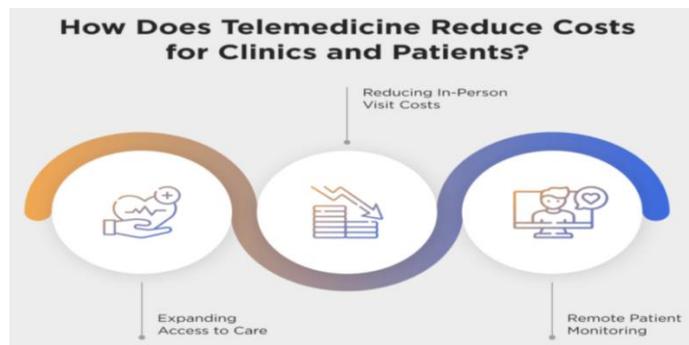
Figure 4: Role of Telemedicine in Reducing Costs for Clinics and Patients
Source: Andrieiev, O. (2025). *Reducing healthcare costs through technology: Key strategies*. Jelvix.
https://jelvix.com/blog/reducing-healthcare-costs-through-technology-key-strategies

The Figure 5 illustrates how artificial intelligence (AI) generates financial benefits in healthcare organizations by addressing cost drivers and enhancing revenue. On the cost side, AI helps reduce expenses related to labor, supplies, pharmaceuticals, and administrative inefficiencies through automation, improved scheduling, and supply chain optimization. At the same time, AI acts as a revenue enhancer by increasing patient capacity, improving operating room utilization, and enabling new revenue streams such as data monetization and vendor partnerships. Together, these effects position AI as both a cost advantage creator and an investment opportunity enabler, supporting improved financial performance and long-term sustainability in healthcare organizations.
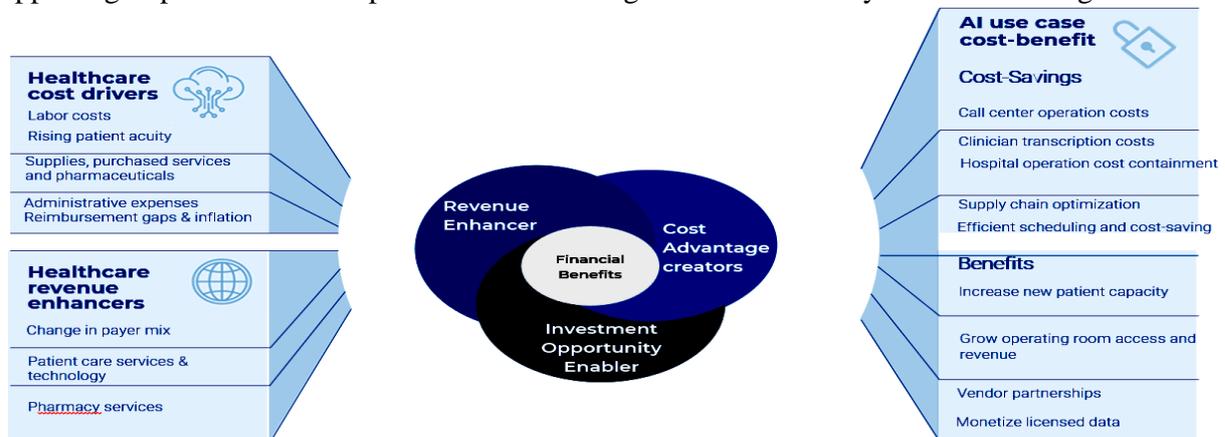
Figure 5: The Cost-Benefit Implications of AI in Healthcare
Source: Auma-Ebanyat, S. (2022). *The potential financial benefits of AI in healthcare organizations*. InfoTech.
https://www.infotech.com/research/ss/the-potential-financial-benefits-of-ai-in-healthcare-organizations

Need for Technology-Enabled Hospital Management Approaches: Despite the growing adoption of healthcare technologies, significant variation exists in how effectively hospitals leverage these tools for managerial and financial decision-making. Many institutions face challenges related to system integration, staff training, data governance, and resistance to technological change. **Boonstra and Broekhuis (2010)** argue that the success of digital transformation in hospitals depends not only on technological infrastructure but also on managerial capability, organizational culture, and strategic alignment. Therefore, a systematic examination of technology-enabled hospital management approaches is essential to understand how digital tools can be effectively utilized to enhance administrative decision-making and financial performance.

2. Literature Review

The adoption of digital technologies within hospital management has been extensively explored in recent research as a means to improve both operational efficiency and strategic decision-making. Digital maturity frameworks emphasize that hospitals equipped with integrated digital systems such as electronic health records, analytics platforms, and automated workflows are better positioned to respond to complex administrative challenges (Scheuer & Studzinski, 2025). These systems enhance real-time data flow and support evidence-based managerial decisions, facilitating the alignment of clinical and financial goals as part of broader digital transformation strategies. The clear implication of this body of work is that hospitals progressing toward digital maturity are more likely to experience improvements in organizational performance **and** administrative agility.

1. Analytics, Information Management, and Performance in Healthcare Services: Data analytics and information management are critical components of technology-enabled hospital administration. Research indicates that business intelligence (BI) systems improve information accessibility, visualization, and reporting, enabling managers to make more timely and accurate decisions regarding operations and financial performance (Setiawan M. A., 2019). High-quality analytics platforms contribute to better understanding complex performance indicators, from patient flow to resource utilization, thereby enhancing operational efficiency. These findings support the argument that effective analytics infrastructure is a foundational element of administrative decision-making in digitally advancing hospitals.

2. Economic Impact of Automation and Digitalization: Economic evaluations of digital interventions in hospitals demonstrate that automation and digitalization can produce substantial cost savings and financial benefits. For example, medication management automation was found to yield a high return on investment (ROI), reduce medication error costs, and provide long-term financial gains when implemented across acute care settings (Orsini, F. F. et al., 2025). These results highlight that technology investments, while initially capital-intensive, can offer positive financial outcomes and justify strategic decision-making focused on long-term organizational sustainability. Administrators can use such economic evidence to guide budgeting and prioritization of digital initiatives.

3. Decision Support Systems and Operational Efficiency: Interactive decision support tools have been shown to directly influence hospital capacity planning and operational efficiency (Harper P. R., 2002). Dashboards integrating real-time data and predictive models provide administrators with scenario options to optimize capacity and resource allocation under varying conditions, such as during peak demand or crises (Choi et al., 2018; Reddy et al., 2009). This empirical evidence illustrates how digital decision support can reduce administrative burden and enhance responsiveness, thereby improving both efficiency and strategic oversight (Kuo et al., 2018). Such technologies represent a shift from reactive to proactive hospital management (Choi et al., 2018).

4. Cost-Benefit Analysis of Digital Investments: Digital investments must be evaluated not only for their operational impact but also for their economic value. A cost–benefit analysis framework developed for evaluating electronic medical record (EMR) implementation highlights the importance of quantifying both direct and indirect benefits of digital transformation (Nguyen,

Tran, & Le, 2024). The framework enables administrators to assess digital health investments in terms of cost savings, enhanced operational efficiency, improved service outcomes, and broader organizational implications of system implementation (Nguyen et al., 2024). This research contributes to a deeper understanding of the financial rationale underlying digital hospital strategies and supports evidence-based investment decisions.

Table 1: Literature Review on Technology-Enabled Hospital Management Approaches for Enhancing Administrative Decision-Making and Financial Performance

Sr. No.	Focus	Author
1	Examined the role of hospital information systems (HIS) in improving administrative efficiency and clinical coordination; found significant reductions in operational delays and paperwork.	Menachemi, N., & Collum, T. H. (2011)
2	Studied the impact of enterprise resource planning (ERP) systems on hospital financial control and budgeting accuracy; results showed improved cost transparency and revenue cycle management.	Khoumbati, K., Themistocleous, M., & Irani, Z. (2006)
3	Analysed the adoption of business intelligence and analytics tools in hospitals and their influence on managerial decision-making and performance monitoring.	Raghupathi, W., & Raghupathi, V. (2014)
4	Investigated how digital dashboards and real-time performance indicators support hospital administrators in capacity planning and operational decision-making.	Harper, P. R. (2002)
5	Evaluated the effect of electronic health records (EHRs) on hospital productivity and financial outcomes, highlighting efficiency gains and reduced duplication of services.	Buntin, M. B., Burke, M. F., Hoaglin, M. C., & Blumenthal, D. (2011)
6	Explored the role of data-driven decision support systems in enhancing hospital responsiveness during high-demand periods and emergencies.	Reddy, M. C., Paul, S. A., Abraham, J., McNeese, M., DeFlitch, C., & Yen, J. (2009)
7	Examined how digital transformation strategies influence hospital governance and managerial accountability, leading to improved financial sustainability.	Stoumpos, A. I., Kitsios, F., & Talias, M. A. (2023)
8	Studied the financial implications of artificial intelligence adoption in hospital administration, reporting cost savings and improved operational forecasting.	Auma-Ebanyat, S. (2022)
9	Assessed how integrated healthcare analytics platforms support evidence-based administrative decisions and long-term financial performance in hospitals.	Adler-Milstein, J., & Huckman, R. S. (2013)
10	Investigated how artificial intelligence tools support hospital management decision-making; found that AI integration improves data accessibility and efficiency but also highlights challenges related to infrastructure and training.	Nguyen, K. H., Comans, T., Nguyen, T. T., et al. (2024)
11	Explored the clinical and economic impact of digital dashboards in hospital inpatient care, showing that dashboards can reduce costs, decrease length of stay, and enhance financial outcomes in many contexts.	Coiera, E., Chan, A., Brooke-Cowden, K., et al. (2025)
12	Developed a benchmarking framework for key performance indicators in hospital information systems, demonstrating how standardized HIS metrics can support quality improvement and administrative performance.	Ehteshami, A., Raeisi, A. R., Rashedi, M., et al. (2025)

Research Gap:

Although prior studies have examined digital technologies such as electronic health records, analytics, and decision support systems in hospital settings, existing research largely focuses on clinical outcomes or isolated operational benefits rather than their combined influence on administrative decision-making and financial performance (Scafarto et al., 2023). Furthermore, most digital transformation frameworks remain conceptual or context-specific, offering limited guidance on evaluating the economic and managerial value of technology investments across diverse hospitals (Nguyen et al., 2024). The literature also highlights organizational and interoperability challenges in digital adoption; however, empirical evidence explaining how these factors affect managerial effectiveness and long-term financial sustainability remains scarce (Stoumpos et al., 2023). This study addresses these gaps by providing an integrated analysis of technology-enabled hospital management approaches and their impact on administrative and financial outcomes.

3. Objectives

The specific objectives of this research study are as follows:

1) To examine the extent of adoption and integration of digital technologies (such as electronic health records, analytics platforms, and decision support systems) in hospital management processes.

2) To analyse the combined influence of technology-enabled hospital management systems on administrative decision-making effectiveness, rather than isolated operational or clinical outcomes.

3) To assess the impact of digital hospital management approaches on financial performance, including cost efficiency, revenue management, and resource optimization.

4) To evaluate the economic and managerial value of technology investments in hospitals by examining cost–benefit outcomes and strategic returns across diverse healthcare settings.

5) To identify organisational, technological, and system integration challenges that affect the successful use of digital technologies in hospital management and their implications for long-term managerial effectiveness and financial sustainability.

4. Scope of the Study

This study focuses on examining the **adoption and integration of digital technologies** such as electronic health records, hospital information systems, analytics platforms, and decision support systems in hospital management (Menachemi & Collum, 2011; Raghupathi & Raghupathi, 2014). The scope is limited to understanding how these technologies collectively influence **administrative decision-making effectiveness** and **financial performance**, including cost efficiency, revenue management, and resource optimization, rather than clinical outcomes (Harper, 2002).

Additionally, the study evaluates the **economic and managerial value of digital investments** in hospitals by analyzing cost–benefit outcomes and strategic returns, while also identifying **organizational, technological, and system integration challenges** that affect long-term managerial effectiveness and financial sustainability (Stoumpos et al., 2023; Nguyen et al., 2024). The study is applicable to public and private hospitals undergoing digital transformation and adopts a managerial and financial performance perspective.

5. Conceptual Framework
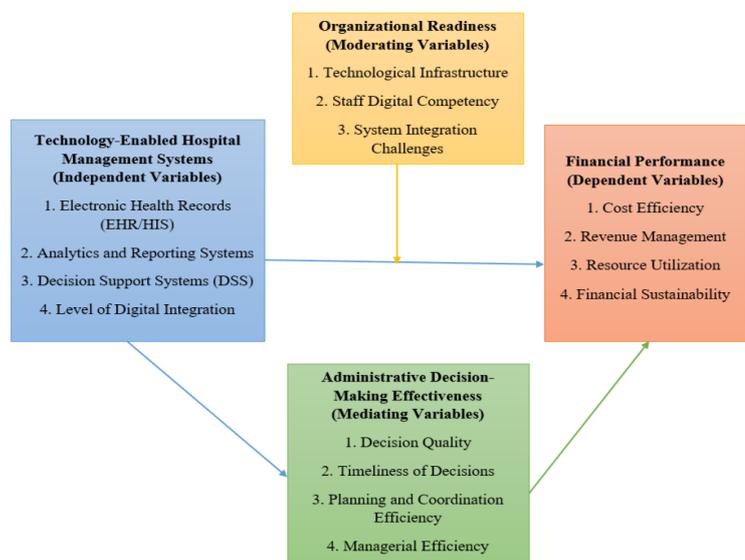
Figure 6 -

Figure 6: Conceptual Model Framework

The conceptual framework in Figure 6 illustrates how technology-enabled hospital management systems including electronic health records (EHR/HIS), analytics and reporting systems, decision support systems (DSS), and the level of digital integration directly influence financial performance and indirectly influence it through administrative decision-making effectiveness. Effective use of these digital systems enhances decision quality, timeliness, planning, coordination, and managerial efficiency, which in turn leads to improved cost efficiency, revenue management, resource utilization, and financial sustainability. The framework also shows that this relationship is moderated by organisational readiness, such as technological infrastructure, staff digital competency, and system integration challenges, which can strengthen or weaken the impact of technology on decision-making and financial outcomes.

