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Original Article

Consumer Engagement on Online Food delivery platforms in context with Virtual Kitchen Brands

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Abstract
Cho et al (2024) stated that Ghost kitchens are also known as virtual kitchens, dark kitchens or cloud kitchens, represent a new business format changing the landscape of food and beverage sector .unlike conventional restaurants virtual kitchen brands depend totally on platform mediated digital signals including rating, menu clarity and visual presentation, social proof and hygiene indicators to define consumer expectations and behaviour .This study investigates how digital platform stimuli influence perceived food quality transparency ,brand trust and perceived value and ultimately consumer engagement with virtual kitchen .Beaumont et al (2025) based drawing on the Stimulus -Organism -Response theory(SOR), the study captures how environmental stimuli influence consumers internal states and subsequent behaviours. A cross sectional structured questionnaire survey was administered to active online OFD users across Luck now, Ghaziabad, Noida and Meerut (N=147).data was analysed using SPSS version 26 through descriptive analysis. Results confirm that social proof and information quality is the strongest predictor of perceived food quality transparency. Perceived quality and perceived value significantly predict consumer engagement .Findings contribute to digital consumer behaviour literature and offer actionable insights for virtual kitchens operators and food delivery platforms
Keywords: *Virtual Kitchens, Cloud Kitchens, Consumer Engagement Social Proof, OFD platforms*

Introduction

The global food service industry has undergone a structural shift driven by proliferation of online food delivery platforms. Virtual kitchens operate with no dine facilities or direct interaction between staff and customers as described by Chiu et al 2024.A report by research markets (2023) stated that global ghost kitchen market could reach US$112.53 billion by 2027. The lack of physical premises and direct human interaction can lead to uncertainty and concerns about invisible food preparation and possible safety threats to add to trust issues. This challenge is acute to Indian context and specially in tier 2 cities such as Lucknow Noida ,Ghaziabad and Meerut where online food delivery adoption among students, working professionals and nuclear families is accelerating at a very fast pace .Consumers must rely on indirect cues such as brand communication ,service consistency and perceived fairness without in person interaction to evaluate whether their expectations are being met .Therefore understanding the mechanism through which digital stimuli are being met .

Problem statement

Virtual kitchens lack physical touch points like ambience, kitchen visibility and face to face service through which traditional restaurants build trust.

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The central research problem is –How do digital stimuli influence consumer engagement with virtual kitchen brands and what is the mediating role of perceived food quality transparency brand trust and perceived value. Based on this research question following research objectives were framed for the study

Research objectives

- To identify the key digital stimuli that drive consumer engagement with virtual kitchen brands
- To examine the mediating role of perceived food quality transparency, perceived brand trust and perceived value in relationship between digital stimuli and consumer engagement

Scope and significance

The study contributes to digital consumer behaviour literature by extending the SOR framework to platform mediated food service consumption. It addresses contextual gap by focussing on urban Uttar Pradesh and NCR adjacent markets largely overlooked in existing Ghost kitchen literature

Review of Literature

Jiang et al (2024) mentioned that the SOR model addresses how the persons internal states and behaviour are influenced by their environment .Factors influencing an individual internal states are referred to as stimuli ,the organism refers to internal mechanism that mediate between stimuli and decision and response is the result of individual reactions .Applied to the present context application based cues constitute stimuli; perceived transparency ,trust and value constitute the organism and consumer engagement constitutes the response .The SOR framework captures how environmental stimuli –online and offline service quality influence consumers internal states and subsequent behaviours .This logic has been applied to digital food ordering research

Virtual Kitchens and Consumer Uncertainty

Broadie et al (2011) stated dark kitchens are delivery only virtual commercial places that do not have a customer facing storefront and operate largely through third party aggregator platforms .Operating at relatively low cost within urban environments with easy access to consumers and potential for large geographical reach dark kitchens offer lucrative business model within a rapidly growing market .Personal ad societal benefits positively influence trust towards ghost kitchens while societal risk minimize it .Personal attitudes and unique aspect of consumption situation significantly shape customer behaviour induced by trust

Digital Stimuli and Perceived Food Quality Transparency

Goyal et al (2023) stated customer rating, ordering review, food tracking and navigational design positively impact technology task fit in mobile food delivery application Information quality including ingredient clarity allergen disclosure and preparation details directly reduce consumer uncertainty about food .Reliability assurance ,maintaining food quality system operation traceability and perceived service value elevate customer satisfaction and optimise the intention to reuse food delivery services.

Social Proof, Brand Trust and Perceived Value

Food related factors are key determinants of initial trust in ghost kitchens significantly affecting advocacy and recommendation. Social proof comprising star ratings ,written reviews ,photo reviews and bestseller labels function as a substitute for physical inspection Perceived value contributes significantly in bridging the relationship between service quality, customer experience, digital marketing, trust and customer loyalty

Customer Engagement Theory

Customer engagement represents the cognitive, emotional and behavioural involvement of consumer with brand beyond the transactional moment .Van et al (2010) stated that Post purchase convenience caused may motivate consumers to repurchase and provide positive feedback, while attitude towards brands reflect the positive or negative reactions of consumers towards a brand. Yeo et al 2017 demonstrated that Post adoption theories focus on continued engagement after initial adoption .Expectation Confirmation Theory has proven particularly valuable for understanding how satisfied users develop continuance intentions, repurchase behaviour and loyalty over time

Promotional Strategies and Perceived Value

Davis et al 2023 stated that customer overall estimation of service quality is based on perception of what is received and supplied constitutes perceived service value, which in the online food delivery context implies users expected benefits from the platform services .Promotions, coupons, loyalty rewards and free delivery enhance perceived value and reduce the perceived cost barrier of trying unfamiliar virtual kitchen brands

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Hypotheses

Based on literature review the following hypotheses are proposed:-

Table:1 Hypotheses

Code	Hypothesis
H1	Information quality positively influences perceived food-quality transparency in virtual kitchen ordering.
H2	Visual appeal and UI/UX positively influence perceived food-quality transparency in virtual kitchen ordering.
H3	Social proof positively influences perceived food-quality transparency in virtual kitchen ordering.
H4	Perceived food-quality transparency positively influences consumer engagement with virtual kitchen brands.
H5	Perceived brand trust and authenticity positively influence consumer engagement with virtual kitchen brands.
H6	Perceived value and convenience positively influence consumer engagement with virtual kitchen brands.

Source: Author

Research Methodology

Research design

The study adopts an empirical, cross –sectional, quantitative survey design .A structured five section questionnaire was used though Google forms targeting active users of online food delivery platforms (Swiggy, Zomato,) who had ordered from a virtual or cloud kitchen within a previous three to six months

Study Area

The study covers four urban markets

Lucknow: State capital with growing student and salaried consumer base

Noida: Tech hub NCR city with dense young professional population

Ghaziabad: Semi metropolitan with rapid delivery infrastructure expansion

Meerut: Tier 2 city with increasing smartphone based ordering adoption

Sampling

Purposive sampling was used since respondents require prior ghost kitchen ordering experience .A total of 147 valid responses were collected and used for SPSS analysis. This sample is considered adequate for exploratory factor analysis

Measurement Instrument

All constructs are measured on a Five point Likert scale .The instrument covered

Section A: Demographic Profile

Section B: Online Ordering Behaviour

Section C: Digital Stimuli evaluation

Section D: Perceived Mediators

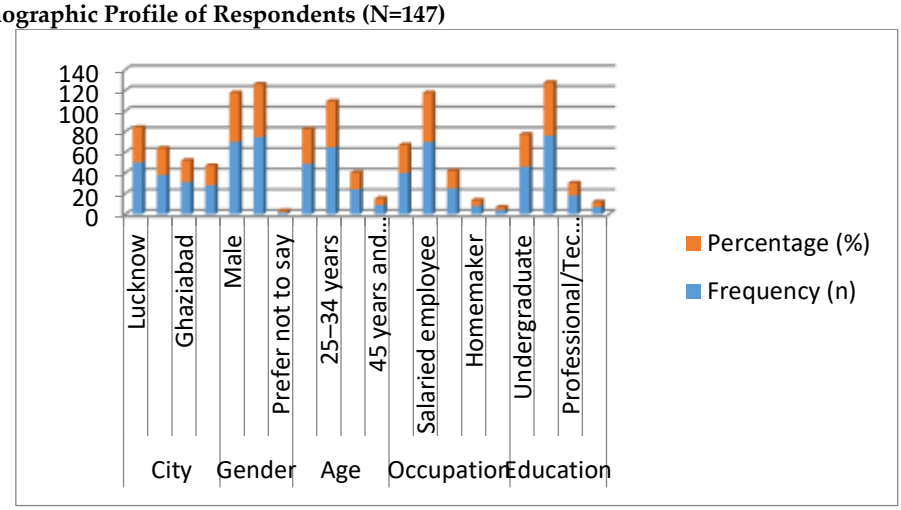
Section E: Consumer Engagement

Data Analysis and Results

Respondents Profile

The dominant respondent profile is urban, educated (post graduate: 51.7%), employed (47.6%) aged 25-34yrs consistent with the expected profile of frequent online food delivery users in Indian metropolitan markets.

Table 2: Demographic Profile of Respondents (N=147)



Source: Primary Data

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Descriptive Statistics:

Table 3: Descriptive statistics

Construct	Code	N	Min	Max	Mean	Std. Dev.	Skewness	Kurtosis
Information Quality	IQ	147	1.5	5	3.76	0.693	−0.412	0.187
Visual Appeal/UI-UX	UI	147	1.5	5	3.89	0.658	−0.491	0.364
Promotional Strategies	PG	147	1.33	5	3.51	0.781	−0.238	−0.118
Social Proof	SP	147	2	5	4.05	0.627	−0.617	0.523
Perceived Food-Quality Transparency	PFQT	147	1.5	5	3.63	0.714	−0.378	0.092
Perceived Brand Trust & Authenticity	PTA	147	1.5	5	3.67	0.703	−0.355	0.074
Perceived Value & Convenience	PVC	147	1.67	5	3.86	0.649	−0.477	0.341
Consumer Engagement	CE	147	1.6	5	3.72	0.681	−0.408	0.213

Source: Author

Interpretation: Social proof recorded as the highest mean (M=4.05 SD=0.63) indicating that consumers rely heavily on peer generated cues when evaluating virtual kitchen brands

Exploratory Factor Analysis

Table 4: KMO and Bartlett's Test of Spherecity

Test	Value
Kaiser–Meyer–Olkin Measure of Sampling Adequacy	**0.888**
Bartlett's Test of Sphericity – Approx. Chi-Square	**2846.37**
df	595
Sig.	**0**

Source: SPSS Output

Reliability Analysis

Table:5 Reliability Statistics of All Constructs

Construct	No. of Items	Cronbach's α	Mean Inter-Item Correlation	Decision
Information Quality (IQ)	4	**0.832**	0.554	Acceptable
Visual Appeal / UI-UX (UI)	4	**0.851**	0.587	Good
Promotional Strategies (PG)	3	**0.783**	0.548	Acceptable
Social Proof (SP)	4	**0.861**	0.609	Good
Perceived Food-Quality Transparency (PFQT)	4	**0.874**	0.634	Good
Perceived Brand Trust & Authenticity (PTA)	4	**0.881**	0.648	Good
Perceived Value & Convenience (PVC)	3	**0.82**	0.601	Good
Consumer Engagement (CE)	5	**0.889**	0.614	Good

Source:SPSS Output

All cronbach alpha values exceeded the accepted threshold of 0.70 (Nunnally ,1978) confirming the internal consistency of the constructs .Consumer engagement yielded the highest alpha (0.889)indicating excellent reliability.

Pearson Correlation Analysis

Table 6: Pearson Correlation Matrix

	IQ	UI	PG	SP	PFQT	PTA	PVC	CE
IQ	1							
UI	.544**	1						
PG	.371**	.413**	1					
SP	.482**	.443**	.393**	1				
PFQT	.619**	.514**	.363**	.591**	1			

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PTA	.573**	.472**	.351**	.637**	.689**	1		
PVC	.501**	.581**	.609**	.432**	.553**	.558**	1	
CE	.539**	.551**	.503**	.580**	.627**	.678**	.653**	1

*** Correlation is significant at the 0.01 level (2-tailed).*

Source: SPSS Output

Interpretation: Consumer engagement shows the highest bivariate correlation with perceived brand trust (r=0.67, p<0.01) followed by perceived value (r=0.65, perceived food quality transparency (r=0.627) and social proof (r=0.584).All correlation are significant and positive.