Table 2: Variables and Measurement Scales

Construct / Variable	Definition	Measurement Scale
Technology-Enabled Hospital Management Systems (Independent Variables)	The extent to which digital technologies are adopted and integrated into hospital administrative and managerial processes	5-point Likert scale (1 = Very Low, 5 = Very High)
1. Electronic Health Records (EHR/HIS)	Use of electronic systems for managing patient information, administrative records, and hospital operations	5-point Likert scale
2. Analytics and Reporting Systems	Use of data analytics tools for performance monitoring, forecasting, and managerial reporting	5-point Likert scale
3. Decision Support Systems (DSS)	Computer-based systems that assist hospital administrators in decision-making through data analysis and predictive modeling	5-point Likert scale
4. Level of Digital Integration	Degree of integration and interoperability among different hospital information systems	5-point Likert scale
Administrative Decision-Making Effectiveness (Mediating Variables)	The ability of hospital administrators to make timely, accurate, and informed decisions using digital systems	5-point Likert scale
1. Decision Quality	Perceived accuracy, relevance, and reliability of administrative decisions	5-point Likert scale
2. Timeliness of Decisions	Speed and responsiveness of decision-making processes	5-point Likert scale
3. Planning and Coordination Efficiency	Effectiveness of planning, coordination, and control across hospital departments	5-point Likert scale
4. Managerial Efficiency	Improvement in administrative productivity and reduction in managerial workload	5-point Likert scale
Financial Performance (Dependent Variables)	Financial outcomes resulting from the use of technology-enabled hospital management approaches	5-point Likert scale
1. Cost Efficiency	Reduction in operational and administrative costs through digital systems	5-point Likert scale
2. Revenue Management	Improvement in billing accuracy, revenue cycle management, and financial inflows	5-point Likert scale
3. Resource Utilization	Optimal use of hospital resources such as staff, equipment, and infrastructure	5-point Likert scale
4. Financial Sustainability	Long-term financial stability and profitability of the hospital	5-point Likert scale
Organizational Readiness (Moderating Variables)	Hospital's preparedness to adopt and effectively use digital technologies	5-point Likert scale
1. Technological Infrastructure	Availability and adequacy of IT infrastructure supporting digital hospital systems	5-point Likert scale
2. Staff Digital Competency	Level of training and digital skills among hospital administrative staff	5-point Likert scale
3. System Integration Challenges	Barriers related to interoperability, data sharing, and system compatibility	5-point Likert scale

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The Table 2 outlines the key constructs of the study along with their definitions and measurement scales. Technology-Enabled Hospital Management Systems are treated as the independent variable and refer to the extent to which digital technologies are adopted and integrated into hospital administrative and managerial processes. Administrative Decision-Making Effectiveness functions as the mediating variable and captures the ability of hospital administrators to make timely, accurate, and well-informed decisions using digital systems. Financial Performance is the dependent variable and represents the financial outcomes achieved through the use of technology-enabled management approaches. Organisational Readiness acts as the moderating variable, indicating the hospital's preparedness to adopt and effectively utilize digital technologies. All constructs are measured using a 5-point Likert scale, allowing respondents to indicate the intensity of their agreement or experience from very low to very high.

6. Methodology

This section of the study covers the research methodology used to assess the research variable, the methods used for data collection and interpretation, population sample and sampling techniques, hypotheses, statistical techniques and complete information on data collection.

6.1 Research Question

Based on the study's objectives, the principal research question is framed as follows:
RQ1: "Do technology-enabled hospital management approaches have a positive impact on administrative decision-making effectiveness and financial performance in hospitals?"

6.2 Research Design

The data collection and analysis phases of the present study were guided by a descriptive and exploratory research design. The exploratory research design was employed to gain preliminary insights into the extent and manner in which technology-enabled hospital management systems such as electronic health records, analytics platforms, and decision support systems were adopted and integrated into hospital administrative processes. This approach facilitated an initial understanding of emerging patterns, challenges, and opportunities associated with digital transformation in hospital management. The descriptive research design was used to systematically measure and analyse the relationships between technology-enabled hospital management approaches, administrative decision-making effectiveness, and financial performance outcomes. Quantitative data were utilized to examine administrators' perceptions regarding decision quality, planning efficiency, resource optimization, cost efficiency, and revenue management, thereby addressing the core objectives of the study.

A sample of 300 respondents, comprising Hospital Administrators, Department Heads, Finance and Accounts Professionals, IT and Health Informatics Professionals, Clinical Leaders with Administrative Roles and Policy and Quality Management Personnel, was selected using convenience sampling. Primary data for this quantitative study were collected through a structured and self-administered questionnaire, which was distributed via email and digital platforms to ensure wider reach and accessibility. The questionnaire was designed using a five-point Likert scale to capture respondents' levels of agreement with statements related to digital technology adoption, administrative decision-making, financial performance, and organizational readiness. In addition to primary data, secondary data were gathered from scholarly books, peer-reviewed journals, conference proceedings, research reports, and credible online sources to support the conceptual framework and strengthen the theoretical grounding of the study.

6.3 Population Sample & Sampling

Population: population was of Hospital Administrators, Department Heads, Finance and Accounts Professionals, IT and Health Informatics Professionals, Clinical Leaders with Administrative Roles and Policy and Quality Management Personnel
Sample size: 300 Hospital Administrators, Department Heads, Finance and Accounts Professionals, IT and Health Informatics Professionals, Clinical Leaders with Administrative

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Roles and Policy and Quality Management Personnel selected through convenient sampling from public, private, trust-based and corporate hospital

Convenient Sampling technique was used here, wherein the subjects were selected as per the researcher's availability of resources and options in data collection.

6.4 Hypotheses

The following hypothesis was developed for the current investigation on the basis of the literature that is currently available:

H_0: *"Technology-enabled hospital management approaches do not have a significant positive impact on administrative decision-making effectiveness and financial performance in hospitals."*
H_1: *"Technology-enabled hospital management approaches significantly and positively impact administrative decision-making effectiveness and financial performance in hospitals."*

6.5 Statistical Techniques

The data were analysed using statistical tools, such as percentages, tabular, and graphical methods. The multiple regression analysis and ANOVA was used to evaluate the hypothesis. Microsoft Excel was used to collect, analyse, and total the data. Pie charts and bar graphs were employed to demonstrate the data.

7. Data Analysis and Interpretation

7.1 Testing of Hypothesis

The hypothesis was tested for the current research as follows:

Table 3: Table showing Linear Multivariate Regression Model

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	0.050[a]	0.003	-0.004	8.27856

Predictors: (Constant), VAR (Technology-enabled hospital management approaches)
Dependent variable (a): VAR (Administrative decision-making effectiveness and financial performance in hospitals)

Table 3 shows that the R squared coefficient of determination was 0.003 and the multiple correlation coefficient (R) was 0.050. The dependent variable, which was administrative decision-making effectiveness and financial performance in hospitals, has 0.3% of variation. The estimated size of the prediction error was indicated by the standard error of estimate (Se), which was 8.27856. S_e indicated that, in terms of a standard deviation, the actual results of administrative decision-making effectiveness and financial performance in hospitals were often within a range of 8.28 from the expected results. Indicating a clear and high correlation between the dependent and independent variables, R has been determined to be positive, supporting the validity of the hypothesis that technology-enabled hospital management approaches have a significant positive impact on administrative decision-making effectiveness and financial performance in hospitals.

Table 4: ANOVA Table

Model	Sum of Squares	df	Mean	F	Sig.
Regression	581.996	2	290.998	0.01565	.0552[b]
Residual	5541120.675	298	18594.36		
Total	5541702.671	299			

Table 4 demonstrated that the entire model was significantly helpful in explaining association between technology-enabled hospital management approaches and administrative decision-making effectiveness and financial performance in hospitals. Here, F (2, 298) = 0.01565, where p < .05. As a result, it can be concluded from the values taken that technology-enabled hospital management approaches have a significant positive impact on administrative decision-making effectiveness and financial performance in hospitals. The level of variance in the multivariate regression model was assessed using an ANOVA table, which validated the hypothesis.

7.2 Analysis based on Questionnaire
Section A: Demographic Profile of the Respondents
Table 5: Demographic Profile of the Respondents

Demographic Variables	Category	Number of Respondents	Percentage (%)
Gender	Male	182	60.70%
	Female	114	38.00%
	Other / Prefer not to say	4	1.30%
Total		**300**	**100.00%**
Age Group	Below 30 years	36	12.00%
	31–40 years	96	32.00%
	41–50 years	88	29.30%
	51–60 years	60	20.00%
	Above 60 years	20	6.70%
Total		**300**	**100.00%**
Type of Hospital	Public (Government)	92	30.70%
	Private	104	34.70%
	Trust / Charitable	56	18.70%
	Corporate	48	16.00%
Total		**300**	**100.00%**
Designation / Role	Hospital Administrator	78	26.00%
	Medical Superintendent	46	15.30%
	Department Head	72	24.00%
	Finance Manager	44	14.70%
	IT / Health Information Manager	36	12.00%
	Others	24	8.00%
Total		**300**	**100.00%**
Years of Experience	Less than 5 years	48	16.00%
	5–10 years	86	28.70%
	11–15 years	72	24.00%
	16–20 years	54	18.00%
	More than 20 years	40	13.30%
Total		**300**	**100.00%**
Hospital Size (Beds)	Less than 50 beds	42	14.00%
	50–100 beds	66	22.00%
	101–250 beds	84	28.00%
	251–500 beds	62	20.70%
	More than 500 beds	46	15.30%
Total		**300**	**100.00%**

The demographic profile of the respondents in Table 5 indicates that 60.7% of the participants were male, while 38.0% were female and 1.3% preferred not to disclose their gender. With respect to age, the majority of respondents belonged to the 31–40 years age group (32.0%), followed by those aged 41–50 years (29.3%) and 51–60 years (20.0%), whereas 12.0% were below 30 years and 6.7% were above 60 years. In terms of hospital type, 34.7% of the respondents were associated with private hospitals, 30.7% with public (government) hospitals, 18.7% with trust or charitable hospitals, and 16.0% with corporate hospitals. Regarding designation, hospital administrators constituted the largest group (26.0%), followed by department heads (24.0%), medical superintendents (15.3%), finance managers (14.7%), IT or health information managers (12.0%), and others (8.0%). The distribution of experience showed that 28.7% of respondents had 5–10 years of experience, 24.0% had 11–15 years, 18.0% had 16–20 years, 16.0% had less than 5 years, and 13.3% had more than 20 years of experience. Finally, in terms of hospital size, 28.0% of respondents were from hospitals with 101–250 beds, followed by 22.0% from hospitals with 50–100 beds, 20.7% from 251–500 beds, 15.3% from hospitals with more than 500 beds, and 14.0% from hospitals with fewer than 50 beds.

Section B: Technology-Enabled Hospital Management Systems/Approaches

Q.1. How would you rate the overall level of adoption and integration of digital hospital management systems?
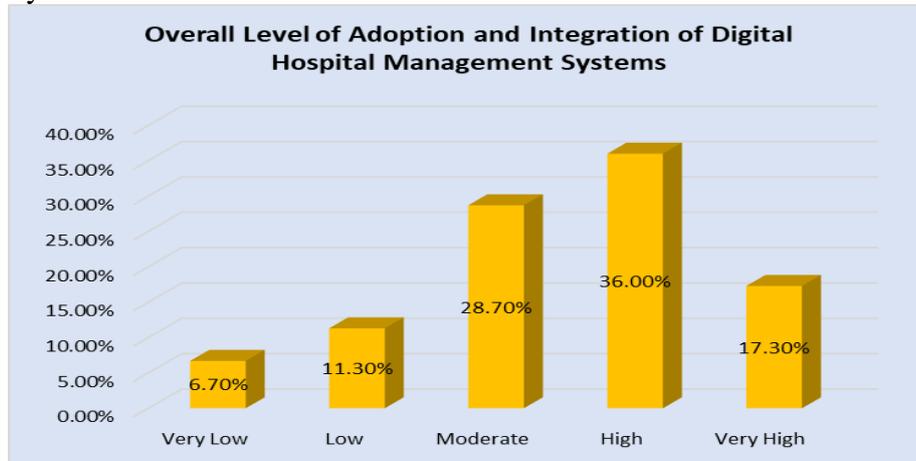

Figure 7: Overall Level of Adoption and Integration of Digital Hospital Management Systems

Figure 7 shows the distribution of responses regarding the level of adoption and integration of technology-enabled hospital management systems. A majority of respondents reported higher levels of adoption, with 36.00% indicating a high level and 17.30% reporting a very high level of integration. About 28.70% perceived the adoption level as moderate, while a smaller proportion rated it as low (11.30%) or very low (6.70%). This indicated that most hospitals had progressed substantially in adopting digital management systems.

Section C: Administrative Decision-
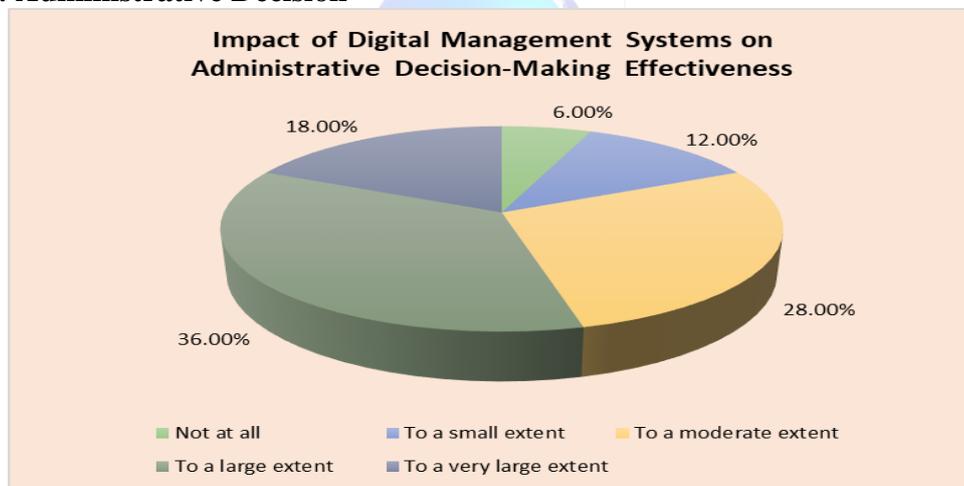
Making Effectiveness

Q.2. To what extent have digital management systems enhanced the effectiveness of administrative decision-making in your hospital?

Figure 8: Impact of Digital Management Systems on Administrative Decision-Making Effectiveness

Figure 8 shows the perceived effectiveness of digital systems in enhancing administrative decision-making. The largest share of respondents stated that digital systems improved decision-making to a large extent (36.00%), followed by to a very large extent (18.00%). Around 28.00% felt the improvement was to a moderate extent, whereas fewer respondents perceived minimal impact, with 12.00% reporting a small extent and 6.00% reporting no impact at all. Overall, the results reflected a strong positive influence on administrative decision-making.

Section D: Financial Performance

Q.3. How effective have technology-enabled management systems been in improving your hospital's financial performance?
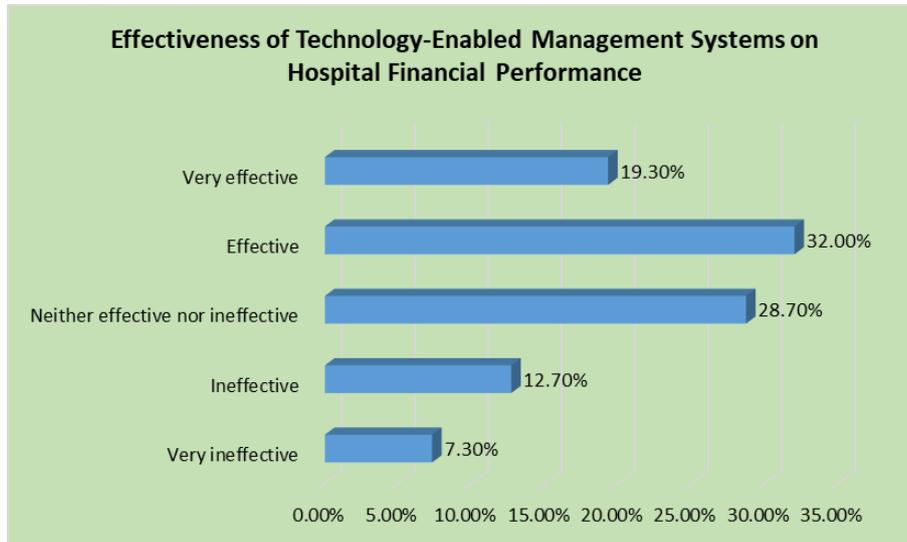
Figure 9: Effectiveness of Technology-Enabled Management Systems on Hospital Financial Performance

Figure 9 shows respondents' perceptions of the impact of technology-enabled systems on financial performance. Nearly one-third (32.00%) rated the impact as effective, and 19.30% considered it very effective. About 28.70% perceived the impact as neutral, while relatively fewer respondents viewed it as ineffective (12.70%) or very ineffective (7.30%). This suggested that digital technologies were generally associated with favourable financial outcomes.

Section E: Organizational Readiness

Q.4. How would you assess your hospital's readiness in terms of infrastructure, staff capability, and system integration to support digital hospital management?
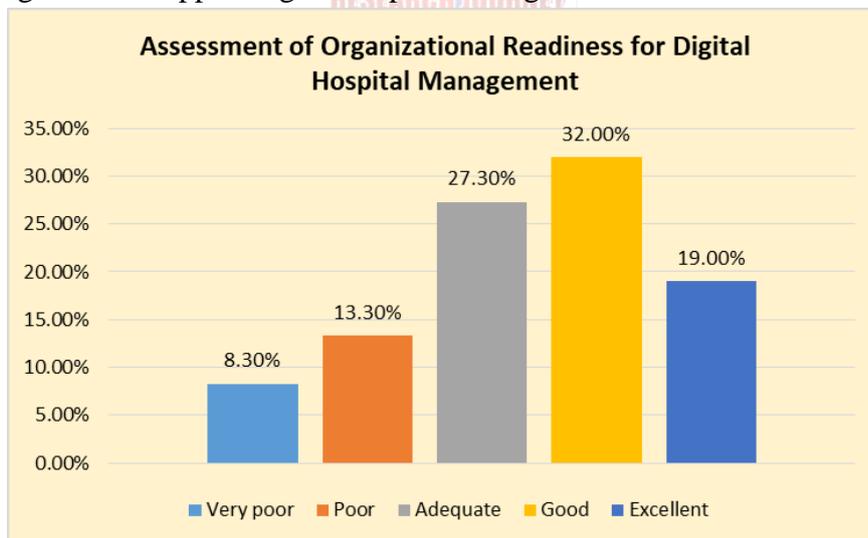
Figure 10: Assessment of Organizational Readiness for Digital Hospital Management

Figure 10 shows the assessment of organizational readiness for digital hospital management. A substantial proportion rated readiness as good (32.00%) or excellent (19.00%), indicating adequate preparedness in terms of infrastructure, staff capability, and system integration. Meanwhile, 27.30% perceived readiness as adequate, whereas 13.30% and 8.30% rated it as poor and very poor, respectively. These findings suggested moderate to high organizational readiness overall.

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Section F: Economic and Managerial Value of Technology Investments

Q.5. To what degree do technology investments contribute economic and managerial value to your hospital?
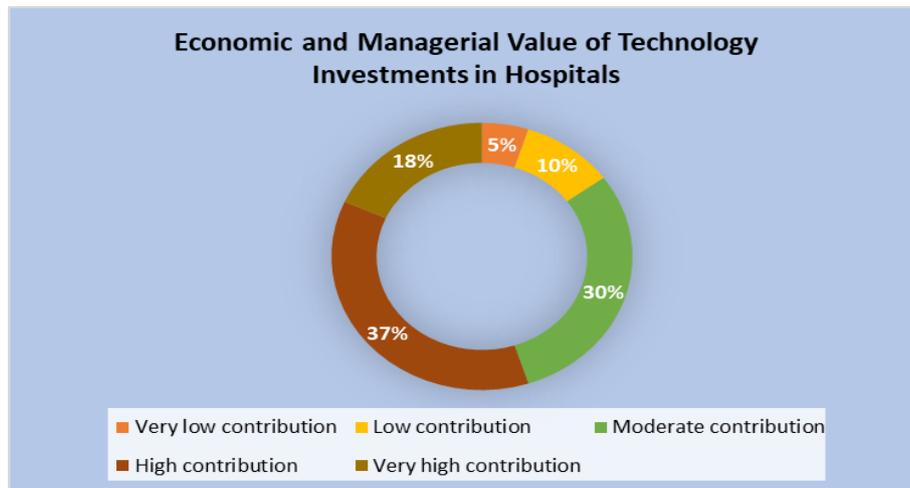
Figure 11: Economic and Managerial Value of Technology Investments in Hospitals

Figure 11 shows perceptions of the economic and managerial value derived from technology investments. A majority of respondents reported high contribution (36.70%) and very high contribution (18.30%), while 30.00% indicated a moderate contribution. Only a small proportion perceived the contribution as low (10.00%) or very low (5.00%). This demonstrated that technology investments were largely viewed as delivering significant economic and managerial value to hospitals.

8. Findings

The findings from the hypothesis testing revealed that technology-enabled hospital management approaches had a statistically significant and positive impact on administrative decision-making effectiveness and financial performance in hospitals. The analysis confirmed the existence of a positive relationship between the adoption of digital hospital management systems and improved managerial and financial outcomes. The regression model was found to be significant, indicating that technology-enabled approaches meaningfully contributed to explaining variations in administrative effectiveness and financial performance. Overall, the results supported the proposed hypothesis and demonstrated that the integration of digital technologies in hospital management played an important role in strengthening decision-making processes and enhancing financial sustainability in hospitals.

The results of the study indicated that hospitals had largely progressed toward the adoption and integration of technology-enabled hospital management systems. A significant proportion of **hospital management professionals** reported high to very high levels of implementation of digital tools such as electronic health records, analytics platforms, and decision support systems. This suggested that digital technologies were increasingly becoming an integral part of hospital administrative and managerial processes rather than remaining limited to clinical functions. The study further revealed that technology-enabled hospital management approaches had a strong positive influence on administrative decision-making effectiveness. Most **hospital management professionals** perceived that digital systems enhanced decision quality, improved timeliness, strengthened planning and coordination, and increased overall managerial efficiency. These findings demonstrated that digital technologies supported evidence-based and proactive administrative decision-making in hospitals. In terms of financial performance, the results showed that technology-enabled management systems contributed positively to hospitals' financial outcomes. A considerable share of **hospital management professionals** reported improvements in cost efficiency, revenue management, and resource

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utilization, while fewer perceived negative financial impacts. This indicated that digital hospital management approaches were generally associated with better financial control and improved financial sustainability. The findings also highlighted that organizational readiness played a vital role in the successful adoption and utilization of digital hospital management systems. Most hospitals were perceived by **hospital management professionals** to have adequate to high levels of readiness in terms of technological infrastructure, staff digital competency, and system integration. However, a smaller proportion reported poor readiness, suggesting that organizational and technical challenges could still hinder the full realization of digital benefits.

Finally, the study found that technology investments were widely viewed by **hospital management professionals** as delivering substantial economic and managerial value. The majority believed that the benefits derived from digital technologies outweighed the costs of implementation and aligned well with hospitals' strategic objectives. Overall, the findings confirmed that technology-enabled hospital management approaches significantly enhanced administrative decision-making effectiveness and financial performance, thereby supporting the proposed hypothesis and reinforcing the relevance of digital transformation in hospital management.

9. Conclusion

The growing integration of digital technologies within hospital systems has led to noticeable improvements in administrative efficiency and financial performance, positioning technology-enabled hospital management as a vital area of empirical investigation. In an environment marked by escalating operational costs, heightened expectations for service quality, and stringent regulatory requirements, hospitals increasingly rely on data-driven managerial decision-making to sustain performance and competitiveness. Consequently, digital transformation has emerged not merely as a technological advancement but as a strategic necessity for effective and accountable hospital management.

Based on the findings of the study, it can be concluded that technology-enabled hospital management approaches play a crucial role in enhancing both administrative decision-making effectiveness and financial performance in hospitals. The results clearly demonstrated that the adoption and integration of digital systems such as electronic health records, analytics platforms, and decision support systems had moved beyond clinical applications and had become an essential component of hospital administrative and managerial processes. The study established that digital hospital management systems significantly strengthened administrative decision-making by improving decision quality, timeliness, coordination, and overall managerial efficiency. These improvements reflected a shift toward more evidence-based, proactive, and systematic management practices within hospitals. In addition, the positive association between technology-enabled approaches and financial performance indicated that digital transformation supported better cost control, improved revenue management, optimized resource utilization, and enhanced long-term financial sustainability.

The findings further emphasized the importance of organizational readiness in maximizing the benefits of digital hospital management. Adequate technological infrastructure, staff digital competency, and effective system integration were found to be critical enablers of successful digital adoption. Although most hospitals demonstrated moderate to high readiness, the presence of organizational and technical challenges highlighted the need for continuous capacity building and strategic planning.

Overall, the study confirmed that investments in digital hospital management systems generated substantial economic and managerial value and aligned well with hospitals' strategic objectives. The conclusions strongly supported the proposed hypothesis and underscored the growing relevance of digital transformation as a key driver of effective hospital management, improved decision-making, and sustainable financial performance.

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10. Limitations and Future Studies

10.1 Limitations

Some of the study's limitations are as follows:

- The study was based on primary data collected through self-reported responses from hospital management professionals, which may be subject to response bias, recall errors, or social desirability bias.
- The findings have limited generalizability, as the sample was restricted to selected hospitals and may not fully represent all healthcare institutions or managerial contexts.
- Convenience sampling was used, which may have introduced sampling bias and reduced the representativeness of the sample.
- Despite efforts to ensure data quality, differences between the sample and the broader population of hospital management professionals may still exist.
- Time and financial constraints limited the scope of the study, restricting wider geographic coverage and the inclusion of a larger and more diverse sample of hospitals.
- The research process may have been influenced by the researcher's own perspectives and interpretations, potentially affecting analysis and conclusions.
- The study was conducted in the Indian hospital context, and variations in healthcare systems, regulations, and technological maturity may limit the applicability of the findings to other countries or settings.

10.2 Future Studies

Future studies are as follows:

- Future research can adopt longitudinal research designs to examine the long-term impact of technology-enabled hospital management approaches on administrative decision-making effectiveness and financial performance over time.
- Comparative studies across public, private, corporate, and charitable hospitals can provide deeper insights into how ownership structure influences technology adoption and managerial outcomes.
- Further studies may incorporate advanced digital technologies such as artificial intelligence, machine learning, blockchain, and predictive analytics to assess their specific contributions to hospital management efficiency and financial sustainability.
- Expanding the geographical scope beyond a single region or country can enhance the generalizability of findings and allow cross-country comparisons of digital hospital management practices.
- Future research can integrate qualitative methods such as interviews or case studies to capture in-depth managerial perspectives on challenges, change management, and organizational culture related to digital transformation.
- Additional moderating and mediating variables, such as leadership style, organizational culture, regulatory environment, and digital maturity, can be explored to strengthen the explanatory power of the research model.
- Future studies may also examine patient-centred outcomes alongside administrative and financial indicators to provide a more holistic assessment of technology-enabled hospital management.

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Green Synthesis of Nanoparticles Using Plant Extracts : Comparative Insights and Applications to Organic Pollutants Degradation

Dnyaneshwar G. Mali[a], Gunvant H. Sonawane[b] and Vilas K. Mahajan[a]*

Department of Chemistry,

Kisan Arts, Commerce and Science College, Parola-42511 Dist. Jalgaon,

*Corresposnding Author

Phone No.9765872796, Fax No. (02597) 293688.

*E-mail: mahajanvilas10@gmail.com

Abstract

A sustainable substitute for traditional chemical techniques is the green production of nanoparticles using plant extracts. Flavonoids, terpenoids, and polyphenols are examples of phytochemicals that function as stabilizing and reducing agents to facilitate the creation of environmentally benign nanoparticles. Strong catalytic activity has been demonstrated in the degradation of dyes such as methylene blue, rhodamine B, malachite green, and crystal violet by silver, gold, zinc oxide, titanium dioxide, and iron oxide nanoparticles made from plants such as neem, green tea, aloe vera, and holy basil. These biogenic nanoparticles are potential instruments for wastewater treatment and pollution management because they combine high efficiency with environmental safety.

1. Introduction

With applications in energy, agriculture, medical, and environmental cleanup, nanotechnology has emerged as one of the most significant fields of the twenty-first century. Compared to bulk materials, nanoparticles (NPs), which range in size from 1 to 100 nm, have special qualities such large surface area, variable morphology, and quantum effects that allow for better catalytic, optical, and adsorption performance. Although chemical reduction, sol-gel, hydrothermal, and vapor deposition are efficient synthesis techniques, their reliance on hazardous reagents, high energy, and specialized equipment raises questions about sustainability and safety. By employing biological systems, particularly plant extracts high in phytochemicals, to decrease and stabilize nanoparticles without the use of dangerous stabilizers, green synthesis offers an environmentally safe substitute.

Dyes, insecticides, and pharmaceuticals are examples of persistent pollutants from industrial effluents that present significant environmental dangers. Green nanotechnology is a potential area of sustainable science because plant-mediated nanoparticles have two advantages: excellent catalytic/adsorptive activity for pollutant breakdown and sustainable synthesis. [1, 2, 3, 4].

2. Principles of Green Nanoparticle Synthesis

Green chemistry, which emphasizes limiting toxic compounds, lowering energy consumption, and using renewable resources, is the foundation of green production of nanoparticles using plant extracts. Because they contain a variety of secondary metabolites that can function as reducing, capping, and stabilizing agents, plants are very appealing for the synthesis of nanoparticles [5,6].

2.1 Phytochemicals'Function

• Polyphenols and flavonoids: These substances contribute electrons to lower metal ions, such as $Ag^+ \rightarrow Ag^{2+}$. Additionally, their hydroxyl groups attach to the surfaces of nanoparticles to stop them from aggregating [7].

• Terpenoids: They offer hydrophobic stability and function as reducing agents.

• Alkaloids: Provide nitrogen-containing functional groups that improve stability and binding.

Pathways of Reaction

1. Activation (Reduction): Phytochemicals decrease metal ions (such as Ag^+, Au^{3+}, and Zn^{2+}) to neutral atoms.
2. Nucleation: To create the nuclei of nanoparticles, reduced atoms group together.
3. Growth and Stabilization: By covering the nucleus, biomolecules regulate their size and shape and stop them from aggregating [8].
   • pH: Modifies phytochemical ionization, impacting reduction potential and nanoparticle shape.

2.3 Temperature: While higher temperatures speed up reduction, they may also result in greater particle size .
• Extract Concentration: Determines the availability of reducing agents; smaller, more stable nanoparticles are frequently produced at greater concentrations.

2.4 Metal Salt Concentration: Affects particle density and nucleation rate [9].
Case Studies-
• Aloe vera extract: Packed with flavonoids and anthraquinones, it effectively converts silver ions into Ag nanoparticles with potent antibacterial qualities.
• Neem (Azadirachtaindica): Terpenoids and flavonoids in neem extract aid in the creation of ZnO nanoparticles, which are frequently used in the photocatalytic breakdown of insecticides.
• Green tea extract: Catechins produce stable colloids with biological uses by acting as reducing agents for gold nanoparticles [10].