Hypotheses Testing Summary

Table 7: Hypotheses Testing Results

Hypothesis	Path Tested	Std. β	t-value	p-value	Direction	Result
H1	IQ → PFQT	0.332	4.31	0	Positive	Supported
H2	UI → PFQT	0.168	2.27	0.024	Positive	Supported
H3	SP → PFQT	0.309	3.77	0	Positive	Supported
H4	PFQT → CE	0.177	2.41	0.017	Positive	Supported
H5	PTA → CE	0.294	3.91	0	Positive	Supported
H6	PVC → CE	0.257	3.64	0	Positive	Supported

All hypotheses are supported at significance level of p<0.05

Discussion

Social proof emerged as the single strongest digital stimulus predictor of consumer engagement consistent with findings of Cai et al (2022) who found that personal and social benefits positively influence trust .This underscores the pivotal role of the peer generated content plays when physical inspection is unavailable. Information quality ranking second among stimuli reflects the growing consumer expectations for ingredient transparency, allergen disclosure and sourcing detail. Reliability, assurance, maintaining good quality and traceability are found to elevate customer satisfaction and optimise the intention to reuse food delivery services confirming that information rich platforms create higher engagement propensity .Perceived value and convenience similarly showed strong effect .In online food delivery context perceived service value implies users expected benefits from platform services.

Theoretical implications

This study operationalizes and empirically tests the SOR framework in delivery only food service context adding a verified empirical layer to established logic that environmental cues function as stimuli ,internal processes as the organism and observable reactions as the response. The study demonstrates that perceived transparency, trust and value are not just attitudinal outcomes but active mediators in translating digital stimuli into consumer engagement, hence enriching the engagement theory. By focussing on Uttar Pradesh and NCR adjacent markets the study fills a geographic gap in ghost kitchen research predominantly conducted in metropolitan India.

Conclusion

This study examined how digital platforms stimuli ,information quality ,visual appeal ,promotional strategies and social proof drive consumer engagement with virtual kitchen brands in Lucknow ,Noida ,Ghaziabad and Meerut. Using SPSS based EFA, reliability analysis on 147 Reponses all six hypotheses were empirically supported. Consumers must rely upon indirect cues such as brand communication, service consistency and perceived fairness without in person interaction and this study confirms that digital stimuli mediated by perceived transparency ,trust and value can successfully create meaningful consumer engagement even in absence of physical dining spaces

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Conflicts of interest

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

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Original Article

Innovative Technology in Dairy Science: Integrating Artificial Intelligence and Smart Technologies for Sustainable Development and Viksit Bharat 2047

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Abstract
India is the world's milk producer giving about 24 % of all dairy worldwide.. Dairy in India has many problems. Milk per cow is low. Farms are small. Split apart. Heat from the climate hurts animals. The cold chain that keeps milk fresh is slow and wasteful. To reach the Indian Government's Viksit Bharat 2047 plan—turning India into a $30 trillion economy and meeting net-zero carbon goals—India must change the way livestock is managed by using tools. This paper looks at how Artificial Intelligence (AI) the Internet of Things (IoT) computer vision and precision animal nutrition can fit into dairy science. We show a system that connects small dairy farms with fast processing facilities. We examine the environmental and structural effects of this system on sustainable development.

Introduction & Contextual Framework

1 The Viksit Bharat 2047 Imperative

The Viksit Bharat 2047 agenda imagine a nation that's inclusive advanced with technology and friendly to the environment. Dairy farming is a part of this vision because:

- Dairy gives direct jobs to more than 80 million rural households in India.
- Dairy provides a financial safety net, against crop losses caused by climate.
- Dairy adds greatly to the agricultural Gross Value Added (GVA).

VIKSIT BHARAT 2047
(Socio-Economic Inclusivity & Net-Zero Sustainability)

Precision Dairy Farming	Digital Supply Chain
• IoT collars and sensors	• Blockchains and traceability
• Computer vision analysis	• AI optimized cold chains
• Genomic selection models	• Quality assured logistics

SMART DAIRY AGRI-TECH ENGINE
(Edge computing, deep learning and climate smart feeds)

2 Structural Challenges in Indian Dairying

1. Low Productivity per Bovine: Average annual yields stay below standards because of unorganized breeding and poor feed management.

2. Detection Delays: estrus (heat) and sub-clinical mastitis lead to big financial losses per animal per lactation cycle.

3. Methane Footprint: Enteric fermentation from ruminants creates a greenhouse gas (GHG) output in the agricultural sector.

4. Supply Chain Losses: Not enough cold-chain monitoring causes souring, spoilage and risks of chemical adulteration.

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Core Technological Integrations

1 AI-Driven Precision Animal Health & Herd Management

Modern dairy science changes animal care from veterinary treatment to predictive non-invasive diagnostics.

Smart Wearables & IoT Sensor Arrays

• **Rumen Boluses & Smart Collars:** IoT-enabled sensors track internal pH, body temperature, rumination hours and movement patterns.

• **Predictive Health Analytics:** Machine learning algorithms look at changes, in rumination time and core temperature finding metabolic disorders (ketosis, acidosis) 48 to 72 hours before visible symptoms show.

Computer Vision for Behavior & Morphometry

• **Estrus & Calving Prediction:** Overhead cameras use neural networks (CNNs) to monitor tail-chalking, mounting behaviors and restless movement. This helps identify the time for Artificial Insemination (AI) with high accuracy.

• **Body Condition Scoring (BCS):** 3D vision systems measure fat layers around the spine and pelvic areas. These systems produce BCS metrics allowing farmers to adjust feed rations without needing to handle the animals.

EDGE-AI HERD MANAGEMENT PLATFORM

• Anomaly Detection Pipeline (Isolation Forests)

• Early Disease Alerts (Mastitis, Ketosis)

• Precise Insemination Window Optimization

[Actionable Farm-Level Insights]

2 Genomics, Bioinformatics and AI Breeding Strategies

To speed up genetic improvement in local cattle breeds like Gir, Sahiwal, Red Sindhi and Kankrej:

• **Genomic Estimated Breeding Value (gEBV):** Deep learning models analyze large SNP chip arrays to estimate traits such as milk yield, heat tolerance and disease resistance early in a calf's life.

• **Sex-Sorted Semen & Assisted Reproductive Technologies (ART):** Machine learning improves flow cytometry for sexed semen increasing the chance of calves to over 90 percent. This reduces the number of calves abandoned on farms.

3 Automated Milking & Quality Testing Systems

• **Robotic Milking Systems (RMS):** Optical sensors help robots attach to teats and measure milk flow in each quarter. These systems also track conductivity, which signals early mastitis and monitor milk temperature.

• **Spectroscopic Quality Verification:** Infrared spectroscopy at Bulk Milk Cooling (BMC) centers checks for common adulterants like detergents, urea and starch. It also measures fat, solids-not-fat (SNF) and protein content before milk is loaded into tankers.

Climate-Smart Dairy Science & Sustainability Metrics

Sustainability is the difference, between growth and true development. Smart technology helps reduce the impact of dairy farming in three main areas:

Sustainable Dairy Ecosystem

ENTERIC METHANE MITIGATION
• Precision Feed Formulations
• Tannin & Seaweed Supplements
• AI-Optimized Digestion Metrics

CIRCULAR WASTE RECOVERY
• IoT Anaerobic Digesters
• Compressed Biogas (CBG) Plants
• Bio-fertilizer Extraction

Computer Vision for Behavior & Morphometry

• **Estrus & Calving Prediction:** cameras that use convolutional neural networks (CNNs) watch for tail-chalking, mounting actions and restless movement and find the best time for Artificial Insemination (AI).

• **Body Condition Scoring (BCS):** 3D vision systems measure the layer under the skin along the spine and pelvis and they create BCS values on the fly so that feed can be adjusted without any manual handling.

[IoT Wearable Collars]

[3D CNN Cameras]

(Real-time Biometrics)

(Locomotion & BCS Data)

1 Precision Feeding & Methane Reduction

Enteric fermentation produces a lot of methane (CH_4). Using precision feeding algorithms links the protein-to-energy balance with the animals metabolic needs using real-time data:

\"DMI Requirement\"=f(\"Body Weight\" \"Fat-Corrected Milk (FCM)\" \"Stage of Gestation\")

Adding feed additives—Asparagopsis taxiformis seaweed extracts, essential oils and condensed tannins—along with AI-controlled feed intake reduces enteric methane emissions by 18–30% for each liter of milk produced.

2 Waste-to-Energy & Circular Economy

IoT-Integrated Anaerobic Digesters: Farm waste is sent in a way to village-level biogas plants that are watched by microcontrollers.

Compressed Biogas (CBG) & Organics: Manure becomes CBG for local transport fuel and slurry is turned into organic fertilizer, which cuts the need for fossil-fuel-made synthetic urea.

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Socioeconomic Impact Framework, for Viksit Bharat 2047

To help marginal farmers who own 1–4 cattle technology must be shared in affordable scalable ways.

Comparative Operational Matrix

Parameter	Traditional Dairy Practice	AI & Smart-Enabled Precision Dairy	National Impact Projection by 2047
Average Yield per Bovine	4.5 – 8.0 L/day	12.0 – 22.0 L/day	**+120%** increase in national milk productivity
Disease Detection	Visual observation (Late stage)	AI Biomarkers (48h prior to clinical onset)	**65% reduction** in veterinary treatment costs
Estrus Detection Accuracy	45–55% (High missed cycles)	>90% (Continuous wearable telemetry)	Inter-calving interval reduced from 18 to 13 months
Cold-Chain Traceability	Paper logs, periodic testing	Blockchain + IoT real-time temperature tracking	Spoilage loss reduced from ~12% to **<1.5%**
Carbon Footprint / Liter	~2.4 kg CO_2 equivalent	~1.1 kg CO_2 equivalent	Aligns with India's **Net-Zero 2070 / Interim 2047** goals

Implementation Roadmap & Policy Imperatives

Achieving implementation by 2047 requires a phased strategic roadmap:

[Phase 1: 2026–2030] ——► [Phase 2: 2031–2040] ——► [Phase 3: 2041–2047]

Digital Infrastructure Scaling & Cooperatives Full Autonomy & Net-Zero

• BharatNet rural fiber • Edge-AI deployment at • Complete farm-to-fork

• Low-cost IoT collars village BMCs traceability

• National Genomic Database • Farmer-Producer (FPO) • Fully autonomous circular

tech subsidies dairy hubs

1.Digital Infrastructure Expansion: Extend high-speed wireless connectivity and edge computing hardware to primary milk collection centers.

2. Data Governance & Standardization: Build an open-access National Livestock Digital Stack under private partnerships protecting farmer data privacy while enabling algorithmic models.

3. Subsidies & FPO Aggregation: Offer target incentives through Milk Unions and Farmer Producer Organizations (FPOs) to deploy shared community-owned sensors and automated milking systems.

4. Capacity Building: Train frontline dairy extension workers (Pashu Sakhis) to interpret sensor dashboards and deliver data-backed advice to smallholders.

Conclusion:

Integrating Artificial Intelligence and smart technologies into dairy science is not a small change in the industry—it is a key part of building Viksit Bharat 2047. By changing ways of raising animals that are affected by the weather into a better system that is fast, accurate, safe and good for the environment India can help people in rural areas make sure there is enough food, for the whole country and show the world how to manage animals in a better way.

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Original Article

Computational Analysis of the Time–Fractional Navier–Stokes Equation

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Abstract
In this manuscript, an analytical solution approach based on the fractional complex transform method (FCTM) is proposed for obtaining approximate solutions of the time-fractional Navier–Stokes equations. The proposed technique transforms the considered fractional-order problem into an equivalent form that can be treated effectively to construct an accurate approximate solution. The applicability, reliability, and computational efficiency of the method are examined through a representative example. The obtained solutions are evaluated using graphical comparisons with the corresponding exact solution. The graphical results demonstrate that the proposed method provides highly accurate approximations with small error and exhibits rapid convergence toward the exact solution. The presented simulations further illustrate the effectiveness of FCTM in capturing the behavior of solutions for different fractional orders. Overall, the results confirm that the fractional complex transform method is a simple, efficient, and reliable analytical technique for solving the time-fractional Navier–Stokes equation and can serve as a useful computational tool for a broad class of nonlinear fractional fluid-flow models.

Keywords: *the fractional complex transform method(FCTM), the time- fractional Navier–Stokes equation, approximate solutions.*

Introduction:

The Navier–Stokes equations constitute one of the fundamental mathematical models for describing the motion of viscous fluids. They arise in a wide range of applications involving fluid transport, hydrodynamics, aerodynamics, environmental flows, and industrial processes. In many practical systems, the classical integer-order formulation may not adequately represent processes in which the present state depends on the previous evolution of the system. Such hereditary and nonlocal characteristics have motivated the incorporation of fractional derivatives into mathematical models of complex physical systems. Fractional calculus provides a natural framework for extending conventional differentiation and integration to non-integer orders. Fractional differential equations have attracted considerable attention because their nonlocal operators can incorporate memory and history-dependent effects that are difficult to represent through classical differential operators. In particular, time-fractional formulations have been employed to describe anomalous transport and diffusion processes in which the evolution of a system differs from the standard classical behavior. The time-fractional Navier–Stokes equations therefore provide an extended framework for investigating fluid dynamics with memory-dependent temporal behavior. Several analytical and numerical techniques have been developed for solving time-fractional Navier–Stokes equations. Wang et al. [1] investigated the analytical treatment of time-fractional Navier–Stokes equations using modified reduced differential transform and iterative Elzaki transform methods, demonstrating the applicability of transform-based techniques for constructing analytical solutions.