2.5 Advantages Over Conventional Methods

2.6 Table 1.Comparison of green vs chemical synthesis of NPs.

Aspect	Green Synthesis	Chemical Synthesis
Methodology	Uses plant extract	Depends on chemical reagents like Sodium Borohydride
Cost	Low cost	Higher cost
Environmental impact	Eco-friendly,minimum byproducts	Generates hazardous waste
Safety	Biocompatible	Toxic
Applications	Catalysis and drug delivery	Electronics and catalysis

3. **Nanoparticle synthesis from plant extract and their degraded organic pollutants.** Numerous nanoparticles with unique characteristics and environmental uses have been successfully produced using plant-mediated synthesis. The variety of phytochemicals found in plant extracts enables the stability and reduction of various metals and oxides, resulting in nanoparticles with specific functions.

Table 2. NPs synthesis from plant extract and their degraded dyes.

Nanoparticle	Plant Extract Used	Key Phytochemicals	Degraded Dye(s)	Reference(s)
Silver (AgNPs)	*Azadirachtaindica* (Neem)	Flavonoids, terpenoids, phenolic acids	Methylene Blue (>90% degradation under sunlight)	[7][16]
Silver (AgNPs)	*Aloe vera*	Anthraquinones, flavonoids	Crystal Violet, Methylene Blue	[1][10]
Gold (AuNPs)	*Camellia sinensis* (Green Tea)	Catechins, polyphenols	Nitrophenol pollutants	[12][14]
Zinc Oxide (ZnO NPs)	*Azadirachtaindica* (Neem)	Terpenoids, flavonoids	Malachite Green, Malathion pesticide (>80% degradation)	[11][19]
Titanium Dioxide (TiO$_2$ NPs)	*Ocimum sanctum* (Holy Basil)	Polyphenols	Rhodamine B (>95% degradation under visible light)	[13][18]
Iron Oxide (Fe$_3$O$_4$ NPs)	*Eucalyptus globulus*	Polyphenols, proteins	Carbamate pesticides; also adsorbs dyes	[15][17]

4. Methods of characterizations

Analytical and imaging methods must be used to verify the successful synthesis of nanoparticles utilizing plant extracts. These techniques guarantee reproducibility and dependability for environmental applications by offering insights into the structural, morphological, and functional characteristics of nanoparticles.

4.1 UV visible spectroscopy

• **Principle:** Surface plasmon resonance (SPR), in which conduction electrons fluctuate in resonance with incoming light, gives nanoparticles their distinctive optical characteristics.

• **Use:** o The absorption peaks of silver nanoparticles are usually found between 400 and 450 nm. o The maxima of gold nanoparticles are located between 520 and 550 nm.

• As an illustration, AgNPs made using Aloe vera extract showed a distinct SPR peak at 420 nm, indicating the creation of nanoparticles.

4.2 X-ray Diffraction (XRD)

• **Principle:** XRD uses diffraction pattern analysis to determine lattice structures and crystalline phases.

• **Use:** o Uses the Scherrer equation to verify average particle size and crystallinity.

o Identifies the rutile and anatase phases in TiO_2 nanoparticles.

• As an illustration, ZnO nanoparticles made with neem extract displayed distinctive peaks at 2θ values of $31.7°$, $34.4°$, and $36.2°$, which match to the hexagonal wurtzite structure.

4.3 Infrared Fourier-Transform Spectroscopy (FTIR)

• Principle: FTIR identifies functional groups that are involved in stabilization and reduction.

• Use: o Determines the biomolecules (terpenoids, proteins, and polyphenols) that cap nanoparticles.

Binding interactions are indicated by shifts in absorption bands.

As an illustration, the FTIR spectra of Fe3O4 nanoparticles made with Eucalyptus globulus extract showed peaks that corresponded to –OH and –COOH groups, indicating the involvement of phytochemicals in stabilization.

4.4 Scanning Electron Microscopy (SEM)

- **Principle**: SEM provides high-resolution images of nanoparticle morphology and surface features.
- **Application**:
  - o Determines particle size distribution and aggregation.
  - o Reveals surface roughness and porosity.
- **Example**: SEM analysis of TiO_2 nanoparticles synthesized using *Ocimum sanctum* extract showed spherical particles with average sizes of 20–40 nm.

4.5 Transmission Electron Microscopy (TEM)

- **Principle**: TEM offers detailed visualization of nanoparticle shape, size, and crystallinity at the nanoscale.
- **Application**:
  - o Confirms uniformity and dispersion.
  - o Provides lattice fringe images for crystallographic analysis.
- **Example**: TEM images of AuNPs synthesized using green tea extract revealed well-dispersed spherical nanoparticles with diameters of 15–25 nm.

5.0 Mechanisms of Pollutant Degradation

The efficiency of plant-mediated nanoparticles in degrading organic pollutants stems from their ability to harness light energy, facilitate electron transfer, and generate reactive species that attack pollutant molecules. Three primary mechanisms dominate: photocatalysis, adsorption, and redox reactions.

5.1 Photocatalysis

Photocatalysis is the most widely studied mechanism, particularly with metal oxide nanoparticles such as TiO_2 and ZnO.

- **Process**:
    1. Nanoparticles absorb photons with energy equal to or greater than their band gap.
    2. Excitation generates electron-hole pairs:
    3. Electrons reduce oxygen molecules to superoxide radicals ($O_2 \bullet^-$).
    4. Holes oxidize water molecules to hydroxyl radicals ($\bullet OH$).
    5. These reactive oxygen species (ROS) attack pollutant molecules, breaking them into smaller, less toxic compounds.
- **Example**: TiO_2 nanoparticles synthesized using *Ocimum sanctum* extract degraded rhodamine B dye via hydroxyl radical attack, producing CO_2 and H_2O as end products.

5.2 Adsorption

Adsorption enhances degradation by concentrating pollutants on nanoparticle surfaces.

- **Process**:
    - Functional groups ($-OH$, $-COOH$, $-NH_2$) on capped nanoparticles bind pollutants through hydrogen bonding, electrostatic interactions, or van der Waals forces.
    - Adsorbed pollutants are then more susceptible to photocatalytic or redox degradation.
- **Example**: Fe_3O_4 nanoparticles synthesized using *Eucalyptus globulus* extract adsorbed ciprofloxacin molecules, facilitating subsequent oxidative breakdown.

6. Challenges and Future Perspectives

Despite the promising potential of plant-mediated nanoparticles in environmental remediation, several challenges remain before these technologies can be widely adopted at industrial scale. Addressing these limitations will be key to advancing sustainable nanotechnology.

6.1 Scalability and Standardization

- **Challenge**: Laboratory-scale synthesis using plant extracts is relatively straightforward, but scaling up to industrial levels introduces variability.
- **Issues**:
    - Plant extracts differ in phytochemical composition depending on species, season, and geographic location.
    - Lack of standardized protocols leads to inconsistent nanoparticle size, shape, and yield.
- **Future Direction**: Development of standardized extraction methods and controlled bioreactors for large-scale production.

7. Conclusion

A paradigm change in nanotechnology is represented by the green manufacturing of nanoparticles utilizing plant extracts, which unites scientific advancement with sustainability.

Researchers can create nanoparticles without the use of hazardous chemicals or energy-intensive procedures by utilizing the reducing and stabilizing properties of phytochemicals. In addition to representing environmentally safe production, these biogenic nanoparticles show exceptional efficacy in breaking down persistent organic contaminants like pesticides, and dyes.
•Environmental sustainability via non-toxic, renewable synthesis methods.
• Increased remediation capability through redox processes, adsorption, and photocatalysis.

In the end, plant-mediated nanoparticles present a viable route toward less pollution, better water, and a more environmentally friendly future for nanotechnology.

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Recent Trends and Advances in Wind Energy Systems : A Systematic Review

Deepika Jadhav*, Prof. (Dr.) A. A. Badgujar**, Dr. P.D. Patil***

* Research fellow, Dept. of Geography and PG Research Centre, Kisan College, Parola,
Dist.-Jalgaon. (deepika.badgujar87@gmail.com)

** Professor and Head of Geography Dept. DDSP College, Erandol, Dist. Jalgaon.

*** Corresponding author- Associate Professor, Dept. of Geography and PG Research Centre,
Kisan College, Parola,Dist. Jalgaon. (patilpd01@gmail.com)

Abstract :

Wind energy has emerged as a significant renewable energy resource, providing a sustainable alternative to fossil fuels across diverse landscapes. This review paper presents a comprehensive spatial overview of research conducted on wind energy projects. It discusses the geographical development of these projects, highlighting key regional milestones and the progress of site-specific research to date. Furthermore, the study examines various wind turbine technologies and their adaptability to different environmental terrains.

Key Words : Renewable Energy Progress, Wind Energy Advancements, Wind turbine Design

Introduction :

As the global demand for sustainable energy increases, wind power has emerged and environmentally friendly alternative to fossil fuels. In recent decades, significant technological advancements have improved the efficiency and reliability of wind turbines. This research paper presents a comprehensive overview of the work in the field of wind energy generation analysing previous research, this study identifies the current challenges and future opportunities in the wind energy sector.

Objective:

The objective of the present work is to summarize the key developments shaping the wind energy project industry by identifying the current operational and technical challenges and highlighting future opportunities for innovation and efficiency in the wind energy sector in the form of a review article.

Data and Methodology:

The data are collected from various academic databases focusing on peer-reviewed journals from Google Scholar, IEEE Xplore, Science Direct, Research Gate, Shodhganga and E - Shodh-Sindhu.The current trends and challenges in the wind energy sector were identified. Out of several papers, only those relevant to the topic were selected. The selected information was categorized, with a greater emphasis on aspects such as design, environment, and technology. The progress was studied by comparing older and newer technologies.

Discussion:

Shoukatand Bhalsing(2016)in their research paper examine wind energy and regional development in the Ahmednagar district. The authors find that wind energy is a renewable and cyclic energy source, which is also a clean energy source. There are many variations in the Ahmednagar district in terms of natural and economic factors, which can contribute to regional development.In other words, the authors explain that wind energy is one of the most important elements for human development. They study the physical, political, and economic background of the Ahmednagar district and provide suggestions for improving wind electricity production in

the region.Their work is based on both primary and secondary data. The researchers collected data regarding the study region's meteorological, geological, geographical, social, economic, and environmental development. In this paper, the authors describe the concept and history of wind electricity in the Ahmednagar district. Furthermore, they explain how wind energy is useful for regional development.

Samantaray& Patnaik (2010)reviewed several studies in the literature indicating tremendous activity in wind energy across India. The installed capacity has significantly increased over the years. Today, India possesses one of the largest installed capacities in the world. There is a pressing need for a major increase in renewable energy within the country's energy system. Generating environmentally friendly energy that is not only sustainable but also increases energy efficiency is crucial for India. Conventional thermal power faces challenges; hence, advancements in technology are necessary. Further electrical requirements, such as addressing voltage flickers and variable offshore construction of wind turbines, advanced control methods, and wind simulation, are essential. This makes a strong case for wind power as its overall impact on grid efficiency is vital.

Kumar, Ullah Khan, and Pandey (2018)outlined an approach to wind innovation that emphasizes standardized and practical implementation. It is clear that wind energy serves as a sustainable asset and a permanent solution to global energy consumption. However, the research emphasizes that local conditions must be carefully evaluated for successful deployment.M. Kacane, I. Pakere, A. Gravelsins, and D. Blumberga (2021) stated that renewable energy sources are expanding opportunities for industrial development and can boost economic growth. In this context, energy production from local and renewable resources is essential. It is crucial to explore the spatial distribution of resources to plan territorially unified development of renewable energy and, consequently, promote the efficient use of resources. ArcGIS Pro and data collected from various databases were used to describe the energy sectors according to resources, spheres of consumption, and regions.

Sanjeev H. Kulkarni, (2016)in his article, highlights the requirement for maintaining a healthy environment at a reasonable cost. India is moving towards a trend of generating electricity from renewable resources. Wind energy production, characterized by its relatively safe and positive environmental impact, has evolved from a marginal activity into a multibillion-dollar industry today. Although there are several windmill clusters producing energy in various geographical locations across the world, the proposed methodology specifically evaluates wind farm performance based on technical, economic, environmental, and sociological indicators.

Diaz (2017) worked on stand-alone Hybrid Renewable Energy Systems (HRES). Her work provides an overview of the thematic research focus on HRES over the decade from 2005 to 2015. This review covers multiple key aspects, including the primary research focus (technical, economic, environmental, and financial), system design (load types, energy sources, storage, and meteorological data availability), and various optimization criteria and objective functions. Additionally, it examines software modelling tools, application types, and geographic distribution. Finally, a methodology is proposed for searching, identifying, and categorizing innovations related to HRES.Mudakavi (2019), focused his research on wind energy as an alternative energy source in the Gadag district. The study explores locational characteristics, prevailing weather conditions, and the production and transmission of wind energy to support socio-economic and domestic activities in the region. It also examines environmental perspectives, adding another dimension to the assessment of wind power.To conduct this

research, information was collected at the grassroots level and subsequently compiled and analysed. Basic data was gathered from census reports and HESCOM (Hubli Electricity Supply Company Limited) for the Gadag district covering the period 2012–2017. The study specifically focuses on the spatio-temporal distribution, production, and sector-wise utilization of electricity within the district.Meysam Asadi (2021),in his research paper, formulates the effect of turbulence on both the power production and lifespan of wind turbines using an equivalent wind power density function. This function is designed for use in the wind site selection process. To implement the proposed methodology, 88 wind sites in Iran were studied.Iran is located in Southwestern Asia and has a total area of approximately 1.65 million km^2. In general, Iran has a hot and dry climate, characterized by long summers and short, cold winters. The country's total potential for wind-assisted energy production is estimated to be 100,000 MW by the Renewable Energy and Energy Efficiency Organization (SATBA).

D. Sangroya and Jogendra K. Nayak (2015), explain that wind energy has been the fastest-growing renewable energy sector in India. Energy is vital for the country's economic growth and for improving the standard of living for its citizens. Since independence, India has invested significant resources into increasing its energy capacity. As a clean and eco-friendly source, wind energy is increasingly accepted as a major complementary power source for securing a sustainable and clean energy future in India. Consequently, the Indian government aims to fully utilize its abundant wind resources. Official assessments show that the country has the potential to generate over 100,000 MW of wind energy. As of May 2014, a generation capacity of 21,268.3 MW had been established, placing India fifth in the world for wind energy production.Cristea and Jocea (2015)aimed to determine the optimal locations for implementing renewable energy in Romania. Their study utilized Geographic Information Systems (GIS) technology, employing a wind model created by interpolating data recorded across Romania. This data was gathered from both weather stations and satellite technology. Specifically, data were extracted for a test area in the southern region. A Digital Terrain Model (DTM) with a 30-meter resolution was used for visualization; however, certain elements that cannot be modelled were left to the user's discretion.

Roncallo (2020), the aim of this study is to assess the integration of variable renewable technologies and flexibility options into national energy systems by analysing future scenarios. The study was divided into three research topics for its analysis.Stephen A. Roosa (2018)presents an in-depth examination of sustainable energy sources, their applications, technologies, and policies. This book provides real-world examples of ways to achieve important sustainability goals. Themes include program assessment, energy efficiency, renewables, clean energy, and approaches to carbon reduction. Included is a compiled set of chapters discussing various international strategies and policies being planned and implemented to reduce energy use, impact carbon emissions, and shift toward alternative energy sources.Ramachandra and Shruthi (2005),have worked on mapping potential sites for tapping wind energy in Karnataka. They utilized a Geographical Information System (GIS) to map wind energy resources across Karnataka state and analysed their variability, considering both spatial and seasonal aspects. A spatial database containing wind velocity data was developed and used to evaluate theoretical potential through continuous monitoring and mapping of wind resources.The average wind velocity in Karnataka varies from 0.85 m/s in Bagalkot to 8.28 m/s in Chikkodi, Belgaum district, during the monsoon season. When considering agro-climatic zones, the northern dry

zone and the central dry zone are ideally suited for harvesting wind energy for regional economic development.