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Similarly, numerical approximation has been investigated using finite-difference discretization in time combined with a Legendre-spectral method in space. The resulting scheme was shown to be unconditionally stable, with a theoretically established convergence estimate [2]. Other studies have considered decomposition and transform-based procedures, including multi-Laplace transform decomposition methods for one- and two-dimensional time-fractional Navier–Stokes problems [3].

Analytical and semi-analytical methods are particularly attractive for fractional fluid models because they can provide approximate solutions in series form while avoiding some of the computational requirements associated with fully discretized numerical schemes. For example, Ali et al. employed the Optimal Homotopy Asymptotic Method to obtain semi-analytical solutions of time-fractional Navier–Stokes equations under the Caputo derivative and demonstrated that the resulting approximations can achieve high accuracy when compared with exact solutions [4]. More recently, homotopy perturbation combined with the Laplace transform has also been used to construct analytical and approximate solutions for time-fractional Navier–Stokes equations, further demonstrating the continuing interest in efficient transform-based solution procedures [5].

Among the various analytical techniques developed for fractional differential equations, the fractional complex transform method(FCTM) has received attention because of its ability to transform a fractional differential problem into an associated problem involving conventional derivatives under the framework in which the transform is formulated. The fractional complex transform was developed as a useful procedure for simplifying the treatment of fractional differential equations and has subsequently been applied to a variety of fractional models [6]. Li and He investigated the application of the fractional complex transform to fractional differential equations, demonstrating its usefulness in converting fractional formulations into corresponding differential problems [7]. The method has subsequently been employed in different fractional mathematical-physics models, including heat-conduction and wave-type equations [8].

The principal motivation for employing FCTM in the present study is its relatively simple transformation structure and its potential to reduce the complexity of the fractional temporal derivative. Instead of directly discretizing the fractional operator, the transformation introduces a suitable new independent variable associated with the fractional order. The resulting transformed equation can then be treated using familiar analytical procedures. This feature makes FCTM an attractive candidate for investigating nonlinear fractional partial differential equations in which the direct treatment of the fractional operator may become cumbersome.

Despite the availability of several numerical, analytical, and semi-analytical approaches for time-fractional Navier–Stokes equations, there remains a need for solution procedures that are computationally simple, accurate, and capable of providing a clear analytical representation of the resulting solution. Existing investigations have demonstrated the effectiveness of transform methods, decomposition techniques, spectral schemes, and homotopy-based procedures, but the search for efficient approaches for different fractional fluid models remains an active research area [1–5]

Motivated by these considerations, the present manuscript applies the fractional complex transform method to the time-fractional Navier–Stokes equation. The objective is to construct an accurate approximate solution and examine the performance of the proposed method for representative problems. The obtained results are evaluated through graphical representations, allowing the accuracy of the approximation to be assessed against the corresponding exact solution. In addition, the influence of the fractional order on the resulting solution is investigated to illustrate the capability of the proposed approach to capture the behavior associated with fractional temporal dynamics. The numerical and graphical findings demonstrate that FCTM provides an effective and computationally convenient framework for obtaining approximate solutions of time-fractional Navier–Stokes equations.

Fractional Complex Transform Method:

The fractional complex transform(FCT), introduced by Li and He [9], has emerged as an efficient technique for solving fractional differential equations. The method provides a simple framework for transforming fractional differential equations into their corresponding classical differential equations. Consequently, conventional analytical techniques developed for integer-order differential equations can be readily employed to obtain solutions of fractional-order problems.

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Consider the following general fractional differential equation

$$f(u, u_t^{\alpha}, u_x^{\beta}, u_y^{\gamma}, u_z^{\lambda}, u_t^{2\alpha}, u_x^{2\beta}, u_y^{2\gamma}, u_z^{2\lambda}, \dots\dots\dots) = 0$$

where $u_t^{\alpha} = \frac{\partial^{\alpha} u}{\partial t^{\alpha}}$ denotes He's fractional derivative; u is a continuous function.

$$0 < \alpha \leq 1, 0 < \beta \leq 1, 0 < \gamma \leq 1, 0 < \lambda \leq 1$$

Introducing the following fractional complex transforms

$$T = \frac{at^{\alpha}}{\Gamma(1+\alpha)}, X = \frac{bx^{\beta}}{\Gamma(1+\beta)}, Y = \frac{cy^{\gamma}}{\Gamma(1+\gamma)}, Z = \frac{dz^{\lambda}}{\Gamma(1+\lambda)},$$

where a, b, c and d are unknown constants. Then, using the chain rule of differentiation and basic properties of special functions like the gamma function, fractional derivatives are converted into integer-order partial derivatives as:

$$\frac{\partial^{\alpha} u}{\partial t^{\alpha}} = a\frac{\partial u}{\partial T}$$
$$\frac{\partial^{\beta} u}{\partial x^{\beta}} = b\frac{\partial u}{\partial X}$$
$$\frac{\partial^{\gamma} u}{\partial y^{\gamma}} = c\frac{\partial u}{\partial Y}$$
$$\frac{\partial^{\lambda} u}{\partial z^{\lambda}} = d\frac{\partial u}{\partial Z}$$

Therefore, the fractional partial differential equations can be effectively transformed into their corresponding classical partial differential equations. The resulting equations can then be solved using suitable iterative or analytical techniques, thereby simplifying the treatment and solution of fractional calculus problems.

Convergence:

Here we present the condition for the convergence of the series $\sum u_i$.

Theorem 3.1. *If N is analytic in a neighbourhood of u_0 and*

$$\|N^{(n)}(u_0)\| = Sup\{\|N^{(n)}(u_0)(h_1, h_2, \dots, h_n)\|/\|h_i\| \mid 1 \leq i \leq n\} \leq L,$$

for any n and for some real $L > 0$ and $\|u_i\| \leq M < \frac{1}{e}, i = 1, 2, \dots$, then the series $\sum^{n}\infty_{n=0} G_n$ is absolutely convergent and moreover;

$$\|G_n\| \leq LM^n e^{n-1}(e-1), \quad n = 1, 2, \dots$$

Now, to show boundedness of $\|u_i\|$, for every i the conditions on $N^{(n)}(u_0)$ are given, which are sufficient to guarantee convergence of the series.

Theorem 4.2. *If f is analytic and $\left\|N^{(n)}(u_0)\right\| \leq M < \frac{1}{e}$, for every n then the series $\sum^{n}\infty_{n=0} G_n$ is absolutely convergent.*

Numerical Application:

In this section, we consider the time-fractional Navier–Stokes equation to assess the effectiveness and computational efficiency of the FCTM. All numerical computations are carried out using Mathematica software.

Consider a time–fractional–Navier Stokes equation as

$$\frac{\partial^{\alpha} u(x,t)}{\partial t^{\alpha}} = K + \frac{\partial^2 u(x,t)}{\partial x^2} + \frac{1}{x}\frac{\partial u(x,t)}{\partial x} \qquad (4.1)$$

with the initial condition

$$u(x,0) = 1 - x^2 \qquad (4.2)$$

by using the transformation

$$T = \frac{t^{\alpha}}{\Gamma(1+\alpha)}$$

hence

$$\frac{\partial^{\alpha} u}{\partial t^{\alpha}} = \frac{\partial u}{\partial T}$$

using this transformation in equation (4.1), we obtain

$$\frac{\partial u}{\partial T} = K + \frac{\partial^2 u(x,t)}{\partial x^2} + \frac{1}{x}\frac{\partial u(x,t)}{\partial x} \qquad (4.3)$$

by applying the Integral operator I_T on both sides of equation (4.3) and utilizing the initial condition given in equation (4.2), we derive the series solution as

$$u(x,t) = \sum_{i=1}^{\infty} u_i(x,t)$$

where the first few terms are as

$u_0(x,t) = 1 - x^2$,

$u_1(x,t) = (-4+K)\frac{t^{\alpha}}{\Gamma(1+\alpha)}$,

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$u_2(x,t) = K\frac{t^\alpha}{\Gamma(1+\alpha)}, \ldots\ldots$

In the same way, we can obtain the further terms of the approximate solution.

We get the approximate solution of equation (4.1) as

$u(x,t) = u_0(x,t) + u_1(x,t) + u_2(x,t)$

The exact solution of equation (4.1) given by [10] is

$u(x,t) = 1 - x^2 + (K-4)t$

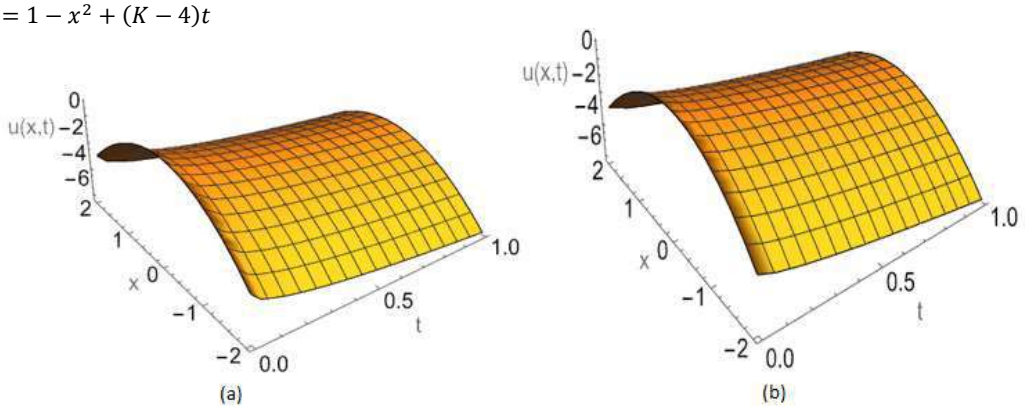

Figure 4.1 presents the three-dimensional surfaces corresponding to the approximate solutions of the time-fractional Navier–Stokes equation for different values of the fractional order α, together with the exact solution. The surface in **Figure 4.1(a)**, corresponding to $\alpha = 0.5$, exhibits a comparatively pronounced temporal variation, indicating the stronger influence of fractional-order memory effects at a lower fractional order. As α increases to 0.75 in **Figure 4.1(b)**, the solution surface becomes progressively closer to the classical behaviour.

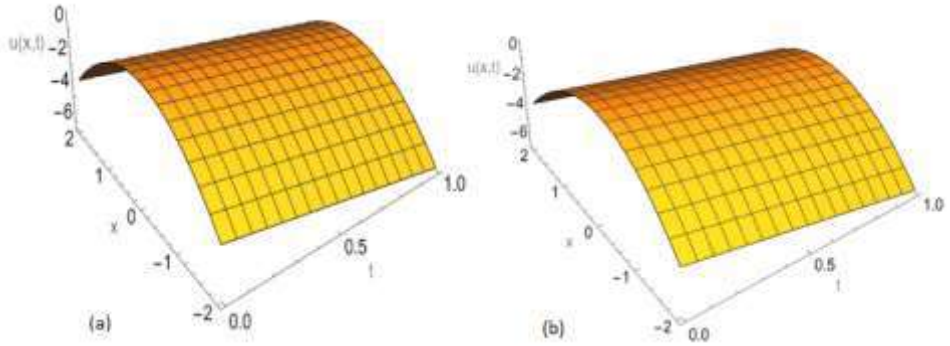

Figure 4.1: $3D$ Surface of the approximate solutions and the exact solution of equation (4.1) when $k = 1$; (a) $\alpha = 0.5$ (b) $\alpha = 0.75$ (c) $\alpha = 1$ (d) Exact.

For $\alpha = 1$, shown in **Figure 4.1(c),** the fractional model reduces to the corresponding integer-order formulation, and the computed surface closely resembles the exact solution depicted in **Figure 4.1(d)**. The close agreement between the approximate and exact surfaces, particularly for $\alpha = 1$ demonstrates the accuracy and reliability of the proposed solution technique. Overall, the gradual change in the solution profiles with increasing α illustrates the effect of the fractional parameter on the evolution of the solution and confirms that the numerical/analytical approximation captures the essential behavior of the governing equation over the considered range of fractional orders.

Conclusion

In this study, the time-fractional Navier–Stokes equation was successfully analyzed using the fractional complex transform method. The method effectively transforms the fractional differential equation into a simpler form, allowing the solution to be obtained with less computational complexity. The approximate solutions for different values of the fractional order α were presented graphically and compared with the exact solution. The close agreement between the obtained and exact solutions, particularly for $\alpha = 1$, confirms the accuracy and effectiveness of the proposed method. The results demonstrate that the fractional complex transform method is a simple and reliable technique for solving time-fractional fluid-flow problems and can be extended to other nonlinear fractional differential equations.

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Original Article

Promoting Environmental Sustainability through Green Practices in Higher Educational Institutions: A Pathway towards Viksit Bharat @2047

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Abstract
Green practices at Higher Educational Institutions (HEIs) are crucial to achieving environmental sustainability because they ensure that social and economic development progresses without jeopardizing the environment. In addition to improving quality of life and enhancing the institution's reputation, these activities also help safeguard the environment by lowering carbon footprints. Utilizing renewable energy sources, managing and conserving plants and animals, collecting rainwater, properly disposing of e-waste and lab chemical waste, lowering dependency on non-renewable resources, and encouraging recycling and reuse of scarce resources are some of the major activities. Additionally, urgent global challenges like climate change and global warming can be addressed by designing green, eco-friendly structures, utilizing locally sourced materials, and incorporating traditional wisdom. It is imperative that HEIs set a good example by encouraging environmental consciousness among students and the larger society. With the main aim of raising environmental awareness among all stakeholders, the present study, which is based on secondary data, investigates the green practices implemented by Higher Educational Institutions (HEIs). Additionally, it looks for sustainable projects and suggests suitable policy actions to support environmentally friendly growth and enhance HEIs' role in realizing Viksit Bharat @2047.

Key words: *Green Practices, Environmental Sustainability, HEI's, Carbon Footprints, Renewable energy and E-waste and lab chemical waste*

Introduction

The only planet in our solar system that is home to life is Earth. Only the biosphere, or the thin layer that covers the earth, is home to life. Every living thing interacts with its surroundings and depends on one another. Our mother Earth is in grave danger as a result of flawed development models that lead to an opulent lifestyle or a modern use-and-throw society. We didn't recognize this until the early 1970s, when air pollution began to have a detrimental impact on human health and the need for sustainable development—that is, improving our quality of life and conserving and enhancing our valuable natural resources—became apparent. The issue of sustainability has been discussed and implemented at numerous international conferences in the field of education, which has also eliminated domain boundaries on a worldwide scale. As a result, since its introduction at the 1987 United Nations Conference on Environment and Development under the title "Our Common Future," the concept of sustainable development has garnered attention on a global scale (Brundtland, 1987). When it comes to incorporating green practices into their institutional policies to achieve sustainability, universities and colleges continue to lag behind. Higher education establishments are little representations of Mother Earth, shaping the minds of future generations.

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According to Alshuwaikhat and Abubakar (2008), their work culture not only influences college life but also carries environmental sustainability traditions off campus.Therefore, employability, housing, and socioeconomic contentment are all linked to quality of life. According to Kadir et al. (2012), green practices are crucial to the campus environment and the university's reputation. The United Nations' Sustainable Development Goals Report 2023 states that "youth have emphasized the need for interdisciplinary, action-oriented education that is both globally relevant and tailored to local realities, along with adequate teacher support." The urgent need for environmental education in schools was finally addressed in 2020 when India established the National Education Policy (NEP). In order to guaranty that students obtain a thorough education that raises environmental consciousness and promotes practical action, the government has effectively implemented measures through the policy.

Literature Review

The current status of green education in India, its difficulties, and its potential to further sustainability are all examined in this survey of the literature. India's official education system has incorporated green education more and more during the past ten years. The Indian government and a number of non-governmental organizations have taken steps to integrate sustainability concepts into school curricula, according **to Mukherjee (2019).** These programs align with the global Sustainable Development Goals (SDGs), particularly SDG 4, which emphasizes giving everyone access to high-quality education and opportunities for lifelong learning. Despite these initiatives, there are still several barriers to the adoption of eco-friendly education in India. **Reddy (2020)** states that inadequate infrastructure, a lack of funding, and insufficient teacher preparation are the primary challenges. Furthermore, **Jha and Kumar (2017)** note that the successful dissemination of environmental education is often hampered by a lack of alignment between policy creation and implementation in schools. For green education to be successful, effective curriculum design and pedagogical techniques are essential. Students' understanding and retention of sustainability concepts can be improved by incorporating environmental issues into other curricula rather than treating them as stand-alone modules, claim **Sharma and Singh (2018).** According to **Bhardwaj and Sharma (2020),** green schools set an example for pupils to follow by teaching and practicing environmental ideals. These schools frequently promote water conservation, implement trash segregation, and employ renewable energy.

Statement Of The Problem

India's growing industrialization and urbanization are causing deforestation, air and water pollution, and biodiversity loss. For the next generation to understand sustainability and environmental care, green education is crucial. When it comes to incorporating green practices into their institutional policies to achieve sustainability, universities and colleges continue to lag behind. Instead of concentrating on the higher education system, the literature review primarily examines the current green education system and its difficulties in schools. The current study is being conducted to close this research gap.

Objectives Of the Study

The study aims at

1.To examine the ongoing green initiatives and programmes in higher educational institutions

2.To create environmental awareness among all stakeholders

3. To recommend policy measures to ensure sustainability and to move towards the vision of Viksit Bharat @2047.

Research Methodology

This study uses only secondary data and is descriptive in nature. To determine the state of green education and sustainable development at HEIs, a thorough literature review and observation were conducted. The thorough examination of the available data highlighted how important environmental education is to India's long-term, environmentally responsible development.

Results And Discussions

Green education improves students' comprehension of ecological concepts, promotes sustainable practices, and cultivates a sense of environmental responsibility. It encourages critical thinking, develops a sustainable economy, and prepares students to deal with environmental issues. Additionally, it promotes values of responsibility and conservation, improving the general well-being of communities and the environment.

1.Green Practices at Higher Educational Institutions

Some of the HEIs follow following green practices to support the concept of green education

Table 1 Green Practices as practised by Higher Educational Institutions (HEIs)

S. No	List of green practices
1.1	Energy Conservation and Management

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1.2.	Annual Audit of Air, Water and Soil quality
1.3.	Conservation of water (Rain Water Harvesting)
1.4.	Conservation and Management of Flora and Fauna
1.5.	Transport management
1.6.	Green Library
1.7.	Promotion of Reduce Recycle and Reuse mindset

1. Energy Conservation and Management

Since energy powers air conditioners, coolers, computers, fans, heaters, and other essential campus activities at HEIs, life would not be possible without it. Some HEIs use natural lighting and renewable energy sources to improve the ambiance. For instance, using LEDs, low-voltage white light bulbs, setting all campus air conditioners to 25 degrees Celsius to conserve energy, installing solar panels on buildings' roofs, etc. Both economically and environmentally, it is advantageous (Kadir et al., 2012; Bantanur et al., 2015).

2. Green Audit

The three primary ecosystem components—soil, water, and air—have an impact on our environment either directly or indirectly when they deviate from the average. Some HEIs conduct an annual audit of these parameters known as a "green audit," and if there are any deviations from the prescribed range, appropriate steps are taken to improve the campus's soil, water, and air quality.

3. Conservation of Water (Rain water harvesting)

Rainwater is a natural, life-sustaining gift from God. It is now our responsibility to store rainwater so that not a single drop is wasted. Some HEIs use rainwater gathering as a solution to the freshwater problem. Using a catchment system affixed to campus buildings, this indicator gathers rainwater. Rainwater collection is one of the green activities since it offers sustainable water supply. (Ayog and others, 2015). Recycling waste water on campus is another water management project (CGSS, 2009).

4. Conservation and Management of Flora and Fauna

The institutions' rich biodiversity can enhance the soil, water, and air quality. The two basic necessities of stakeholders are clean water and fresh air. In this context, gardening, tree planting, and various environmental awareness programs are encouraged.

5. Transport Management

Vehicles are only allowed to park on campus in order to lessen noise and air pollution. Walking and cycling will undoubtedly improve the surrounding environment and reduce the amount of vehicles on campus, according to Kamal et al. (2015). It is also possible to lessen vehicle-related noise pollution (Darus et al., 2009). In order to achieve a clean environment on university campuses, Kadir et al. (2012) recommended carpooling and public transit.

6. Green Library

The idea of a "green library" is applied in several HEIs to reduce adverse environmental effects and enhance interior air quality. In order to optimize the utilization of natural sunlight and fresh air, library buildings are constructed and designed in an environmentally sustainable manner. Traditional knowledge and locally accessible building materials are used as much as feasible. By offering correct information on all green themes, libraries assist the community and serve as role models for sustainability, according to Antonelli (2008).

7. Promotion of Reduce, Recycle and Reuse mindset

People with a "Reduce, Recycle, and Reuse" mentality can revolutionize environmental sustainability. Through a variety of eco-friendly activities, certain HEIs encourage students to adopt the reduce, recycle, and reuse idea, which contributes to a clean and green environment.

The majority of government-run institutions either have operational roof-top solar panels or are in the process of installing them in order to meet the Sustainable Development Goals of the United Nations by lowering carbon footprints. Additionally, several private HEIs have solar street lighting and solar panels on their roofs. Due to a lack of funding and technical means, routine audits of the quality of the air, water, and soil are rarely conducted. Every HEI participates in an annual tree planting campaign during the monsoon season, however a significant plant mortality rate is shown as a result of inadequate post-plantation maintenance. In order to increase the plant survival percentage, post-plantation care should be prioritized. Nifa et al. (2015) state that green buildings with lower energy and water consumption as well as a smaller carbon footprint are supported by sustainable development. The primary sources of carbon footprints on campus are furniture trash, chemical waste, e-waste, and paper waste. Recycling and appropriate disposal can reduce these.

Green Education for Viksit Bharat @2047

By producing individuals who are sustainable and ecologically conscientious, green education is essential to realizing the vision of Viksit Bharat @2047. It raises awareness of issues such as biodiversity, water conservation, waste

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management, renewable energy, climate change, and sustainable lifestyles. Through tree planting, energy conservation, rainwater collection, garbage segregation, recycling, and eco-friendly campus programs, educational institutions can encourage green behaviors. Additionally, green education inspires students to create creative solutions for environmental problems and incorporate sustainability into their future enterprises and jobs. Education can play a major role in creating a clean, sustainable, resilient, and developed India by 2047 by fostering responsible behavior, green skills, and environmental leadership among young people.

Suggestive Green Practices:

Following are some policy suggestions to encourage green education in higher education institutions to move towards Viksit Bharat @2047

1. **Curriculum Integration**

Require the introduction of multidisciplinary projec ts on green practices and the inclusion of environme ntal studies, sustainability, and climate change mod ules in all courses, not only science streams.

2. **Green Campus Guidelines**

Choosing sustainable energy sources (biogas units, solar panels) and encouraging recycling facilities, garbage segregation, and rainfall collection.

3. **Incentives & Funding**

The government should honor staff members and students who take green initiatives and offer grants, tax breaks, awards, and other perks to institutions that obtain green campus certification. Budgets for eco-clubs, sustainable technology research, and green audits should be set aside by the institution.

4. **Capacity Building & Awareness**

Educating teachers on environmental education tec hniques and planning frequent workshops,seminars , and field trips on sustainable practices.

5. **Student Engagement Policies**

Promoting studentled green enterprises, innovation laboratories, and research initiatives as well as enco uraging students' involvement in eco-friendly activities as part of credit-based grading.

6. **Partnerships & Collaborations**

Signing Memorandums of Understanding and work ing together on green projects, internshipsand other cooperative sustainability initiatives with NGOs, g overnment agencies, and businesses

7. **Monitoring & Accountability**

Publishing sustainability reports, carrying out yearly green audits, and establishing quantifiable goals for lowering resource usage and carbon emissions.

Conclusion

Through a variety of on-campus and off-campus environmental initiatives, HEIs are currently playing a significant role in raising environmental awareness among their stakeholders. By implementing ecological projects on campus, they are also educating the general public. Green campuses serve as models for other educational establishments. However, there is still more work to be done because safeguarding the environment is now a complicated problem that may be managed by better integrating green techniques with spirit to achieve sustainable growth. Therefore, developing a generation of environmentally conscious people requires green education, which includes sustainable practices, eco-friendly technologies, and environmental consciousness. India's rapid economic expansion and particular environmental issues need for an education system that incorporates sustainability at every level. Green education may greatly contribute to sustainable economic growth and assist India in realizing the goal of Viksit Bharat @2047 by providing students with green knowledge, skills, and values.

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Conflicts of interest

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

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Original Article

Green Entrepreneurship for Climate Resilience: Pathways and Barriers for Rural Women in India

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Abstract
As climate change worsens livelihood insecurities in rural India, grassroots women carry a heavy and unequal burden. They face daily struggles in farming, managing local resources, and handling unpaid care work. In this scenario, green entrepreneurship offers a practical way forward. It helps these women earn a steady income, protect their environment, and build lasting resilience. This conceptual paper explores how women-led eco-friendly businesses intersect with climate resilience and sustainable livelihoods. Drawing on the sustainable livelihood framework and the capability approach, we argue that green entrepreneurship is not just about starting eco-friendly businesses. It is fundamentally about expanding women's agency, giving them real control over productive assets, and ensuring their voices matter in climate decisions. We highlight ground-level opportunities in climate-smart farming, millet value chains, renewable energy, and waste management. At the same time, we acknowledge the harsh realities—barriers like lack of land titles, heavy household duties, and weak market links still hold them back. Finally, the paper proposes a conceptual model connecting enabling resources to community resilience, offering practical policy steps for a truly inclusive green transition.