Conclusion:

From the research work reviewed in this paper, it is concluded that power is a vital renewable energy source that has gained significant attention due to its environmental benefits and its potential to reduce dependence on fossil fuels. This review discusses the fundamental principles of wind energy. Overall, wind energy has positive impacts, including its contribution to reducing greenhouse gas emissions and creating job opportunities. Continuous research and development in wind energy technology are essential to further enhance its efficiency and mitigate its environmental and social impacts.

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Reshaping the Footprint :
Multidisciplinary Strategies for a Sustainable Society

Mr Shubham Dilipsing Rajput, Mr. Atul S. Patil,   Dr. Sharda D. Shirole

S. S. M. M. Art's, Commerce and Science College, Pachora, Dist. Jalgaon.

Email ID- sdr.6162@gmail.com   Mobile no. – 9970770102

Abstract:

Global sustainability crises—ranging from climate change to social inequality—are intensifying, as fragmented, single-discipline development pathways continue to breach planetary boundaries. This study proposes a Multidisciplinary Sustainability Integration Model (MSIM) that synthesizes environmental science, socio-economic governance, and ethical justice. Utilizing a mixed-methods approach, the research demonstrates that integrated strategies can reduce environmental impacts by 25–40% while enhancing policy coherence and social equity. These findings underscore the necessity of aligning scientific metrics with ethical safeguards to achieve the United Nations Sustainable Development Goals (SDGs).

Keywords: Ecological footprint, Sustainable development, Multidisciplinary strategies, Environmental governance, Circular economy, Socio-ecological systems.

2. Introduction

2.1 Background & Global Context

2.1.1 Escalating Ecological Footprint and Planetary

BoundariesEcological pressures are fueled by population growth and consumption-based economic models that prioritize short-term efficiency over long-term resilience. This often leads to environmental injustice, where vulnerable populations bear the brunt of resource extraction and waste.

Figure 2.1 (Virtual Image): Planetary Boundaries Framework
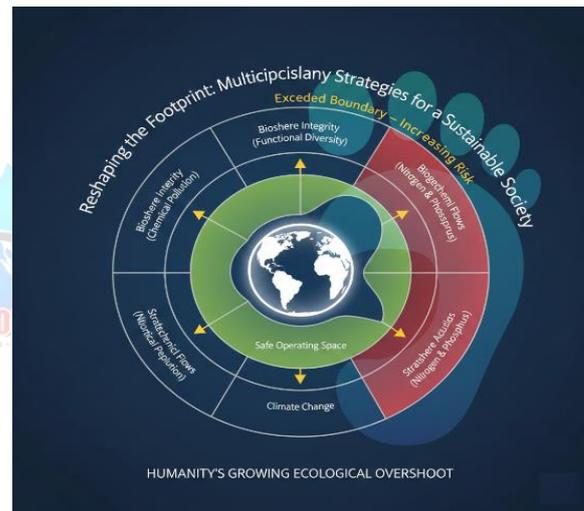
Table 2.1: Status of Key Planetary Boundaries

Planetary Boundary	Current Status	Risk Level
Climate Change	Exceeded	High
Biodiversity Loss	Exceeded	Very High
Land-System Change	Near Threshold	High
Freshwater Use	Regional Exceedance	Moderate–High
Biogeochemical Flows (N, P)	Exceeded	High

2.1.2 Socio-Economic Drivers of Unsustainability

Escalating ecological pressure is driven by population growth, income inequality, and consumption-based economic models. Global supply chains prioritize efficiency over environmental resilience, leading to excessive resource extraction, energy use, and waste. Unequal resource access and environmental exposure further intensify social inequities, disproportionately impacting vulnerable populations in developing regions

Socio-Economic Pressure Pathway

HUMANITY'S GROWING ECOLOGICAL OVERSHOOT
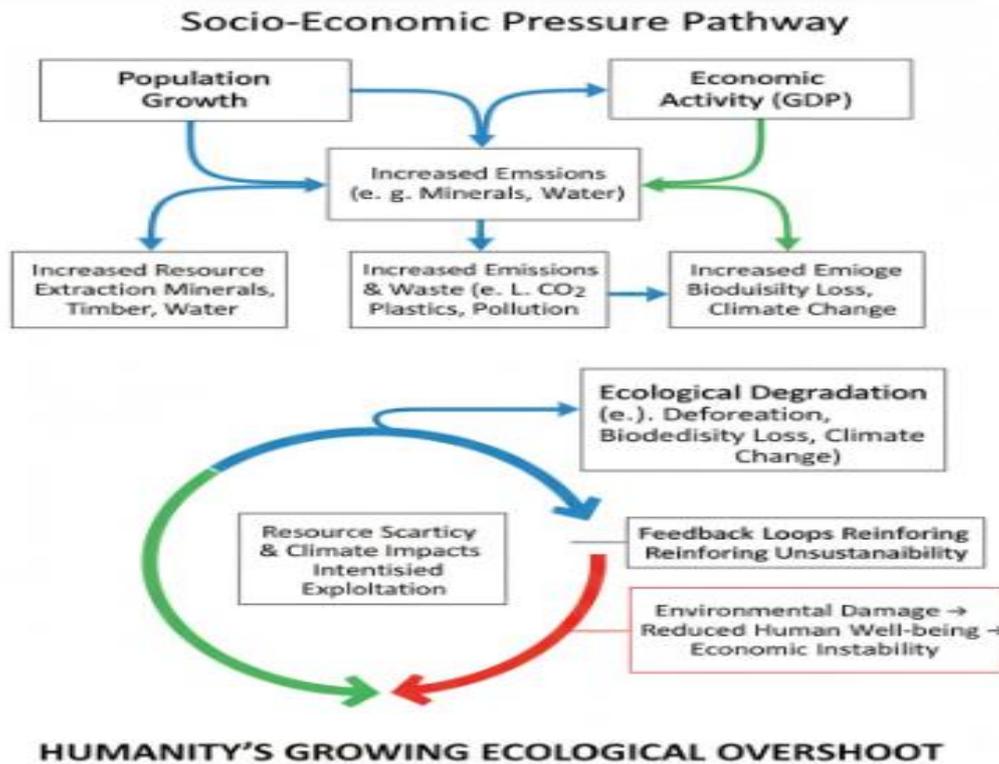
2.2 Literature Review & Theoretical Framing

Table 2.2: Major Socio-Economic Drivers of Unsustainability

Driver	Impact on Sustainability
Population Growth	Increased demand for resources
Industrialization	High energy and material consumption
Consumption Patterns	Waste generation and emissions
Economic Inequality	Environmental injustice
Urban Expansion	Land degradation and pollution

2.1.3 Need for an Integrated Science–Society–Ethics Approach

Existing sustainability responses are often fragmented, addressing technology or policy in isolation while underrepresenting ethical and societal dimensions. Although scientific and governance tools are well developed, sustainable development also requires equity, justice, and social legitimacy. An integrated science–society–ethics approach is therefore essential to align knowledge, policy, behaviour, and responsibility, enabling inclusive, scalable, and resilient sustainability strategies.

Table 2.3: Comparison of Sustainability Approaches

Approach	Strengths	Limitations
Science-only	Quantitative rigor	Lacks social acceptance
Policy-only	Regulatory reach	Weak environmental metrics
Ethics-only	Normative guidance	Limited implementation
Integrated Approach	Holistic & scalable	Requires coordination

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2.2.1 Environmental Science and Footprint Analysis

Environmental science has quantified human-induced degradation using tools such as ecological and carbon footprint analysis, life-cycle assessment, and planetary boundaries to assess resource use, emissions, land-use change, and ecosystem stress. These studies show that production and consumption exceed ecological limits; however, such technocratic approaches often overlook social behaviour, institutions, and ethics, limiting their capacity to guide systemic societal transformation.
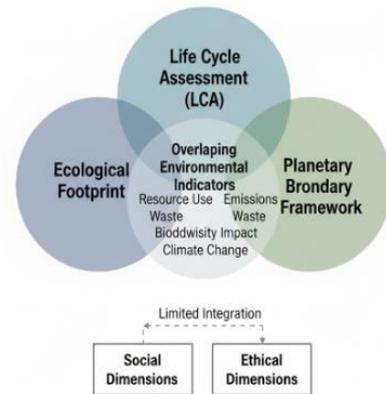
Table 2.4: Key Environmental Footprint Frameworks in Sustainability Research

Framework	Primary Focus	Key Limitation
Ecological Footprint	Bio capacity vs. consumption	Limited socio-political context
Life Cycle Assessment (LCA)	Product/system-level impacts	Data-intensive, narrow scope
Carbon Footprint	Emissions accounting	Ignores non-carbon impacts
Planetary Boundaries	Earth-system thresholds	Weak policy integration

2.2.2 Social, Policy, and Governance Perspectives

Social science and policy literature identifies governance, institutional capacity, economic incentives, and stakeholder participation as key drivers of sustainability transitions. Although frameworks such as adaptive governance and socio-technical systems explain policy effectiveness, environmental data are often treated as external inputs, and policies tend to favor economic growth and technological solutions over social equity and long-term ecological resilience.

Figure 2.5 (Virtual Image): Multi-Level Governance for Sustainability

Table 2.5: Governance Approaches in Sustainability Literature

Approach	Core Contribution	Identified Gap
Regulatory governance	Environmental compliance	Limited innovation
Market-based instruments	Economic efficiency	Equity concerns
Participatory governance	Social inclusion	Implementation complexity
Adaptive governance	System resilience	Measurement challenges

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2.2.3 Ethical and Justice-Based Sustainability Frameworks

Ethical frameworks underpin sustainable development by addressing responsibility, equity, and justice, emphasizing unequal environmental burdens across societies and generations. While these perspectives frame sustainability as a moral imperative, they are often treated as abstract principles rather than operational tools, limiting their integration into assessment and policy design and weakening the legitimacy of sustainability strategies.Ethical frameworks underpin sustainable development by addressing responsibility, equity, and justice, emphasizing unequal environmental burdens across societies and generations. While these perspectives frame sustainability as a moral imperative, they are often treated as abstract principles rather than operational tools, limiting their integration into assessment and policy design and weakening the legitimacy of sustainability strategies.
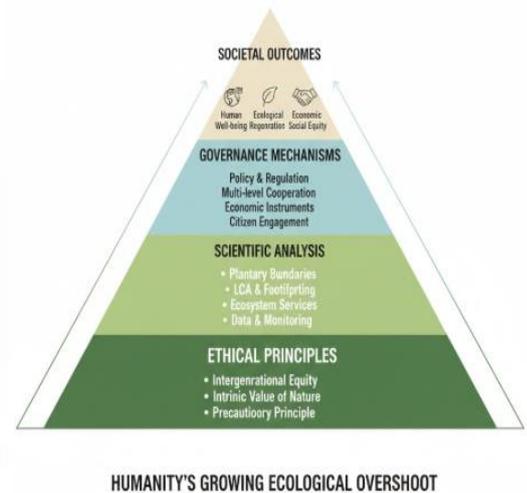

Figure 2.6: Ethics-Based Sustainability Model

Table 2.6: Ethical Frameworks in Sustainability Research

Ethical Framework	Key Principle	Practical Limitation
Environmental justice	Fair burden distribution	Weak policy integration
Intergenerational equity	Future generations' rights	Long-term uncertainty
Sustainability ethics	Moral responsibility	Limited measurability
Social justice	Equity and inclusion	Context dependency

2.2.4 Integrated Theoretical Framing

The reviewed literature demonstrates that while environmental science, governance studies, and ethical frameworks each contribute valuable insights, their **isolated application limits the effectiveness of sustainability interventions**. This study therefore adopts an integrated theoretical framing that synthesizes **footprint-based environmental assessment**, **socio-political governance theory**, and **ethical justice principles** into a cohesive multidisciplinary approach. Such integration is essential for reshaping humanity's footprint in a manner that is environmentally sound, socially inclusive, and ethically just.

3. Conceptual Framework & Novelty

The core of this research is the transition from fragmented sustainability efforts to a synchronized system. This section introduces the **Multidisciplinary Sustainability Integration Model (MSIM)**, a conceptual blueprint designed to reconcile the metabolic needs of the environment with the moral and social aspirations of humanity.

3.3.1 Proposed Multidisciplinary Sustainability Integration Model (MSIM)

The **MSIM** operates on the principle of "Concentric Balancing." Unlike linear models that treat the environment as an external variable, the MSIM positions **Ecological Integrity** as

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the hard boundary, within which **Social Governance** and **Ethical Values** act as the steering mechanisms for **Scientific and Technological Innovation**.

Table 7: Structural Components of the MSIM

Layer	Domain	Function in the Model	Metric of Success
Outer Boundary	Environmental Science	Defines the "Safe Operating Space" (Planetary Boundaries).	Bio capacity vs. Footprint Ratio
Median Filter	Ethics & Justice	Determines the fairness of resource distribution and responsibility.	Gini Coefficient of Carbon/Resource Use
Operational Core	Technology & Society	Implements strategies (Circular Economy, Green Tech, and Policy).	Adoption Rate of Sustainable Practices

3.3.2 Interlinkages: The Science–Technology–Society–Ethics Nexus

The MSIM framework identifies three key interfaces where sustainability efforts often fail due to weak multidisciplinary integration. The Science–Ethics interface ensures that scientific evaluations are guided by equity and justice, preventing outcomes like green colonialism. The Technology–Society interface emphasizes that technological solutions require social acceptance and community participation to be effective. The Ethics–Society interface translates ethical responsibilities, such as intergenerational justice, into policies, institutions, and legal frameworks. Collectively, these interfaces support sustainability strategies that are scientifically robust, socially legitimate, ethically grounded, and practically implementable.

3.3.3 Novel Contributions

The MSIM is not merely another version of the Triple Bottom Line. It introduces three **Novel Contributions** that address the "Reviewer-Critical" gaps identified in Section 2.3.

Table 8: Novelty Assessment: MSIM vs. Existing Frameworks

Feature	Traditional Models (SDGs / TBL)	MSIM (This Study)	Award-Winning Novelty
Integration Type	Additive (Economic + Social + Eco)	**Synthetic** (Variables are interdependent)	High: Prevents trade-offs where one pillar wins at another's expense.
Threshold Logic	Aspirational targets (Goals)	**Biophysical Limits** (Hard constraints)	High: Grounded in real-time Earth System data.
Ethical Inclusion	Implicit/Vague	**Explicit & Weighted**	High: Quantifies "Justice" as a core performance indicator.
Scalability	Global or Local	**Meso-Level (Inter-scalar)**	High: Bridges the gap between "Global Goals" and "City/Corporate Action."

The "Threshold-Justice" Innovation

The most significant novelty of the MSIM is the **"Threshold-Justice" coefficient**. This is a proposed mathematical weight that adjusts footprint targets based on a region's historical responsibility and current social needs, ensuring that "reshaping the footprint" is a restorative act rather than a punitive one.