Keywords: *Green entrepreneurship; Rural women; Climate resilience; Sustainable livelihoods.*

Introduction

Climate change is no longer just an ecological concern; it is deeply intertwined with livelihoods, development, and gender equity. In rural India, households that depend heavily on agriculture, livestock, and informal work are highly vulnerable to erratic weather patterns and market disruptions. However, this burden is not shared equally. As noted by the Intergovernmental Panel on Climate Change (IPCC, 2022), poverty, inequality, and climate change form a vicious cycle. Rural women bear the brunt of this crisis, constantly juggling farm work, unpaid care, and informal earning, while having far less access to land, credit, and decision-making spaces.Echoing this reality, the Food and Agriculture Organization (FAO, 2024) highlights that climate shocks cause significantly higher income losses for women-headed farm households. As climate stress intensifies, women's daily workload increases—often meaning longer, more exhausting journeys to fetch water and firewood. These ground realities make it quite clear that building climate resilience isn't just about technical fixes. It demands livelihood diversification, genuine social inclusion, and recognising women as key environmental decision-makers. This is where green entrepreneurship offers a vital pathway. At its core, it means creating economic value while healing the environment. For rural women, this could mean organic farming, renewable energy services, or sustainable handicrafts. When rural women lead these ventures, the impact is multi-dimensional: generating steady income, strengthening personal agency, and tackling local ecological challenges. In the Indian context, women's Self-Help Groups (SHGs) provide a robust institutional foundation for this shift.

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Driven by the Deendayal Antyodaya Yojana–National Rural Livelihoods Mission (DAY-NRLM), SHGs have successfully linked rural women to financial inclusion. As of January 2025, nearly 10.05 crore women have been mobilised into 90.90 lakh SHGs (Ministry of Rural Development, 2025). While this massive network holds immense potential, mere membership does not automatically guarantee enterprise growth or true climate resilience. Against this backdrop, this article builds a conceptual understanding of how green entrepreneurship among rural women can drive climate resilience.

Rationale of the study

While there is a growing body of literature on rural entrepreneurship and climate change adaptation, there is a distinct gap in understanding how these two domains intersect specifically for rural women in India. Most existing studies either focus purely on the ecological impacts of climate change or look at women's empowerment through microfinance in isolation. There is a need to bridge this gap by examining green entrepreneurship as a holistic tool for climate resilience.

Furthermore, while the government has mobilised millions of women into SHGs, there is a lack of conceptual clarity on how to transition these groups from basic credit and savings entities into robust, climate-resilient green enterprises. The rationale of this study lies in addressing this gap. It seeks to move beyond the romanticised view of women as mere "victims" of climate change or passive beneficiaries of state welfare, and instead conceptualise them as dynamic innovators. By identifying the structural barriers—such as lack of land titles (pattas), the heavy burden of unpaid care work, and poor market linkages—this study provides a grounded rationale for why isolated training workshops fail and why a comprehensive support ecosystem is the need of the hour.

Objectives

- To address the aforementioned gaps, this conceptual study is guided by the following objectives:
- To explore the realistic forms that green entrepreneurship can take for rural women in India.
- To examine how these women-led green enterprises strengthen household and community climate resilience.
- To identify the structural and social barriers that restrict the growth of green enterprises among rural women.
- To propose a conceptual model linking enabling resources to community resilience outcomes.
- To offer actionable, gender-responsive policy recommendations for an inclusive green transition.

Hypothesis

Based on the conceptual framework and secondary literature reviewed, the following hypotheses are proposed to guide future empirical extensions of this study:

H1: Gender-responsive green finance positively influences the adoption of green entrepreneurial practices among rural women.

H2: Access to climate advisories and digital literacy positively influences the overall performance of women-led green enterprises.

H3: Active participation in SHGs and Farmer Producer Organisations (FPOs) strengthens the link between green practices and market access.

H4: The adoption of green practices enhances livelihood resilience primarily via income diversification and natural asset protection.

H5: Women's agency acts as a mediating variable between green entrepreneurship and sustainable socio-economic outcomes.

H6: The burden of unpaid care work and weak land rights negatively moderate the growth and scalability of women-led green enterprises.

Methodology

This study adopts a conceptual approach relying entirely on secondary data. Since the primary aim is to build a theoretical understanding and map out pathways rather than measure empirical variables on the ground, primary data collection was not undertaken.

Method: A qualitative conceptual method was employed to synthesise existing literature, policy documents, and reports.

Research Design: An exploratory and descriptive conceptual research design was used. This allowed for the integration of various theoretical lenses, such as the Sustainable Livelihoods Framework and the Capability Approach, to build a cohesive narrative.

Sampling: Purposive sampling was used to select secondary data sources. The selected literature included peer-reviewed journal articles, reports from international bodies (like the FAO and IPCC), and official government publications (such as the Ministry of Rural Development dashboards and PIB releases). Only sources published primarily between 2015 and 2025 were considered to ensure the relevance of the climate and policy context.

Tool: Thematic analysis and conceptual mapping were the primary tools used. The secondary data was analysed thematically to identify patterns in opportunities, barriers, and resilience outcomes, which were then used to construct the proposed

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conceptual model and formulate the research hypotheses.

Analysis and data analysis

Since this is a conceptual study based on secondary data, the "data analysis" involves a thematic synthesis of the literature to understand the dynamics of green entrepreneurship. The analysis is broadly categorised into three themes:

Thematic Area 1: Ground-Level Opportunities for Women

The secondary data reveals that green entrepreneurship for rural women is deeply rooted in local resources. Climate-smart agriculture (CSA) opens up avenues in drought-resistant crops, particularly millets (Shree Anna), which require less water and promote nutritional security. Women's collectives can add value at the post-harvest stage. Additionally, the transition to a circular economy offers 'waste-to-wealth' ventures, such as producing organic compost or reusable bags. Renewable energy services also present a massive opportunity, where women can be trained not just as sales agents, but as technical owners and maintainers of solar lanterns and clean cookstoves.

Thematic Area 2: Structural and Social Barriers

Despite these opportunities, the literature highlights severe bottlenecks. Green enterprises demand higher upfront investments, yet most rural women lack collateral or formal land titles (pattas). While small-ticket loans via MUDRA sustain micro-enterprises, scaling up requires patient capital. Furthermore, access to technical training remains a gap; training must be hands-on and in the local vernacular. Socially, the overwhelming burden of domestic chores and restrictions on mobility severely constrain enterprise growth. Climate shocks only inflate these demands. There is also a distinct risk of maladaptation and exclusion, where programmes might only benefit better-connected women, leaving behind landless labourers, Adivasi, and Dalit women.

Thematic Area 3: Building the Conceptual Model

By synthesising these themes, we mapped out a conceptual model across four dimensions: Inputs (green finance, digital access), Practices (climate-smart production, circularity), Enterprise Outcomes (profitability, job creation), and Resilience Outcomes (income diversification, enhanced agency). The analysis shows that enabling conditions catalyse green practices, but structural realities like caste positioning and unpaid care work moderate outcomes and can constrain them. Social capital (via SHGs) and women's agency act as crucial mediating variables that drive the success of these enterprises.

Conclusions

At its heart, green entrepreneurship offers rural women a unique pathway to weave together economic empowerment, climate adaptation, and ecological conservation. The evidence from secondary sources is clear: rural women are not just passive victims of climate change. They are dynamic innovators and natural custodians of local resources, fully capable of leading grassroots resilience. When women control their earnings and engage with external institutions, their household bargaining power grows, translating into better decisions regarding children's education and family nutrition.

However, we must not romanticise this narrative. Simply encouraging women to start eco-friendly micro-enterprises without addressing deep-rooted structural barriers is a disservice. Without reliable green finance, secure land rights, and concrete support for unpaid care work, women risk being pushed into precarious livelihoods. A truly just transition requires moving away from isolated training workshops to build comprehensive support ecosystems. Ultimately, empowering rural women through green entrepreneurship is a critical step towards achieving global sustainability, specifically advancing SDG 5 (Gender Equality), SDG 8 (Decent Work), SDG 12 (Responsible Consumption), SDG 13 (Climate Action), and SDG 15 (Life on Land). When rural women are equipped to lead the green economy, their households, communities, and local ecosystems thrive alongside them.

Recommendations

To foster an inclusive green transition, policymakers and implementing agencies must adopt the following integrated strategies:

Democratising Green Finance: Establish dedicated, collateral-free green finance windows with tailored insurance and working-capital facilities. Nodal agencies like NABARD and SIDBI should design gender-responsive credit guarantees.

Village-Level Resource Centres: Provide continuous, vernacular-language handholding support in bookkeeping, packaging, and digital marketing at the Gram Panchayat level.

Strengthening Collectives: Upgrade SHGs and FPOs from mere credit and savings groups into robust, mentorship-backed business entities capable of absorbing market shocks.

Investing in Common Facility Centres (CFCs): Subsidise shared infrastructure for processing, cold storage, and professional branding to help women capture a fairer share of the value chain.

Assured Market Linkages: Integrate women's enterprises into public procurement (like the GeM

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portal) and supportive e-commerce channels that can absorb logistical shocks.

Embedding Climate Intelligence: Provide hyper-local, vernacular early-warning systems linked directly to business-continuity planning for the enterprises.

Recognising the Care Economy: Mandate safe mobility, flexible work schedules, and Anganwadi-linked childcare as foundational enterprise support, recognising care infrastructure as a critical economic intervention.

Holistic Impact Frameworks: Measure success beyond mere profit. Track resource efficiency, shifts in unpaid workload, and improvements in women's agency.

Gender-Disaggregated Data: Systematically track green enterprise creation, finance access, and climate-induced losses to continuously course-correct policies.

Safeguarding Traditional Knowledge: Ensure transparent benefit-sharing and protect community intellectual property when traditional ecological knowledge is commercialised.

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Original Article

Advertising the Sustainable Future: AI, Immersive Media and Behaviour Change for Viksit Bharat 2047

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Abstract

Viksit Bharat 2047 will not be achieved through infrastructure and technology alone. Much of the change will be visible in ordinary routines: the way electricity and water are used at home, the way waste is handled, the products people choose, and the willingness of communities to take part in local environmental efforts. Advertising is relevant here because it already knows how to reach large audiences, tell memorable stories and influence everyday choices. Advertising itself is changing quickly. Artificial intelligence (AI), augmented reality (AR), virtual reality (VR), spatial computing and algorithmic personalisation are giving audiences more interactive forms of communication. This paper considers what these developments could mean for sustainability campaigns. The main concern is a familiar one: people may genuinely care about environmental issues and still struggle to turn that concern into consistent behaviour. The discussion draws on secondary material relating to the IndiaAI Mission, NITI Aayog policy directions, Sustainable Development Goal 12 and media-effects research. On this basis, the paper develops the AI-Immersive Sustainable Advertising Behaviour Model (AISABM). It brings together five connected ideas: context-sensitive communication, immersive experience, trustworthy information, a simple route to action, and feedback based on observable behaviour. Technology can also create a new divide if access is taken for granted. High-end VR is unlikely to be equally available to everyone, whereas radio, podcasts, smartphones and lightweight AR applications can travel much further. This is why the paper does not present immersive media as a replacement for older channels. It argues for a combination of both. The discussion also considers surveillance, manipulation, greenwashing and the energy cost of AI itself. The larger argument is that sustainability advertising has to do more than ask people to 'be green'. A useful campaign should make the issue understandable, connect it with everyday life, provide evidence people can trust and make the next step reasonably easy. Where possible, that step should also be observable over time.

Keywords: *Artificial Intelligence; Immersive Media; Augmented Reality; Virtual Reality; Behaviour Change; Viksit Bharat 2047; Green Advertising; SDG 12; Transmedia Communication; Media Credibility*

Introduction

Advertising is usually discussed in terms of products, brands and sales. Yet its influence is not limited to buying decisions. Advertising can direct attention, shape meanings around everyday practices and help normalise repeated behaviours. That wider influence is what makes it worth examining as a public-interest tool. In sustainability campaigns, the persuasive techniques of advertising can be turned towards responsible consumption, conservation and civic participation. The setting in which advertising works has changed just as much.

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People move between search engines, social platforms, streaming services, mobile applications and recommendation feeds, often receiving different versions of a message. Generative AI makes this process even more flexible because text, images and audio can be adapted at a much faster pace than before. India provides an especially important setting for examining this change. The source material used in this paper reports more than 806 million active internet users and about 491 million social-media identities in 2025 (Data Reportal, 2025). Such scale creates an opportunity for communication campaigns, but it also highlights the problem of unequal access. A strategy designed only for advanced devices could leave out people who depend on simpler forms of media.

The idea of Viksit Bharat@2047 places development, innovation and sustainability within the same long-term national vision. NITI Aayog's DPI@2047 framework also treats digital public infrastructure as an important means of supporting inclusive socio-economic development. In parallel, Sustainable Development Goal 12, particularly Target 12.8, calls for information and awareness that support lifestyles in harmony with nature (United Nations, 2026).

The problem, then, is not a shortage of environmental messages. The harder question is what happens after the message is seen. Conventional campaigns can make environmental damage seem distant or too large for an individual to influence. AI and immersive media may make the connection more immediate by relating an issue to a person's surroundings or a decision they are about to make. The same technologies, however, can become problematic when they rely on manipulation, weak environmental claims or unnecessary data collection.

This paper responds to that challenge through the AISABM framework. It asks how technology, media experience, message credibility and convenient action pathways can be brought together to support measurable sustainable behaviour in the Indian context.

Theoretical Foundations: How Advertising Is Changing

1 From Mass Messaging to Adaptive Communication

Earlier mass advertising generally worked with broad audience categories. A campaign could be designed for a particular demographic group and distributed through print, radio or television. The message itself remained largely fixed, even though individual audience members could interpret it differently.

Digital advertising introduced more detailed segmentation. Online behaviour, searches, interests and interactions made it possible to address narrower groups. AI takes this further by allowing communication systems to adjust content according to context. The paper's original framework describes variables such as local weather, electricity-grid conditions and regional market changes as possible contextual signals. Generative AI can then help create different text, audio or visual versions for different situations.

This shift is important for sustainability communication. A general message such as 'saves electricity' may be easy to ignore. A context-sensitive message that appears during a local heatwave or at a time of high electricity demand can make the same idea more immediate. The value of personalisation, therefore, should be judged not by how much personal data is collected, but by whether the message becomes more useful while respecting consent and privacy.

2 Immersion, Presence and the Ability to Act

Traditional environmental communication often uses photographs, statistics and explanatory narratives. These can inform audiences, but the problem may still feel far away. Immersive media works differently because it can create a stronger sense of presence—the feeling that one is experiencing a situation rather than simply hearing about it.

AR can place information into the user's immediate surroundings. For example, a mobile screen could show the likely environmental cost of a product while the shopper is considering it. VR can create simulated experiences of environmental conditions that a person may never encounter directly. The purpose is not entertainment for its own sake. The purpose is to make an otherwise distant consequence easier to understand.

The original paper connects this idea with Cue-Utilization Theory and Cognitive Load Theory. In simple terms, useful visual or sensory cues can make information easier to process when they are presented in a relevant setting. At the same time, too much information can overwhelm the audience. Immersive advertising should therefore remain focused on a small number of meaningful choices rather than turning sustainability into a complicated digital spectacle.

India's Digital and Technological Landscape

This communication model depends on the reality of India's digital infrastructure. The source material points to strong growth in internet use, mobile connections and domestic AI capacity, while also noting that access to high-end immersive hardware remains uneven.

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Indicator / area	Reported position in the source	Communication implication
Internet users	806 million (2025)	A very large digital audience
Social-media identities	491 million (2025)	Useful for social and participatory campaigns
Mobile connections	About 1.12 billion	Mobile formats can reach many users
5G / digital infrastructure	Rapidly expanding	Can support richer interactions where coverage permits
High-end VR	Concentrated in affluent / metropolitan settings	Cannot be the only access route
Smartphone AR	More widely deployable	A practical route to lightweight immersion
Radio and spoken audio	Resilient and regionally adaptable	Useful for local-language and inclusive outreach

Source: Figures and observations are based on the source document's use of DataReportal (2025), MeitY (2026) and NITI Aayog (2026).

The important point is that connectivity and behavioural impact are not the same thing. A country may have extensive digital access without automatically seeing corresponding changes in consumption or civic habits. The next stage of communication planning should therefore focus on what people actually do after receiving a message.

The infrastructure trajectory presented in the original document also points towards a continuing expansion of internet access and smartphone use up to 2047, alongside increasing availability of AR/spatial-web experiences. The strategic implication is that communication systems should be designed to work across different levels of technological access rather than waiting for every citizen to own advanced immersive hardware.

The AI-Immersive Sustainable Advertising Behaviour Model (AISABM)

AISABM is the central conceptual contribution of this paper. Instead of treating AI, AR or VR as separate advertising tools, the model places them inside a complete behavioural pathway. The basic idea is simple: a person first receives a relevant message, then experiences or understands the issue, checks whether the claim is trustworthy, receives an easy way to act, and finally generates evidence of what happened.

AISABM layer	What it does	Example in sustainability communication
1. Contextual and predictive personalisation	Chooses a relevant message or format from contextual signals, without making unnecessary personal profiling the basis of the campaign.	A local water-conservation message linked to current municipal conditions.
2. Immersive sensory interface	Helps the audience see or experience an issue more directly.	AR product information; VR simulation of drought or sea-level rise.
3. Cognitive mediation and credibility	Adds evidence behind the environmental claim.	Verified lifecycle information and transparent environmental data.
4. Frictionless behavioural resolution	Gives the audience a clear and manageable next step.	UPI incentive, QR/Web-AR interaction, recycling or repair option.
5. Feedback and attribution	Looks at what people actually did and uses the learning to improve later communication.	Verified packaging returns or sustained reduction in household electricity use.

The five layers should not be treated as five independent technologies. They are stages in one communication system. A visually impressive VR experience, for example, has limited value if it ends without a clear action. Likewise, a technically accurate carbon label may have little effect if the audience cannot understand it. AISABM therefore places human decision-making at the centre of the technology stack.

1 Layer 1: Contextual Personalisation

The framework proposes a privacy-conscious approach to personalisation. Instead of relying on invasive identity or biometric profiling, the system can use broader contextual information such as ambient temperature, local water advisories,

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electricity-grid conditions or regional supply conditions. The intention is to make the message relevant without making surveillance the foundation of persuasion.

2 Layer 2: Immersive Interface

The model gives AR and VR different roles. AR is particularly useful when people are already making a practical decision. A phone can place repairability, lifecycle or environmental information directly over a product. VR is more suitable when the goal is empathy or emotional understanding—for example, showing a simulated experience of drought in Marathwada or changing coastal conditions in the Sundarbans.

3 Layer 3: Credibility

Immersion can attract attention, but it does not automatically make a claim true. Sustainability communication needs evidence that audiences and independent reviewers can examine. Environmental databases, third-party verification and transparent records can help reduce the risk of exaggerated claims. Without this layer, immersive advertising may actually increase cynicism.

4 Layer 4: Easy Action

A campaign should not leave the audience with only a feeling or intention. It should provide a realistic next step. The original paper suggests using India's digital public infrastructure, including UPI-based incentives, ONDC-linked circular logistics and municipal smart-meter connections, where appropriate. The broader principle is to reduce the distance between 'I want to help' and 'I have done something.'

4.5 Layer 5: Feedback

The final layer shifts attention from conventional advertising metrics to behaviour. Instead of counting only views, clicks or impressions, a campaign can examine evidence such as repeated packaging returns, participation in composting programmes or changes in household electricity use. Measurement must remain aggregated and privacy-conscious, but it should still provide enough information to determine whether communication is producing a real-world effect.

Moving from Environmental Concern to Everyday Action

A recurring difficulty in sustainability communication is the distance between stated concern and routine behaviour. Someone may support environmental protection and still choose the cheaper, easier or more familiar option when making a purchase. That does not automatically mean that the concern is insincere. Everyday habits, convenience, price and the availability of alternatives can all pull behaviour in another direction.

1 Illustration: AR at the Point of Purchase

Consider a supermarket where a shopper scans a packaged product with a mobile phone. Instead of seeing another generic 'eco-friendly' claim, the AR layer could provide a short set of practical indicators.

Information shown	Purpose	Possible action
Water footprint in relation to local water conditions	Makes resource use locally meaningful	Compare alternatives
Expected breakdown under landfill versus circular treatment	Shows why disposal choices matter	Choose recyclable / reusable option
Deposit-refund amount and return location	Adds an immediate practical benefit	Return packaging and receive UPI credit

This example changes the role of advertising. The message is no longer simply asking the consumer to feel responsible. It gives information at the point of decision and connects that information with a feasible action. The concept remains illustrative and would require field testing before claims about actual behaviour change could be made.

Digital Inclusion: An Integrated Audio-Transmedia Approach

A Viksit Bharat 2047 communication strategy cannot assume that every citizen will have access to expensive VR equipment or constant high-speed connectivity. If sustainability campaigns become dependent on advanced devices, the people who most need accessible information may be left out.

One practical option is a hybrid media system. Radio, community broadcasting and digital audio can provide the narrative foundation, while mobile Web-AR and other lightweight tools can add interactive elements for users who have suitable devices.

1 Why Radio and Spoken Audio Still Matter

The source material emphasises radio's regional reach, resilience and familiarity. It also notes the growth of podcasting and digital audio. Spoken communication can carry sustainability stories in local languages and dialects, explain practical steps and involve voices that audiences already recognise. This makes audio a useful bridge between mass communication and digital interaction.

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2 The Transmedia Loop

Stage	Channel	Role in the campaign
1. Shared introduction	Terrestrial / community radio	Introduce the issue through familiar regional voices.
2. Detailed explanation	Vernacular podcasts / digital audio	Explain costs, benefits and practical choices.
3. Interactive verification	Mobile Web-AR / QR or messaging link	Allow users to see relevant information and complete a simple interaction.
4. Local action	Community / household activity	Turn communication into a visible physical behaviour.
5. Feedback	Aggregated digital reporting	Record participation and improve future communication.

This approach treats media as a connected system rather than a collection of isolated channels. A radio message can lead to a mobile interaction; the mobile interaction can lead to a household or community activity; and the resulting action can provide measurable evidence for the next campaign cycle.

Ethical Governance: Persuasion with Responsibility

The more capable advertising technology becomes, the more important ethical safeguards become. AI can personalise messages, immersive media can intensify emotional responses, and behavioural data can reveal patterns of everyday life. Used carelessly, the same features that make campaigns effective can also make them intrusive.

1 Autonomy Rather Than Algorithmic Pressure

Sustainability campaigns should build people's ability to make informed decisions rather than secretly steering them through psychological vulnerabilities. Scarcity messages, social-pressure loops and dark patterns may increase short-term response, but they are difficult to justify as responsible public-interest communication. Users should know why they are being shown an intervention and should retain meaningful choice.

2 Greenwashing in Immersive Advertising

Immersive media could make greenwashing more persuasive. A company could surround a high-emission product with beautiful images of forests, rivers or clean landscapes, creating a strong emotional association without addressing the product's actual environmental impact. A credible system should therefore require environmental claims to be backed by verifiable lifecycle information and, where possible, independent validation.

3 The Computational Carbon Problem

AI and immersive rendering also consume energy. A campaign designed to promote sustainability should not ignore the environmental cost of the technology used to deliver it. The source paper recommends lightweight and fine-tuned models, efficient rendering and explicit processing-energy budgets. This introduces an important test: the communication system should be proportionate to the environmental benefit it aims to create.

Strategic Roadmap for Sustainable Advertising

The paper's six principles can be converted into a practical planning checklist for advertisers, public agencies and media planners.

Principle	Plain-language meaning	Practical question
1. Purpose before personalisation	Begin with the communication purpose, not with data collection.	What behaviour are we trying to improve?
2. Evidence before emotional spectacle	Claims about environmental benefits need supporting evidence.	Can every major claim be independently checked?
3. Useful experience before technological novelty	Use immersive technology when it genuinely helps the audience.	Does the technology make the decision easier?
4. Universal multi-tiered access	Offer more than one route to the message.	Can the campaign work through audio, mobile and low-bandwidth formats?
5. Radical transparency	Be open about data, evidence and verification.	Can users understand how the message was produced?
6. Behavioural yield as the main success measure	Look beyond views and clicks to meaningful behaviour.	What measurable behaviour changed?

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Comprehensive Measurement Matrix

A sustainability campaign should be evaluated as a progression from exposure to material action. The original paper's five-tier framework can be presented as follows.

Level	What is measured	Illustrative indicators
1. Delivery and reach	Whether the message reached the intended audience.	Algorithmic targeting precision; reach; frequency; audience penetration.
2. Sensory interaction	Whether people actually engaged with the experience.	AR/VR exposure time; interaction depth; completion of immersive elements.
3. Cognitive state	Whether the message improved understanding and reduced resistance.	Comprehension; greenwashing scepticism; pre/post knowledge or attitude measures.
4. Behavioural intent	Whether people show a credible intention to act.	Commitment rates; configuration of a desired action; sign-ups; stated plans.
5. Material action	Whether behaviour changed in the real world.	Verified returns; resource-saving activity; participation in local programmes; measurable conservation.

For a sustainability campaign, the last level matters most. A message can reach a very large audience without changing anything outside the media environment. At the same time, it would be too strong to attribute every later behaviour change to advertising. Future studies should therefore use comparison groups and, where feasible, follow participants over a longer period.

A limitation should be made clear: AISABM is presented here as a conceptual model. The paper does not claim that all five layers have already been tested together in an Indian campaign. The framework is intended to provide a practical starting point for such testing.

Discussion and Future Research

The framework developed in this paper suggests that advertising can serve a role beyond stimulating consumption. It can become part of the communication infrastructure through which sustainability policies are explained, experienced and translated into daily habits. The key change is not simply technological. It is a change in how success is defined.

AISABM places human agency between the algorithm and the outcome. AI may help select a relevant message and immersive media may make that message more engaging, but the audience still needs trustworthy information and a realistic opportunity to act. This is why credibility and frictionless action are separate layers in the model.

The Indian context also makes a hybrid approach essential. A strategy built entirely around high-end immersive technology would risk excluding users who depend on radio, basic smartphones or low-bandwidth services. Combining advanced interfaces with trusted audio channels creates a more inclusive communication environment.

The paper is conceptual and based on secondary material; it does not claim that AISABM has already been empirically validated. Its value at this stage is as a structured framework that can be tested. Future research should move from conceptual design to controlled field studies.