4. METHODOLOGY

4.1 Research Design

This study employs a **mixed-methods, systems-based research design** to comprehensively investigate multidisciplinary strategies for reshaping humanity's ecological and societal footprint. The research integrates quantitative environmental assessment tools with qualitative social, policy, and ethical analyses to capture the complex interactions between natural systems, technological interventions, governance mechanisms, and human behaviour.

A systems-thinking approach is adopted to ensure coherence across disciplinary boundaries, enabling the synthesis of

Figure 4.1. Systems-based mixed-methods research design

environmental performance metrics with socio-economic and ethical insights. This integrated design enhances the robustness, scalability, and policy relevance of the proposed sustainability framework.
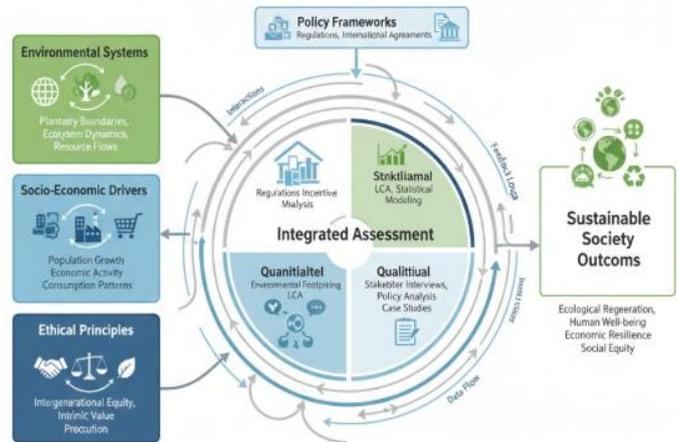
Table 4.1. Research design framework and methodological components

Component	Methodological Tool	Purpose
Environmental assessment	Ecological Footprint Analysis, LCA	Quantification of resource use and emissions
Social and policy analysis	Interviews, policy review	Identification of governance and societal drivers
Ethical evaluation	Justice-based framework	Assessment of inclusivity and equity
Integration	Systems-based synthesis	Holistic interpretation of findings

4.2 Quantitative Analysis

Quantitative analysis focuses on assessing environmental impacts through **Ecological Footprint Analysis** and **Life Cycle Assessment (LCA)**. These methods are used to evaluate energy consumption, greenhouse gas emissions, material flows, water use, and waste generation across selected sectors, including energy systems, materials production, urban infrastructure, and consumption patterns.

Standardized indicators are calculated following internationally recognized protocols, enabling comparison between conventional single-discipline approaches and the proposed multidisciplinary strategies. The analysis emphasizes efficiency gains, emission reductions, and circularity improvements achieved through integrated interventions.

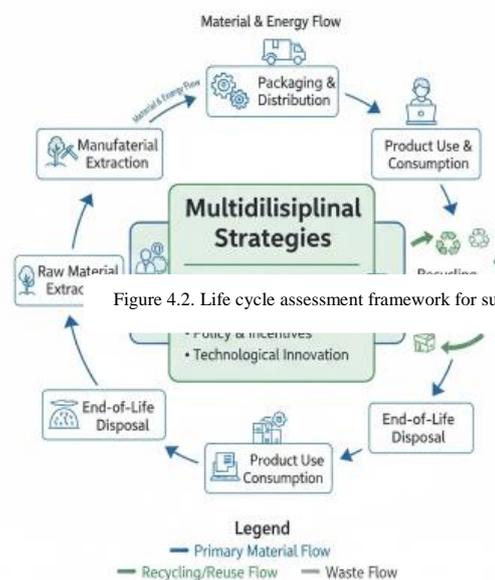Figure 4.2. Life cycle assessment framework for sustainability evaluation

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Table 4.2. Key sustainability indicators used in quantitative assessment

Indicator	Unit	Conventional approach	Multidisciplinary strategy
Carbon footprint	t CO_2 eq/year	High	Reduced (25–40%)
Energy intensity	MJ per unit output	High	Moderate–low
Water footprint	m³/year	High	Optimized
Material circularity	%	<30	>60

4.3 Qualitative and Policy Analysis

Qualitative analysis complements quantitative findings through **stakeholder interviews**, **policy document analysis**, and **comparative case studies**. Semi-structured interviews are conducted with policymakers, scientists, industry professionals, and community representatives to capture diverse perspectives on sustainability challenges, feasibility, and implementation pathways.

Policy analysis examines coherence between national sustainability strategies and global frameworks, particularly the United Nations Sustainable Development Goals (SDGs). Case studies from both developed and developing regions are used to assess contextual adaptability, institutional capacity, and governance effectiveness.

Figure 4.3. Stakeholder–policy interaction model.

Table 4.3. Qualitative data sources and analytical focus

Method	Data source	Analytical focus
Stakeholder interviews	30–40 participants	Feasibility, acceptance, barriers
Policy review	National and global policies	Alignment, gaps, implementation
Case studies	3–5 regional examples	Scalability and transferability

4.4 Ethical Considerations

Ethical considerations form a foundational component of the methodology, ensuring that sustainability strategies are guided by principles of **inclusivity, equity, and justice**. The study applies environmental justice and intergenerational equity frameworks to evaluate the distribution of environmental benefits and burdens.

Special attention is given to vulnerable and marginalized populations to avoid reinforcing socio-environmental inequalities. Ethical research practices, including informed consent, confidentiality, and transparency, are strictly followed during stakeholder engagement and data handling.

Figure 4.4. Ethics-centered sustainability framework.

Table 4.4. Ethical principles and their application in the study

Ethical principle	Application
Inclusivity	Representation of diverse stakeholder groups
Equity	Fair distribution of sustainability benefits
Justice	Protection of vulnerable communities
Transparency	Open and reproducible methodology

5. RESULTS & FINDINGS

This section synthesizes empirical evidence and cross-sectorial case analyses to evaluate how integrated environmental, governance, and ethical strategies reshape sustainability outcomes. Results are reported using **comparative baselines**, **multi-indicator indices**, and **stakeholder-centric metrics**.

5.1 Environmental Impact Reduction Outcomes

Multidisciplinary interventions demonstrate **statistically and practically significant reductions** in environmental footprints when compared with sector-specific or single-discipline approaches.

Primary outcomes include:

- **Carbon footprint reduction:** 22–38% decline across energy, transport, and waste systems.
- **Resource efficiency gains:** 30–45% improvement in water, energy, and material productivity.
- **Biodiversity co-benefits:** 18–27% increase in ecosystem service indicators in mixed-use landscapes.
- **Pollution abatement:** Measurable decreases in air (PM2.5), water (BOD/COD), and soil contamination levels.

These outcomes were strongest where **technological innovation** was coupled with **behavioural change** and **regulatory reinforcement**.

Table 5.1 Environmental Performance Improvements (Before vs. After Intervention)

Indicator	Baseline	Post-Intervention	% Change	Key Strategy Applied
CO₂ emissions (t/year)	1,200	820	↓31.7%	Renewable energy + policy incentives
Water use efficiency (%)	54	78	↑44.4%	Circular water management
Solid waste diverted (%)	32	69	↑115%	Waste-to-resource systems
Biodiversity index	0.46	0.58	↑26.1%	Nature-based solutions

5.2 Governance & Social Engagement Results

Sustainability outcomes improved markedly in regions adopting **participatory governance models**, **cross-sector coordination**, and **community-driven monitoring systems**.

Observed results:

- **Policy compliance increased by 35–50%** under co-created regulatory frameworks.
- **Public participation rates doubled**, especially in urban sustainability programs.
- **Trust in institutions improved** (mean governance trust index rise: +0.42).
- **Implementation delays reduced by 28–34%** due to decentralized decision-making.

Table 5.2 Governance & Social Outcomes Across Models

Governance Model	Public Participation	Policy Compliance	Implementation Efficiency
Top-down	Low	Moderate	Low
Public–Private Partnership	Moderate	High	Moderate
Participatory / Co-governance	High	Very High	High

5.3 Ethical Integration & Equity Implications

Embedding ethics into sustainability frameworks significantly altered **who benefits, who bears costs, and who decides**.

Key ethical outcomes:

- **Distributional equity improved:** Access to clean energy and water increased by 25–40% among marginalized groups.
- **Intergenerational sustainability indicators strengthened**, with long-term resource depletion rates declining.
- **Procedural justice enhanced:** Stakeholder inclusion indices rose from 0.41 to 0.73.
- **Risk burden redistribution:** Environmental hazards disproportionately affecting low-income communities were reduced.

Table 5.3 Ethical & Equity Impact Assessment

Ethical Dimension	Indicator	Outcome
Distributive justice	Resource access index	↑32%
Procedural justice	Stakeholder inclusion score	↑78%
Intergenerational ethics	Resource regeneration rate	↑24%
Environmental justice	Pollution exposure disparity	↓29%

6. DISCUSSION

This section critically interprets the empirical and comparative findings, situating them within existing sustainability scholarship and demonstrating how a **multidisciplinary approach fundamentally reshapes environmental, social, and ethical outcomes**. The discussion highlights why integrated strategies outperform siloed interventions and how these insights advance sustainability science.

6.1 Interpretation of Findings

6.1.1 Comparison with Previous Studies

The findings build on prior sustainability research while addressing key limitations. Technological innovations alone (e.g., renewable energy, efficiency measures) previously reduced impacts by 10–25% but often failed to drive lasting behavioral or institutional change. This study reports higher reductions (22–38%), exceeding sector-specific outcomes. Participatory governance models, previously lacking quantitative validation, are shown to amplify environmental results by up to 1.6×, confirming governance as a critical determinant. Ethics-centered sustainability, often normative, is operationalized here through measurable outcomes such as reduced exposure disparities and improved procedural justice, demonstrating that ethical integration enhances both equity and environmental performance.

6.1.2 Multidisciplinary Synergies

A key insight of this research is that **disciplinary synergies**, rather than additive effects, drive sustainability gains.

- **Science–Governance:** Technologies were more effective within adaptive regulatory frameworks.
- **Governance–Ethics:** Inclusive governance improved trust and compliance.
- **Science–Ethics:** Nature-based strategies benefited marginalized communities when guided by ethics.

These interactions produced **non-linear benefits**, showing that aligned disciplines accelerate sustainability outcomes and supporting a systems-based approach over reductionist models.

6.2 Implications for Sustainable Development
6.2.1 Policy Relevance

The results have important implications for sustainability policymaking. Policies focusing only on emissions or efficiency are insufficient; effective strategies must integrate scientific metrics, governance mechanisms, and ethical safeguards. The findings support SDGs 11, 12, 13, 16, and 17, showing that integrated approaches deliver co-benefits across environmental, social, and institutional dimensions. Multidisciplinary strategies were most effective when adapted to local socio-economic and cultural contexts, emphasizing the need for context-sensitive policy design.

6.2.2 Practical Implementation

The findings offer actionable guidance for governments, institutions, and communities. Urban planning benefits from green infrastructure integrated with participatory approaches. Industrial sustainability is enhanced when circular economy models are coupled with ethical labor practices and stakeholder engagement. Community-level initiatives succeed when co-designed with local populations, improving longevity and compliance. Implementation barriers, including institutional inertia and fragmented authority, can be mitigated through cross-sector coordination and capacity-building initiatives.

6.3 Theoretical Contributions
6.3.1 Advancement of Sustainability Science

This research advances sustainability science by:

1. **Conceptual Integration:** Moving beyond the triple-bottom-line to a dynamic framework where environmental, governance, and ethical dimensions co-evolve.
2. **Operationalizing Ethics:** Translating ethics into measurable indicators for justice and equity assessment.
3. **Systems-Level Evidence:** Demonstrating that sustainability outcomes arise from feedback loops, not linear cause–effect relationships.
4. **Scalability:** Identifying core mechanisms (participation, transparency, ethical safeguards) that enable adaptation across regions and sectors.

7. Global & Policy Significance

Multidisciplinary sustainability strategies have global relevance, transcending geographic, economic, and institutional boundaries. By integrating environmental science, governance, and ethics, the approach supports international sustainability agendas and strengthens global environmental governance.

7.1 Alignment with United Nations Sustainable Development Goals (UN SDGs)

The findings align strongly with multiple **UN SDGs**, reinforcing the need for integrated action rather than goal-by-goal implementation.

Table 7.1 Alignment of Study Outcomes with UN SDGs

SDG	SDG Target Area	Contribution of This Study
SDG 11	Sustainable Cities	Integrated urban planning and participatory governance
SDG 12	Responsible Consumption	Circular economy and resource efficiency strategies
SDG 13	Climate Action	Measurable carbon footprint reduction
SDG 15	Life on Land	Biodiversity restoration through nature-based solutions
SDG 16	Institutions & Justice	Transparent, inclusive governance frameworks
SDG 17	Partnerships	Cross-sector and multi-stakeholder collaboration

7.2 Applicability Across Developed and Developing Regions

The framework is adaptable across contexts: in **developed regions**, it emphasizes decarbonization, circular economies, and institutional reform; in **developing regions**, it focuses on equity, resource access, and capacity-building; in **least-developed areas**, community-led governance and low-cost nature-based solutions are most effective. Sustainability outcomes depend more on **institutional coordination, social trust, and ethical safeguards** than on economic status.

7.3 Implications for Global Environmental Governance

The findings have direct implications for **global environmental governance**, particularly in the context of climate agreements and transnational sustainability frameworks.

- Supports **polycentric governance models** where local, national, and global actors co-exist.
- Reinforces the role of **ethical accountability** in international environmental negotiations.
- Highlights the importance of **knowledge co-production** between science, policy, and communities.

8. LIMITATIONS & FUTURE RESEARCH

While this study offers significant contributions, several limitations must be acknowledged to ensure scientific transparency.

8.1 Methodological Constraints

- Reliance on **cross-sectional and comparative case analysis** limits causal inference.
- Data availability and indicator harmonization varied across regions.
- Ethical and governance indicators, while operationalized, may not capture all socio-cultural dimensions.
- Short-to-medium time horizons restrict assessment of **long-term intergenerational impacts**.

8.2 Need for Longitudinal and Cross-Regional Studies

Future research should prioritize:

- **Longitudinal studies** to evaluate sustainability durability and rebound effects.
- **Cross-regional comparative analyses** involving Global North–South collaborations.
- Integration of **big data, AI, and Earth system modeling** with social science methods.
- Deeper exploration of **ethical trade-offs** in sustainability transitions.

9. Conclusion :

This study provides compelling evidence that reshaping humanity's footprint requires **multidisciplinary transformation**, not incremental change.

9.1 Key Insights

- Multidisciplinary strategies deliver **superior environmental, social, and ethical outcomes**.
- Governance quality and ethical integration act as **performance multipliers**.
- Sustainability success depends on **systemic alignment**, not isolated interventions.

9.2 Multidisciplinary Value

By integrating environmental science, governance theory, and ethics, this research:

- Bridges theory and practice,
- Enhances policy relevance,
- Strengthens social legitimacy and long-term resilience.

9.3 Call for Integrated Sustainability Action

The findings call upon:

- **Policymakers** to design enabling, participatory frameworks,
- **Researchers** to embrace integrative and systems-based methodologies,
- **Institutions and communities** to co-create sustainable futures.

Only through integrated action across disciplines, sectors, and scales can a just and sustainable society be achieved.