Future research area	Suggested study	Main outcome
Controlled longitudinal trials	Compare AI/immersive sustainability campaigns with conventional campaigns over 6–12 months.	Actual behaviour change rather than immediate response.
Open environmental verification	Test open datasets and third-party verification within advertising interfaces.	Trust and perceived credibility.
Culturally grounded communication	Develop and test campaigns in regional languages and community contexts.	Cultural fit and inclusion.
Computational efficiency	Compare energy use of different AI and immersive campaign designs.	Environmental cost per verified behaviour change.

One limitation should be made clear. AISABM has not yet been tested as a complete intervention in the field. It is presented here as a research proposition that needs empirical testing, rather than as proof of a confirmed causal effect.

Conclusion

Advertising has never been only about information. It also shapes attention, social meaning and repeated habits. That influence can be used for sustainability as well as for commercial consumption. For Viksit Bharat 2047, the important question is whether communication systems can encourage responsible use of resources without becoming intrusive or exclusionary.

AI and immersive media create new possibilities because they can make messages more relevant and experiences more immediate. But technology is not the solution by itself. A useful sustainability

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campaign must combine relevance with credible evidence, emotional understanding with practical action, and innovation with accessibility.

The AISABM framework brings these requirements together through five connected layers: contextual personalisation, immersive engagement, credibility, easy action and behavioural feedback. The proposed transmedia architecture further ensures that advanced digital tools are supported by radio and spoken audio, making the system more inclusive across India's diverse media landscape.

The point is ultimately less about how advanced a campaign appears and more about what it helps people do. If people understand the issue, trust the information and can take a practical step without unnecessary difficulty, advertising has a stronger chance of contributing to sustainable behaviour. That is a more useful benchmark for communication aimed at the long-term goals of Viksit Bharat 2047.

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Government Policies and Renewable Energy Adoption: A Critical Review of Policy Instruments, Consumer Barriers and Administrative Challenges

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Abstract
The transition from conventional energy sources to renewable energy has become an important part of national energy and sustainability strategies. Governments have introduced a range of measures, including subsidies, financial incentives, concessional finance, net-metering arrangements, feed-in mechanisms, renewable purchase obligations, awareness programmes and manufacturing support, to encourage renewable-energy adoption. However, the availability of policy support does not necessarily lead to widespread adoption. This paper critically reviews selected empirical and review studies concerning the relationship between government policies and renewable-energy adoption, with particular emphasis on solar photovoltaic and rooftop solar adoption in India. Ten relevant studies published between 2020 and 2024, together with supporting evidence from an earlier Indian study, are examined to identify recurring patterns in the literature. The review shows that high initial investment, limited access to finance, inadequate information, regulatory complexity, uncertainty about technology and maintenance, weak consumer confidence and differences in access to policy benefits continue to affect adoption. The literature also indicates that financial incentives are more likely to produce meaningful results when they are supported by simple application procedures, reliable information, appropriate grid arrangements, consumer protection and accessible financing. The review further suggests that renewable-energy policies need to account for differences among households, commercial establishments and industrial users rather than relying on a uniform approach. Based on these findings, the paper develops a conceptual framework linking government policy instruments, policy implementation, consumer perceptions and renewable-energy adoption. The paper argues that the effectiveness of renewable-energy policy depends not only on the amount of financial support provided but also on how easily consumers can understand, access and use that support. The study concludes with policy suggestions aimed at making renewable-energy programmes more accessible, transparent, financially practical and socially inclusive.

Keywords: *Renewable energy adoption; government policy; solar photovoltaic; rooftop solar; subsidies; financial incentives; consumer behaviour; energy transition; policy implementation; India*

Introduction

The global energy sector is undergoing a gradual transition from conventional fossil-fuel-based systems towards cleaner and more sustainable sources of energy. Renewable energy has become an important part of this transition because it can contribute to energy security, environmental protection, technological development and long-term economic sustainability. Solar, wind, biomass and other renewable sources are increasingly being incorporated into national energy strategies, while households, businesses and public organisations are becoming potential participants in the energy transition. Although renewable-energy technologies have become more affordable and technically reliable, adoption does not occur automatically. Consumers and organisations make investment decisions within a wider economic, regulatory and social environment.

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Initial investment requirements, availability of finance, expected savings, information about technology, electricity-market arrangements and confidence in suppliers can all influence the decision to adopt. Government policy consequently plays a major role in shaping the conditions under which renewable-energy technologies are adopted. Governments use several forms of intervention to encourage adoption. These include capital subsidies, tax benefits, concessional loans, feed-in tariffs, net metering, renewable purchase obligations, competitive procurement, manufacturing incentives and awareness programmes. Such measures attempt to reduce financial barriers, improve investment returns, encourage market development and create confidence among potential adopters.

India offers an important setting for examining these issues. Over the past decade, national and state governments have promoted solar energy through a combination of financial support, regulatory measures and market-development programmes. Rooftop solar has received particular attention because it allows households and organisations to participate directly in electricity generation. Yet the growth of rooftop solar has not been uniform across consumer groups or regions.

The experience of Delhi illustrates this difficulty. Dutt (2020) found that rooftop solar adoption remained below expectations despite a supportive policy environment. Cost, limited access to finance and information, mistrust and complex procedures were among the barriers identified through interviews with vendors, government and electricity-sector officials, and potential or existing users. The study concluded that several barriers needed to be addressed simultaneously rather than through a single policy measure.

Evidence from Jammu and Kashmir similarly highlights the importance of awareness. Dutta and Das (2020) examined stakeholder perceptions of grid-connected rooftop solar and concluded that awareness played an important role in encouraging adoption. Their findings suggest that a technically suitable technology may still have limited diffusion when potential users lack adequate knowledge about its operation, benefits and practical requirements.

The problem is not restricted to individual households. Dhingra et al. (2023), examining the Indian industrial and commercial rooftop solar sector, identified 35 barriers across financial, regulatory, location-related, technical and market categories. Their analysis ranked market-related and financial barriers particularly highly. This indicates that businesses face a wider set of considerations than simply whether a subsidy is available.

The literature also shows that consumers do not necessarily respond to renewable-energy policies in the same way. Dutt and Ranjan (2022) argued that residential consumers in Delhi differ considerably in terms of income, roof availability, education and technological awareness. Consequently, a single strategy may not adequately address the needs of all potential adopters.

A systematic review by Shakeel et al. (2023) further demonstrates the multidimensional nature of solar-PV adoption. Reviewing 146 scientific studies, the authors identified 127 factors and grouped them into economic, environmental, social, personal, demographic, technical, regulatory and market-related categories. This broad evidence suggests that renewable-energy adoption should not be understood simply as a response to electricity prices or subsidies.

More recent Indian evidence reinforces this argument. Kumar et al. (2024), studying non-residential rooftop solar adoption in Chandigarh, found that environmental concern, compatibility, perceived environmental benefits, immediacy of rewards and trialability were important drivers, while high upfront expenditure and inadequate financial incentives remained important barriers. Mathew and Pandian (2024), studying non-adopting households in Kerala, identified financial, informational, technical, regulatory, social and psychological barriers.

Government policy can therefore influence adoption through several different pathways. A subsidy may reduce the financial burden, but the consumer must know that the subsidy exists, understand the eligibility conditions, complete the required procedures and trust the quality of the installation. Similarly, a favourable net-metering arrangement may improve the economic attractiveness of solar power, but uncertainty about approval or grid connection may reduce its practical value.

The paper critically reviews selected literature on government policy and renewable-energy adoption, identifies the major recurring barriers and enabling factors, and develops a conceptual framework linking policy instruments, policy implementation, consumer perceptions and adoption outcomes.

Review of Literature

Badhotiya et al. (2021) examined the determinants of solar-power adoption in India using Interpretive Structural Modelling (ISM) and MICMAC analysis. Thirteen determinants were identified from the literature and expert discussions, and their

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relationships were organised into a structural model.

One of the important contributions of the study is its recognition that the factors affecting solar adoption are interconnected. The authors found that standards development had a particularly important position within the proposed structure. The study suggests that improving solar adoption requires attention to the wider conditions supporting technology development rather than focusing on a single consumer-level variable.

This finding is relevant to government policy because standards, technical requirements and clear operating arrangements can reduce uncertainty for both producers and users. Policy therefore has a role in creating predictable conditions around the technology as well as providing financial support.

Dutta and Das (2020) investigated the adoption of grid-connected rooftop solar systems in Jammu and Kashmir from a stakeholder perspective. Their study highlighted the importance of awareness and examined perceptions surrounding the technology among different groups.

The study is useful because it moves beyond a purely financial explanation of renewable-energy adoption. Even where solar potential exists and government programmes are available, potential users may not adopt the technology unless they understand how it works, what benefits it offers and what procedures are involved.

The findings point towards a practical role for public awareness programmes. Information should not be limited to general statements about the environmental benefits of solar energy. Consumers also need clear information about installation costs, generation capacity, maintenance, financing, grid connection and available support.

Dutt (2020) provides particularly strong evidence concerning the gap between policy support and actual rooftop-solar adoption. The study examined Delhi's rooftop solar market through 40 semi-structured interviews involving solar vendors, housing-society representatives and government or electricity-distribution officials.

The study identified several barriers, including cost, limited access to finance and information, mistrust and complex procedures. The research is important because it demonstrates that a supportive policy environment does not automatically result in widespread adoption.

A consumer may be interested in solar energy but may postpone the investment if the process appears complicated or if expected savings are uncertain. Similarly, a subsidy may have limited practical value if consumers do not know how to claim it or cannot finance the remaining cost.

The study therefore supports a multi-pronged policy approach. Financial support, information, administrative simplification and consumer confidence need to be addressed together.

Dutt and Ranjan (2022) examined the uneven development of the residential rooftop-solar market in Delhi. Their analysis draws attention to differences among households in terms of income, roof space, education and technological awareness.

The study raises an important question about the distribution of the benefits of renewable-energy policy. A policy may increase solar capacity while still leaving some groups unable to participate.

Households with adequate financial resources may be better positioned to invest in rooftop systems, access credit and absorb delays or unexpected expenses. Other households may face constraints that cannot be solved through a standard subsidy alone.

The authors therefore advocate a more tailored approach. The lesson for renewable-energy policy is that the characteristics of potential adopters should be considered when programmes are designed.

Dhingra et al. (2023) identified and prioritised barriers affecting industrial and commercial rooftop solar in India. The study identified 35 barriers and classified them into financial, regulatory, location-related, technical and market categories.

The analysis found that market-related and financial barriers were particularly important, followed by regulatory, technical and location-related barriers.

This finding demonstrates that renewable-energy adoption among organisations involves considerations beyond environmental motivation. Businesses must evaluate capital requirements, expected returns, electricity costs, market conditions, technology performance and regulatory requirements.

The study therefore supports differentiated policy design. Measures intended for household adoption cannot simply be transferred to industrial and commercial consumers without considering their different investment priorities.

Shakeel et al. (2023) conducted a systematic review of household solar-PV adoption literature and identified 127 factors across 146 scientific studies. The factors were grouped into economic, environmental, social, personal, demographic, technical, regulatory and market-related categories.

The importance of this review lies in its breadth. It demonstrates that household solar adoption is influenced by several overlapping considerations rather than one dominant factor.

Economic benefits remain important, but environmental attitudes, social influence, personal

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characteristics, technical considerations, regulations and market conditions can also affect adoption.

The review supports the central argument of the present paper: government policy should not be considered separately from consumer perceptions and market conditions. Financial incentives may encourage adoption, but their effect depends partly on how consumers perceive the technology and the surrounding market.

Münch and Scheifele (2023) examined India's use of local-content requirements in solar auctions. Their analysis covered 41 auctions representing approximately 6 GW of capacity and examined the subsequent performance of participating firms.

The study found that winning auctions with local-content requirements did not significantly increase firms' solar patents or sales. The authors identified limited production scale, insufficient reinvestment in research and development and reduced competition as possible explanations.

This study provides an important caution against assuming that every form of government intervention will automatically produce the intended outcome.

Policy instruments can create demand and support domestic industries, but their design needs to encourage learning, competition and long-term capability development. Renewable-energy policy should therefore be evaluated not only according to immediate deployment but also according to longer-term market and technological outcomes.

Kumar et al. (2024) examined factors affecting non-residential rooftop solar adoption in Chandigarh using survey responses from 207 participants and Partial Least Squares Structural Equation Modelling.

The study found that environmental concern, compatibility, environmental benefits, immediacy of rewards and trialability were significant drivers of adoption. At the same time, high upfront costs and inadequate financial incentives were identified as important barriers.

The study demonstrates the interaction between positive attitudes and practical constraints. An organisation may recognise the environmental benefits of solar power and consider the technology suitable, but still postpone adoption if the initial investment is difficult to justify.

This finding strengthens the argument for combining financial assistance with information and demonstrations that make the economic and practical benefits easier to understand.

Mathew and Pandian (2024) examined barriers to residential rooftop solar adoption in Kerala using face-to-face interviews with 52 non-adopting households.

The study identified six broad categories of barriers: financial, informational, technical, regulatory, social and psychological.

The Kerala evidence is particularly relevant because it demonstrates that non-adoption does not necessarily indicate a lack of interest in renewable energy. Consumers may have favourable attitudes while still being uncertain about cost, maintenance, technology, procedures or other practical matters.