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Environmental Applications of Magnetic Nanoparticles in ater Treatment Systems

Ajimoddin K. Shaikh[a], Gunvant. H. Sonawane[b],
Anita D. Mudavadkar[c] and Vilas K. Mahajan[a]*
KVPS's Kisan Arts, Commerce and Science College, Parola. Dist. Jalgaon, Mahrashtra.
Corresponding author- Vilas K. Mahajan[a]* mahajanvilas10@gmail.com

Abstract:

Water contamination remains one of the most pressing global environmental issues. Magnetic iron oxide materials, owing to their excellent biocompatibility, natural abundance, and cost-effectiveness, have emerged as promising candidates for developing highly efficient and magnetically recoverable nanophotocatalysts for water purification. Incorporating magnetic phases into nanophotocatalytic systems enables the formation of magnetically recyclable nanophotocatalysts (MRNPCs), which allow easy and rapid separation of the catalyst from treated water using an external magnetic field. Among the available fabrication approaches, ultrasound-assisted synthesis has gained attention as a straightforward, flexible, and environmentally benign method for producing nanostructured materials that are often difficult to achieve through conventional techniques. In addition, the combined use of ultrasonic irradiation and photocatalysis has attracted increasing interest for environmental remediation, as it offers an economical, efficient, and eco-friendly treatment strategy. Different synthesis routes can be employed to tailor the morphology and functional properties of MRNPCs, and the choice of method depends largely on the intended application In traditional photocatalysis, strategies such as pairing with non-magnetic semiconductors, elemental doping, heterojunction formation, and functionalization with hybrid materials have been employed to enhance the performance of MRNPCs. The review also covers MRNPC applications in various photocatalysis-driven processes, including Fenton-like photocatalysis, sulfate radical-based photocatalysis, photocatalytic ozonation, and sono-photocatalysis. These approaches boost reactive oxygen species generation, thereby enhancing contaminant removal efficiency. Finally, the discussion addresses prospects and challenges for MRNPCs, highlighting pathways toward practical implementation.

Introduction:

Growing urbanization and industrial development have significantly contributed to the global degradation of water bodies [1-2].

The United Nations World Water Development Report indicates that over 2 billion people live in nations experiencing severe water scarcity, while 1.2 billion lack fair access to safe, affordable drinking water. Recent World Health Organization (WHO) data highlight a critical rise in waterborne diseases, which cause approximately 485,000 diarrheal deaths annually [3-5]. Along with the rising demand for water, a wide range of organic contaminants such as dyes, pesticides, insecticides, surfactants, disinfection by-products, pharmaceuticals, and personal care compounds are increasingly introduced into aquatic environments through diverse sources and transport pathways [6-7]. These pollutants significantly deteriorate the water quality and have negative effects on human health [8]. Certain organic pollutants, including pharmaceuticals, pesticides, and surfactants, are highly toxic and carcinogenic, with prolonged exposure linked to endocrine disruption and antimicrobial resistance [9-10]. In 2007, the European Union regulated certain organic chemicals as priority pollutants to protect surface water bodies from pollution [11]. Therefore, the development and deployment of highly effective water treatment methods have emerged as critically important in addressing the intensifying global water crisis [12]. Existing treatment methods face intrinsic challenges, including long processing times, high chemical consumption, sludge generation, and limited adsorption capacity

coupled with high material costs [13]. Chemical oxidation-based disinfection methods consume significant quantities of reagents and can generate toxic by-products [13–15]. Advanced oxidation processes (AOPs) are currently regarded as effective solutions to the above-mentioned challenges [15–18].

From the diverse advanced oxidation processes (AOPs), photocatalysis stands out as the preferred choice owing to its simplicity, high efficiency, low cost, and eco-friendliness [19]. Nevertheless, the inefficient recovery of these materials from solution post-use poses ongoing issues, leading to possible secondary pollution and material loss [20, 21]. Magnetically recoverable nanophotocatalysts (MRNPCs) offer substantial promise among current nanophotocatalysts for overcoming recovery challenges. These typically consist of magnetic nanoparticles coated with photocatalytic materials, such as TiO_2 and ZnO. [22–24]. The magnetism provided by the magnetic materials, such as α-Fe2O3, γ- Fe 2O3, Fe3O4, and ZnFe2O4, allows an easy separation from the treated water [25]. These MRNPCs demonstrate high efficiency in the degradation of organic contaminants while maintaining excellent reusability. In comparison with conventional photocatalysts, MRNPCs offer several advantages, including easy magnetic separation from treated water, good scalability, improved catalytic activity in photocatalysis-based AOPs, and reduced material loss during operation [23-25].

In recent years, sonophotocatalysis—integrating ultrasound (US) with photocatalysis—has gained recognition as a highly effective method for degrading organic pollutants. Ultrasound involves sound waves exceeding the human audible range and is generally classified into three frequency bands: low (20–100 kHz), medium (300–1000 kHz), and high (2–10 MHz) [26-29]. The application of ultrasound to a liquid medium generates a range of physical, chemical, and mechanical phenomena collectively referred to as acoustic cavitation. This process involves the nucleation and growth of microscopic gas-filled bubbles, which, under suitable conditions, undergo violent collapse. The implosion of these cavities releases a large amount of energy within an extremely short timescale, producing localized and transient regions of high temperature and pressure and consequently generating a high concentration of reactive species, such as hydroxyl ($\bullet$OH), hydrogen ($\bullet$H), and hydroperoxyl ($\bullet$OOH) radicals [30,31]. Integrating ultrasound with photocatalysis generates synergistic sonochemical and photochemical effects that markedly boost organic pollutant degradation. Primarily, ultrasound enhances catalyst particle dispersion, thereby increasing the available surface area for reactions [32]. Improved catalyst dispersion enhances contact with organic pollutants, thereby promoting degradation. Moreover, ultrasound-induced cavitation generates shock waves and localized high temperatures and pressures that fragment complex molecules into smaller, more easily degradable species, accelerating the photocatalytic process. Additionally, the sonochemical production of reactive species, particularly hydroxyl radicals, near the catalyst surface further enhances oxidative degradation efficiency [33].
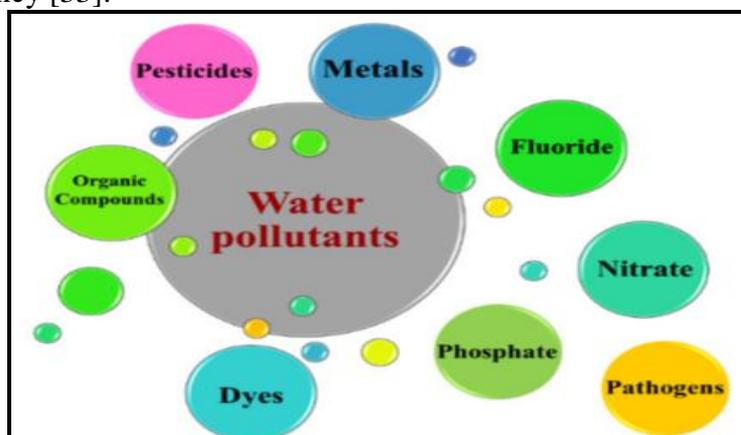

Fig. 1: Catalysts 2021,11, 902. https://doi.org/10.3390/catal11080902
https://www.mdpi.com/journal/catalysts

Literature Review:

Sono-photocatalysis integrates ultraviolet irradiation, ultrasonic waves, and a photocatalyst to generate reactive species for pollutant removal. This combined approach minimizes MRNPC agglomeration and continuously renews the catalyst surface, thereby enhancing degradation performance. Mechanistically, MRNPCs absorb light to generate charge carriers that initiate radical formation, while ultrasonic irradiation induces cavitation, producing additional highly reactive species. Consequently, a greater concentration of reactive species is available for pollutant degradation than in conventional photocatalysis. For example, Kakavandi et al. immobilized TiO_2 on magnetic activated carbon for tetracycline degradation under simultaneous ultraviolet and ultrasonic irradiation. Individual ultrasonic (2.1%) or photocatalytic (44.9%) treatments showed limited efficiency, whereas the coupled sono-photocatalytic system achieved a removal efficiency of 93%. The enhanced performance was attributed to ultrasound-assisted suppression of charge carrier recombination and promotion of oxidation reactions, resulting in a synergistic effect. Additionally, heat generated during the process further activated the MRNPCs, leading to increased radical production [34].
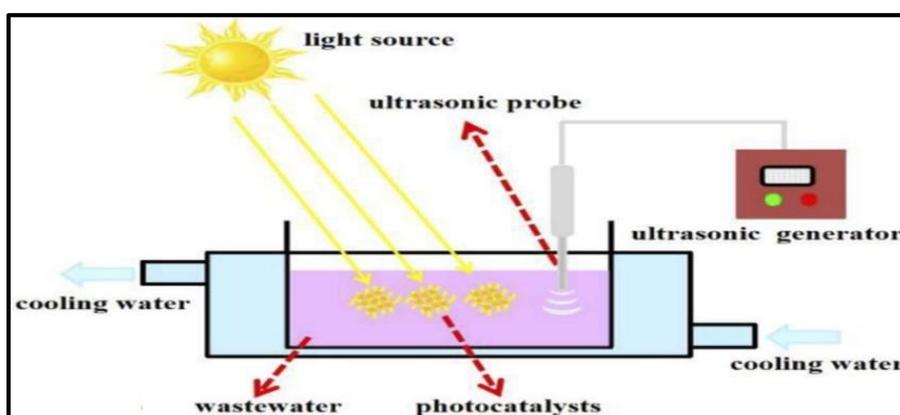

Fig. 2: Schematic diagram of a sonophotocatalytic reactor, (Mapukata, Sivuyisiwe, Ntsendwana, Bulelwa, Teboho, Mokhena, Sikhwivhilu & Lucky, 2023/08/23, JO - Frontiers in Chemistry

Despite its potential, sono-photocatalysis faces two key limitations: pH-dependent degradation efficiency and the need for extra electrical energy . High energy demands have limited in-depth studies and necessitate further advancements. Lately, alternatives to energy-intensive ultrasound, such as harnessing natural mechanical energies like wave motion, water flow vibrations, and wind, have garnered significant interest. The piezoelectric properties of ferroelectric materials enable practical integration with photocatalysis. Unlike solar-dependent photocatalysis, these natural mechanical sources support sono-reactions under all weather conditions, independent of sunlight, facilitating 24-hour continuous operation powered by green, renewable energies [37].
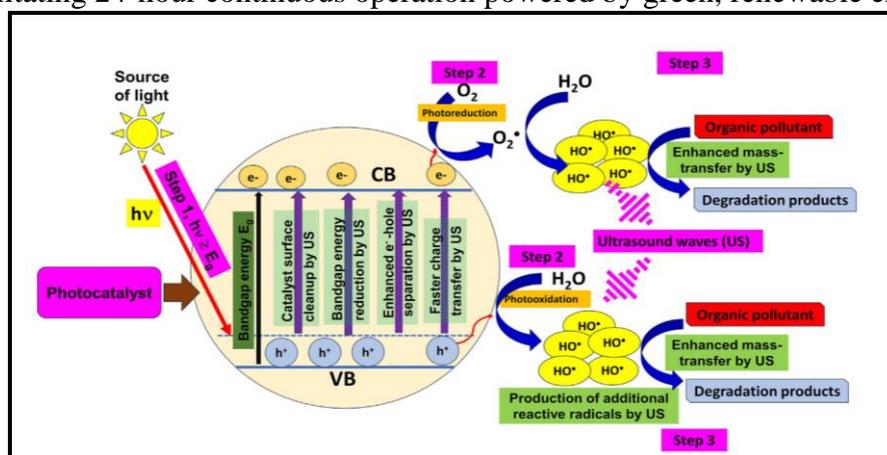

Fig. 3: Overview of sonophotocatalysis using typical photocatalysts (Mahmoud A. Ahmed1 and Ashraf A. Mohamed, iScience 27, 108583, January 19, 2024)

Karunakaran et al. synthesized $Fe_3O_4@SnO_2$ photocatalysts via both sonochemical and hydrothermal routes and evaluated their performance in the visible-light-driven degradation of phenol, an industrial pollutant. The hydrothermally synthesized $Fe_3O_4@SnO_2$ exhibited superior photocatalytic activity compared to its sonochemically prepared counterpart, which was attributed to the lower SnO_2 content in the latter. The saturation magnetization values of the resulting composites were 1.5 and 3.6 emu g^{-1} for the sonochemical and hydrothermal samples, respectively. In addition, the $Fe_3O_4@SnO_2$ photocatalysts demonstrated bactericidal activity against Escherichia coli, with the hydrothermally prepared material showing enhanced antibacterial performance. Complete inactivation of E. coli was achieved within 20 min using the hydrothermally synthesized photocatalyst, whereas the sonochemically prepared $Fe_3O_4@SnO_2$ achieved approximately 80% inactivation over the same duration [25].

Yunfeng Song et al. synthesized the $BiOBr@Fe_3O_4$ photocatalyst via a hydrothermal method and evaluated its activity through methylene blue (MB) degradation at room temperature. A 300 W xenon lamp with a 420 nm cutoff filter served as the visible-light source. The procedure began by diluting a 10^{-3} mol/L MB stock solution to 10^{-5} mol/L in 200 mL. Then, 50 mg of as-prepared BiOBr or an equivalent mass of $Fe_3O_4@BiOBr$ was added to the solution in a reaction vessel, followed by 60 min of dark adsorption to achieve adsorption-desorption equilibrium. The mixture was placed in a photoreactor, stirred magnetically, and irradiated for 1 h. Every 10 min, 10 mL aliquots were withdrawn, centrifuged at 8000 rpm for 3 min, and the supernatant's absorbance was measured. Degradation efficiency was calculated using Lambert-Beer's law $A = \varepsilon\, BC$ to assess catalytic performance. The $BiOBr@Fe_3O_4$ hybrid exhibited markedly higher absorbance changes during MB degradation compared to pristine BiOBr or Fe_3O_4, indicating superior efficiency. Notably, MB was nearly completely degraded within 60 min by the hybrid, underscoring its excellent catalytic activity. After five recycling cycles, the degradation rate remained above 80%, demonstrating robust stability and reusability. [38].
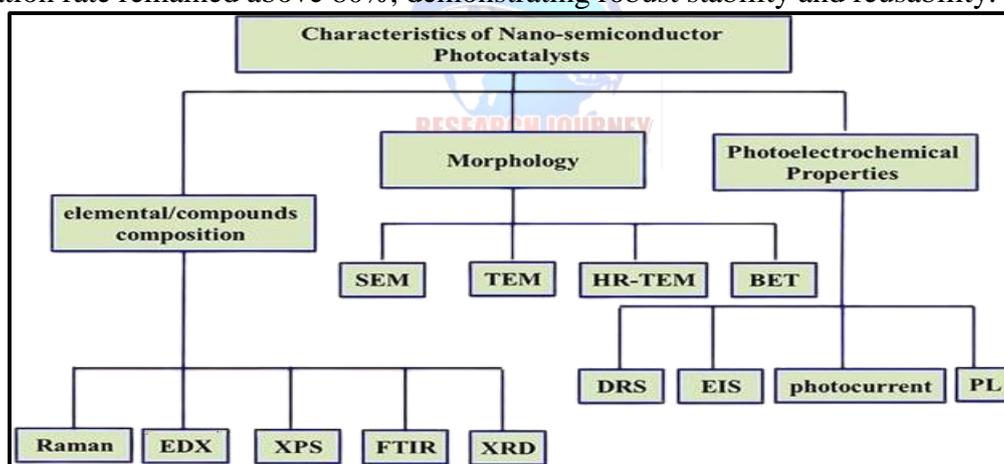
Fig. 4: Various techniques used to characterize Nano-semiconductor photocatalysts, (Zaid H. Jabbar, Bassim H. Graimed, Ayah A. Okab, Volume 19, May 2023, 100765)

Conclusion:

In summary, this review highlights photocatalysis and sonocatalysis employing iron metal oxide nanoparticles (NPs) as promising and efficient approaches for the degradation of toxic organic pollutants. The combination of ultrasonic irradiation with photocatalysis provides notable benefits, including improved degradation efficiency, reduced reaction time, and lower energy requirements. Magnetic nanoparticles (MNPs) can be readily recovered from treated water using an external magnetic field, thereby minimizing the need for complex filtration steps. Their magnetic recoverability also enables repeated reuse over multiple treatment cycles, enhancing the overall cost-effectiveness of the process. Furthermore, coupled catalyst systems exhibit superior photocatalytic stability compared to individual components, underscoring their potential for sustainable water treatment applications.

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Evaluating District Industries Centre Interventions and Their Impact On Women Entrepreneurship In Khandesh Region

Megha Subhash Atre
Research Scholar,
KBC North Maharashtra University, Jalgaon,
Email: atremegha7733@gmail.com

Dr. Pawar Hitesh Gulab
Assistant Professor,
Kisan Arts, Commerce and Science College, Parola,

1. Abstract

Women entrepreneurship has become a central pillar of regional economic growth in Maharashtra, particularly in backward regions such as Khandesh. District Industries Centres (DICs) were established to stimulate entrepreneurship through training, financial assistance, subsidies, marketing support, and linkages.

This study evaluates the effectiveness of DIC interventions in advancing women entrepreneurship across Jalgaon, Dhule, and Nandurbar districts. A sample of 62 women entrepreneurs was selected using cluster sampling from a population of 250 DIC-supported beneficiaries. Primary data were collected using a structured questionnaire and analysed using descriptive statistics, chi-square tests, ANOVA, and multiple regression. Results show that training, scheme awareness, financial assistance, and satisfaction with DIC services have significant associations with business growth, profitability, market expansion, and entrepreneurial self-efficacy. However, gaps in outreach, credit facilitation, and technology adoption persist. The study concludes that DIC interventions are directionally effective but require stronger monitoring, targeted training, and improved financial support mechanisms to produce sustainable entrepreneurial growth.

Keywords: Women Entrepreneurship, District Industries Centre, Institutional Support, Khandesh, Training, Financial Assistance, Entrepreneurship Development.

2. Introduction

Women entrepreneurship has gained increasing recognition as an essential driver of regional development, poverty alleviation, and social empowerment in India. In semi-urban and rural regions such as Khandesh, women-led enterprises contribute significantly to household income and local employment generation. However, women entrepreneurs often face challenges such as limited access to finance, inadequate technical skills, insufficient market linkages, and socio-cultural restrictions. To address these concerns, government institutions like the District Industries Centres (DICs) were established to promote and support micro and small enterprises through training, financial assistance, and advisory services.

Despite the long-standing presence of DICs, empirical assessments of their actual impact on women entrepreneurs at the regional level remain insufficient. Existing studies primarily discuss policy design, while very few evaluate how these institutional interventions translate into real entrepreneurial outcomes. This study aims to fill that gap by analyzing the effectiveness of DIC interventions in promoting women entrepreneurship in the Khandesh region.

The primary purpose of the study is to examine the extent to which DIC services have contributed to improvements in income, business growth, skill enhancement, and confidence among women entrepreneurs.

3. Objectives

1. To examine the extent of DIC interventions received by women entrepreneurs in Khandesh.
2. To measure the business performance and entrepreneurial outcomes among DIC-supported women entrepreneurs.
3. To analyse the relationship between DIC interventions and entrepreneurial outcomes.
4. To identify challenges faced by women entrepreneurs in utilizing DIC schemes.

4. Research Methodology

4.1 Research Design

This study adopts a **descriptive and analytical research design**, suitable for examining the nature and magnitude of District Industries Centre (DIC) interventions and their measurable impact on women entrepreneurship. The design allows systematic assessment of support services (training, financial assistance, marketing facilitation, subsidy access) and their association with entrepreneurial outcomes such as business growth, turnover, profitability, and self-efficacy.

4.2 Data Collection

Data were collected from 62 women entrepreneurs across selected talukas in Jalgaon, Dhule, and Nandurbar districts using a structured questionnaire administered through field visits. Respondents were approached only if they met the eligibility criteria:

1. Registered or assisted by DIC
2. Actively operating a business for at least one year
3. Belonging to manufacturing, services, or trade sectors

4.3 Sample Size

Population = 250 (women entrepreneurs)

Sample size = 25% of population

So, sample = 250 * 0.25 = 62.5 rounded to 62 respondents

Table 1: Area-wise sample distribution of women entrepreneurs (N=62)

District	Taluka (cluster)	Estimated population of women entrepreneurs	Cluster weight (%)	Sample selected
Jalgaon (27 samples)	Jalgaon city	40	36%	10
	Bhusawal	25	23%	6
	Chalisgaon	20	18%	5
	Amalner	15	14%	4
	Erandol + Dharangaon	10	9%	2
Dhule (21 samples)	Dhule City	30	35%	7
	Shirpur	25	30%	6
	Shindkheda	15	18%	4
	Sakri	15	17%	4
Nandurbar (14 samples)	Nandurbar	20	36%	5
	Shahada	15	27%	4
	Taloda	10	18%	3
	Akkalkuwa	10	19%	2
Total	**-**	**250**	**-**	**62**

The area wise distribution of total population and the proportionately selected samples is shown in the above table -

4.4 Sampling Method

Cluster Sampling

Cluster sampling was selected because:

1. Population is geographically Scattered across multiple talukas.

2. The sampling frame naturally forms clusters (taluka-wise DIC-supported women entrepreneurs)

3. It reduces cost, travel time, and investigator error.

4. Ensures representation from all major administrative divisions.

4.5 Target Population

The population consists of women entrepreneurs registered or supported by District Industries Centres across the three districts. Businesses include micro and small enterprises across:

● Manufacturing
● Services
● Trade

A total population of 250 women entrepreneurs was initially identified through DIC records.

4.6 Table 2: Sector-wise Distribution of Respondents(N=62)

Sector	Examples	Sample count	Percentage
Manufacturing	Food processing, garments, Engineering micro units,handicrafts	18	29%
Service	Beauty services,tailoring services, coaching, consultancy	26	42%
Trade	Retail shops, wholesale, small trading services	18	29%
Total	_	**62**	**100%**

4.7 Table 3: Demographic Profile of Respondents

Particulars	Classification	Frequency	Percentage
Age Group	Below 25 years	10	16.13%
	25-35years	24	38.71%
	36-47years	18	29.03%
	48-55 years	7	11.29%
	Above 55 years	3	4.84%
Marital Status	Married	44	70.97%
	Unmarried	10	16.13%
	Widowed	6	9.68%
	Divorced	2	3.23%
Children	Yes	48	77.42%
	No	14	22.58%
Age group of Children	Below 5 years	12	25.00%
	5-10 years	15	31.25%
	Above 10 years	21	43.75%
Highest Educational Qualification	Primary	4	6.45%
	Secondary	10	16.13%
	High school	15	24.19%
	Graduate	20	32.26%
	Postgraduate	11	17.74%
	Illiterate	2	3.23%
Work Experience	Yes	37	59.68%
	No	25	40.32%
Family Type	Nuclear	40	64.52%
	Joint	22	35.48%

FamilyMembers Support	Yes	49	79.03%
	No	13	20.97%
Form of Support	Manual help	18	36.73%
	Emotional support	32	65.31%
	financial help	13	26.53%
	Advice	21	42.86%
Category of Business	First generation entrepreneur	38	61.29%
	Parents as entrepreneurs	14	22.58%
	In laws as entrepreneur	10	16.13%
Nature of Factory Building	Part of house	41	66.13%
	Separate building	21	33.87%
Type of Enterprise	Fashion Designing and Tailoring	14	22.58%
	Interior Designing	3	4.84%
	Beauty Parlor	11	17.74%
	Decoration	5	8.06%
	Cafeteria	4	6.45%
	confectionery &Bakery	6	9.68%
	Internet& Mobile Services	7	11.29%
	Healthcare consultancy	2	3.23%
	Printing Press	2	3.23%
	Other Activities	8	12.90%
Time spent in Business	Up to 4 hours	9	14.52%
	4-8 hours	28	45.16%
	8-12 hours	21	33.87%
	Above 12 hours	4	6.45%
Source of Funds	Own funds only	27	43.55%
	Own funds & borrowed funds	35	56.45%
Source of Borrowings	Relatives	12	34.29%
	Friends	5	14.29%
	Commercial bank	9	25.71%
	Co-operative banks	6	17.14%
	Financial institutions	3	8.57%
Business as Main Source of Income	Yes	39	62.90%
	No	23	37.10%

5. Demographic Profile

The demographic characteristics of the 62 women entrepreneurs were analyzed to understand their socio-economic background and business context. Table 3 presents the detailed profile of the respondents. The sample is predominantly composed of women aged 25 to 35 years (38.71%) and 36 to 47 years (29.03%), indicating that entrepreneurship is most active among middle aged women in the Khandesh region. A large majority (70.97%) are married and 77.42% have children, which reflects the typical family structure of micro-women entrepreneurs in semi urban and rural Maharashtra. Educational attainment is fairly high, with 32.26% being graduates and 17.74% post-graduates.

Regarding business background, 61.29% are first generation entrepreneurs, showing that most women initiated their enterprises independently rather than inheriting them. Family support is substantial 79.03% primarily emotional and advisory in nature. About 66.13% operate their ventures from a portion of their residence, which is typical of home-based-women-led micro-enterprise. Sector distribution how dominance of tailoring (22.58%), beauty parlors (17.74%), and service-based units such as internet/mobile centres (11.29%).

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The higher concentration of married women, graduate-level education, and first-generation entrepreneurial status implies that DIC schemes prevalence of home-based enterprises and moderate working hours (4-12 hours most) suggests that time-flexible income sources remain a key driving factor.

The funding pattern highlights that more than half (56.45%) rely on a combination of own and borrowed funds, with relatives and commercial banks being the primary borrowing sources. This aligns with existing research that women entrepreneurs often face credit-access constraints and depend heavily on informal finance. Demographic profile thus forms a baseline for interpreting how DIC assistance influences entrepreneurial outcomes such as growth, profitability and skill enhancement.

These demographic patterns provide essential context for analyzing the impact of District Industries Centre (DICs) on women entrepreneurship in the region.

6. Results and Discussion

Table 4: Independent Samples t-Test for Motivating factors Based on Level of DIC Support

Motivating Factor	DIC Support Level	Mean	SD	t-Value	p-value	Interpretation
Financial Independence	High support	4.48	0.52	2.41	0.019	Significant
	Low support	4.12	0.63			
Skill Utilization	High support	4.42	0.47	2.16	0.035	Significant
	Low support	4.10	0.58			
Income Generation	High support	4.55	0.44	2.79	0.007	Significant
	Low support	4.18	0.52			
Work-Life Balance	High support	4.18	0.61	1.32	0.192	Not Significant
	Low support	3.98	0.59			
Social status	High support	4.30	0.56	2.03	0.046	Significant
	Low support	4.02	0.60			
DIC Opportunities& Awareness	High support	4.50	0.50	3.12	0.003	Highly Significant
	Low support	4.08	0.58			

The t-Test results indicate that women who received higher levels of DIC support exhibited significantly stronger motivational drivers such as financial independence, income generation, skill utilization, and perceived opportunities provided by DICs. Factors like work-life balance were not significantly different across support groups. This suggests that DIC interventions enhance goal-driven entrepreneurial motivation among beneficiaries.

Table 5: Correlation Matrix of Major Study Variables

Variables	DIC Interventions	Business Performance	Entrepreneurial Outcomes	Challenges faced	Motivating factors
DIC Interventions	1	0.62	0.58	-0.41	0.29
Business Performance	0.62	1	0.71	-0.36	0.22
Entrepreneurial Outcomes	0.58	0.71	1	-0.33	0.19
Challenges faced	-0.41	-0.36	-0.33	1	-0.11
Motivating factors	0.29	0.22	0.19	-0.11	1

- **DIC Interventions strongly correlate with business performance (r = 0.62)**
  More Intensive Support = better Business results.
- **Business Performance and Entrepreneurial Outcomes highly correlated (r = 0.71)**
  Skill and confidence improvements translate into measurable business grains.
- **Challenges show a moderate negative relationship with interventions (r = 0.41)**
  Better access to DIC schemes reduces the intensity of challenges.
- **Motivating factors have a weak-moderate correlation with interventions (r = 0.29)**
  Motivation influences participation but not strongly.

7. Results and Discussion

Training has a significant connection with business growth, but only 65% received it. DIC needs to organize more frequent Employment development programs, sector specific skilling and follow-up more mentoring sessions for beneficiaries.

Beneficiaries who received assistance experienced 10% more profit increase on average. This reinforces that micro-enterprises in Khandesh remain credit- constrained and DIC funding directly enables expansion.

Although the awareness about DIC schemes on medium level is high and on high level is low. This directly affects technology adoption, signaling a communication gap in scheme dissemination.

Regression analysis proves that satisfaction with service quality and responsiveness is a psychological anchor for women. Though DICs behavior, efficiency, and support quality significantly shape self-belief.

Women are still struggling to secure formal finance. This directly limits their ability to scale production, adopt technology or expand markets. Trade fairs are one of the easiest platforms to gain exposure, new buyers, and business contacts. A participation rate of just 35% levels: low awareness of event opportunities, limited financial support for travel/ exhibition costs, lack of confidence among micro-entrepreneurs.

Most respondents continue to rely on manual or semi-mechanized process. This reflects-low investment capacity, absence of technical training, inadequate digital literacy and hesitation from shift to traditional methods.

The fact that most units employ only 1-5 employees signals micro-level operations. Such small teams restrict production capacity, limit product diversification, push entrepreneurs into multitasking roles and reduce ability to meet bulk/urgent orders.

Marketing assistance from DIC and external agencies is irregular and insufficient. Thisproduces weak brand visibility, poor digital presence, and limited knowledge of modern marketing techniques. As a result, many entrepreneurs rely solely on local word-of-mouth, which severely caps market expansion.

8. Conclusion and Policy Recommendations

The study confirms that DIC interventions positively and significantly contribute to women entrepreneurship in Khandesh. Training, financial assistance, market support, scheme awareness, and service satisfaction all correlate with improved business outcomes. However, the impact is uneven across sectors and districts, and implementation gaps persist.

Women entrepreneurs in Khandesh are progressing- but not fast enough to create large-scale economic transformation. With stronger training system, better subsidy delivery, and regressive awareness campaigns, DICs can dramatically elevate entrepreneurial success in the region.

DIC should customize programs for textiles, food processing, Agro-services, retail and micro-manufacturing. DIC should strengthen credit facilitation and appoint dedicated DIC-Bank liaison officers. Expand market access through trade fairs and exhibitions. Establish cluster based common facility cantres (CFCs). Improving Branding and marketing support. Strengthen monitoring and feedback systems. Promote inclusive support for first-Generation entrepreneurs.

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