This distinction is important for policy. Instead of viewing non-adopters simply as consumers who need more environmental awareness, programmes should identify the specific point at which potential adopters hesitate.

Stock and Sovacool (2024) examined social and environmental inequalities associated with different stages of India's solar photovoltaic value chain. Their research considered activities ranging from resource extraction and manufacturing to project development, operation and end-of-life management.

The study identified demographic, spatial, ecological and temporal forms of inequality.

Although the study is broader than household adoption, it has important implications for renewable-energy policy. Increasing renewable capacity is not sufficient to guarantee a fair energy transition. Policymakers must also consider who receives economic benefits, who bears environmental or social costs and which groups have meaningful opportunities to participate.

This perspective strengthens the case for inclusive renewable-energy programmes rather than focusing exclusively on aggregate capacity targets.

Objectives

1. To critically examine the role of government policies in promoting renewable-energy adoption.
2. To identify the major financial, informational, regulatory, technical and behavioural barriers affecting renewable-energy adoption.
3. To examine the effectiveness of subsidies, financial incentives and other policy measures reported in the literature.
4. To analyse the importance of policy implementation, administrative procedures and market conditions in translating policy support into actual adoption.

Discussion And Critical Synthesis

1. Financial incentives remain important, but they are not enough

The most consistent finding across the reviewed literature is the importance of financial considerations. High initial investment remains a major barrier to solar adoption, particularly for households and smaller organisations.

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However, the evidence does not support the idea that simply increasing subsidies will solve the adoption problem.

A subsidy reduces only part of the investment burden. Consumers may still need to arrange the remaining amount through savings or credit. If suitable financing is unavailable, the consumer may continue to postpone adoption.

This distinction between the availability of financial support and its practical accessibility is important.

A more effective policy package may combine: capital subsidies, low-interest loans, longer repayment periods, credit guarantees, transparent information on expected savings, predictable electricity-credit arrangements and clear estimates of payback periods.

The objective should be to reduce the overall financial uncertainty associated with adoption rather than simply reduce the purchase price.

2. **Information can determine whether policy support reaches the consumer**

Several reviewed studies identify inadequate information as a barrier.

Consumers need practical information concerning, system size and capacity, installation cost, subsidy eligibility, expected electricity generation, maintenance, warranties, approved suppliers, financing, grid connection, electricity-credit arrangements and expected payback.

A consumer who does not understand these issues may interpret uncertainty as risk.

Government awareness programmes should therefore move beyond general messages such as "solar energy is environmentally friendly." The information provided should help consumers make an actual investment decision.

3. **Administrative procedures can weaken otherwise attractive policies**

The literature also shows that the process of obtaining support can be as important as the support itself.

Dutt (2020), for example, identified complex procedures as one of the barriers affecting rooftop-solar diffusion in Delhi. If potential adopters must approach several offices, submit repeated documents or wait for lengthy approvals, the time and effort involved can discourage adoption.

A useful way of evaluating renewable-energy programmes is therefore to examine the complete consumer journey:

Awareness → Application → Approval → Installation → Inspection → Grid connection → Subsidy/benefit → Continued use

A weakness at any stage can reduce the value of the overall programme.

Government agencies should therefore monitor application-processing time, approval delays, consumer complaints and cancellation rates in addition to total subsidy expenditure.

4. **Consumer confidence deserves greater attention**

Renewable-energy adoption involves a substantial financial commitment and a technology expected to operate for many years. Consumers consequently depend on installers, manufacturers, electricity providers and public agencies.

Concerns about product quality, maintenance, warranties, after-sales service and system performance can influence adoption.

Dutt (2020) specifically identified mistrust among the barriers affecting rooftop-solar diffusion in Delhi. This suggests that consumer protection should form part of renewable-energy policy.

Useful measures include, accredited installer networks, standard warranty requirements, transparent vendor information, technical quality standards, clear performance guarantees, accessible complaint mechanisms and post-installation service requirements.

Such measures can reduce uncertainty and make consumers more comfortable with the technology.

5. **Regulatory arrangements influence the economic value of solar adoption**

Government policy also affects adoption through electricity-market rules.

Net metering and related arrangements can influence the value of electricity generated by a rooftop system. Similarly, connection procedures, technical requirements and changes in regulations can influence consumer expectations.

This means that renewable-energy policy should be considered as a package of connected measures rather than as a subsidy programme alone.

A financial incentive may have a different effect under a stable and predictable electricity-credit arrangement than under a complicated or uncertain regulatory system.

6. **Different consumers need different policy approaches**

The reviewed studies demonstrate substantial differences between households, commercial establishments and industrial users.

Households may be strongly influenced by: household income, electricity expenditure, roof availability ,awareness , trust, expected savings, social influence, Commercial and industrial organisations may place greater emphasis on investment returns, electricity costs, financing, operational requirements, technology compatibility, business risk, and regulatory conditions.

Therefore, a single policy design may not be equally effective for every adopter group.

7. **Equity should form part of renewable-energy policy evaluation**

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The benefits of renewable energy may not be distributed equally.

Dutt and Ranjan (2022) highlight differences among residential consumers, while Stock and Sovacool (2024) identify wider social and environmental inequalities associated with India's solar value chain.

This raises an important policy question:

8. **Who can actually make use of a renewable-energy incentive?**

A subsidy may appear generous on paper but still be difficult for a low-income household to use if the household cannot obtain the remaining finance or does not have a suitable roof.

Inclusive approaches could therefore include:

targeted financing;
community solar;
shared rooftop systems;
group-based electricity arrangements;
support for apartment residents; and
special programmes for financially constrained households.

The success of renewable-energy policy should consequently be judged not only by total capacity added but also by the breadth of participation.

9. **Policy design should also consider unintended effects**

Government intervention can produce outcomes that differ from its original intention.

Münch and Scheifele (2023), for example, found that local-content requirements in India's solar auctions did not significantly increase participating firms' patents or sales. Their findings suggest that policy instruments designed to promote domestic manufacturing may need sufficient scale, competition and performance requirements to generate lasting technological benefits.

The broader lesson is that renewable-energy policies should be reviewed periodically. A policy that was appropriate at an early stage of market development may need modification as the industry matures.

Findings

The review produces the following major findings.

1: Financial barriers remain significant

High initial expenditure continues to discourage adoption. Financial incentives can reduce this barrier but may not eliminate it.

2: Policy availability does not guarantee policy use

A programme may exist on paper while potential adopters remain unaware of it or find it difficult to access.

3: Information affects investment confidence

Consumers require practical and trustworthy information about technology, costs, financing, benefits and procedures.

4: Administrative simplicity matters

Lengthy procedures, multiple points of contact and delays can reduce the attractiveness of renewable-energy investment.

5: Consumer confidence affects adoption

Concerns about vendors, maintenance, warranties and system performance can delay adoption.

6: Different adopter groups have different needs

Households, commercial establishments and industrial organisations face different financial and practical conditions and therefore require differentiated policy measures.

7: Renewable-energy policies can produce unequal outcomes

Consumers with greater financial resources and better access to information may be better positioned to benefit from government programmes.

8: Government intervention must be evaluated over time

Policy instruments may produce unintended effects or become less suitable as renewable-energy markets develop.

Suggestions

- **Move from subsidy-only programmes towards integrated policy packages**

Financial assistance should be combined with accessible finance, information, consumer protection and simple regulatory procedures.

- **Introduce a genuine single-window application process**

Potential adopters should ideally be able to complete subsidy applications, approvals, installation-related formalities and electricity-connection requirements through a coordinated digital platform.

- **Improve access to affordable finance**

Low-interest loans, longer repayment periods and suitable credit-support mechanisms can help consumers manage the portion of investment not covered by subsidies.

- **Strengthen consumer protection**

Governments should maintain reliable lists of approved suppliers, establish minimum quality standards and ensure that warranties and complaint procedures are clearly communicated.

- **Provide practical rather than purely promotional information**

Government communication should explain actual costs, expected generation, payback, maintenance, eligibility and application procedures.

- **Design separate programmes for different adopter groups**

Residential, commercial and industrial consumers should not necessarily be treated in exactly the

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same way. Their financial capacity, investment objectives and operational requirements differ.

- **Pay greater attention to non-adopters**

Government agencies should study why eligible consumers decide not to adopt renewable energy. This can reveal practical barriers that may remain invisible when policy evaluation focuses only on existing adopters.

- **Improve access for financially constrained households**

Targeted finance, shared solar arrangements and community-based approaches could allow consumers who cannot independently install rooftop systems to participate in renewable-energy programmes.

- **Maintain predictable regulatory arrangements**

Frequent or poorly communicated changes in electricity-credit rules, approval procedures or technical requirements can create uncertainty. Stable and clearly communicated rules can improve investment confidence.

- **Evaluate programmes using outcome-based indicators**

Policy evaluation should include more than the amount of money distributed. Useful indicators include:

number of applications;
approval time;
installation completion rate;
subsidy utilisation;
cancellation rate;
consumer satisfaction;
system performance;
complaint-resolution time; and
participation across different income groups.

Conclusion

Renewable-energy adoption is often discussed in terms of technology cost and environmental necessity. The evidence reviewed in this paper shows that the reality is more complex. Consumers and organisations make adoption decisions within a wider environment shaped by financial conditions, information, regulations, administrative procedures, technology-related concerns and confidence in the organisations involved.

Government policies have an important role in changing this environment. Subsidies can reduce the initial financial burden, while financing schemes can make the remaining investment more manageable. Net-metering and related electricity arrangements can improve the economic attractiveness of rooftop solar. Awareness programmes can reduce information gaps, while quality standards and consumer-protection measures can address concerns about technology and service providers.

Nevertheless, the reviewed literature consistently shows that no single policy instrument is sufficient on its own. Dutt (2020) demonstrates how financial, informational, trust-related and procedural barriers can occur together in Delhi. Dutta and Das (2020) highlight the importance of awareness, while Dutt and Ranjan (2022) show that different residential groups may require different approaches. Dhingra et al. (2023) demonstrate the importance of market and financial barriers in the commercial and industrial sector. Kumar et al. (2024) and Mathew and Pandian (2024) further show that economic, informational, technical, regulatory and psychological considerations can interact in the adoption decision.

The review also reveals an important distinction between policy design and policy delivery. A subsidy that is difficult to understand or access may have less practical value than its nominal amount suggests. Similarly, a favourable regulatory arrangement may have limited effect if consumers face delays, uncertainty or inadequate information.

The conceptual framework developed in this paper therefore proposes that government policy influences renewable-energy adoption through four interconnected stages: policy instruments, policy implementation, consumer perceptions and adoption outcomes. This perspective helps explain why similar policies can produce different results across regions and consumer groups.

The literature also suggests that the success of the energy transition should not be measured solely by renewable-energy capacity. Questions of participation and fairness are equally important. If only financially stronger consumers can make effective use of incentives, renewable-energy programmes may increase capacity without providing broad-based benefits.

Future research can test the proposed framework through empirical studies involving households, commercial organisations and industrial users across different Indian states. Particular attention should be given to the roles of perceived economic benefit, trust, information quality, ease of application and policy awareness. Comparative studies could also examine why similar government programmes produce different adoption levels in different regions.

The overall conclusion is clear: government policy can accelerate renewable-energy adoption, but incentives work best when they are supported by simple procedures, affordable finance, reliable information, predictable regulations and consumer confidence. A successful renewable-energy transition therefore requires not merely more policy support, but better-connected and easier-to-use policy support.

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Original Article

Green Synthesis of Nanoparticles Using Microorganisms: A Sustainable Approach in Microbiology

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Abstract

The transition from conventional energy sources to renewable energy has become an important part of national energy and sustainability strategies. Governments have introduced a range of measures, including subsidies, financial incentives, concessional finance, net-metering arrangements, feed-in mechanisms, renewable purchase obligations, awareness programmes and manufacturing support, to encourage renewable-energy adoption. However, the availability of policy support does not necessarily lead to widespread adoption. This paper critically reviews selected empirical and review studies concerning the relationship between government policies and renewable-energy adoption, with particular emphasis on solar photovoltaic and rooftop solar adoption in India. Ten relevant studies published between 2020 and 2024, together with supporting evidence from an earlier Indian study, are examined to identify recurring patterns in the literature. The review shows that high initial investment, limited access to finance, inadequate information, regulatory complexity, uncertainty about technology and maintenance, weak consumer confidence and differences in access to policy benefits continue to affect adoption. The literature also indicates that financial incentives are more likely to produce meaningful results when they are supported by simple application procedures, reliable information, appropriate grid arrangements, consumer protection and accessible financing. The review further suggests that renewable-energy policies need to account for differences among households, commercial establishments and industrial users rather than relying on a uniform approach. Based on these findings, the paper develops a conceptual framework linking government policy instruments, policy implementation, consumer perceptions and renewable-energy adoption. The paper argues that the effectiveness of renewable-energy policy depends not only on the amount of financial support provided but also on how easily consumers can understand, access and use that support. The study concludes with policy suggestions aimed at making renewable-energy programmes more accessible, transparent, financially practical and socially inclusive.

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Introduction

The global energy sector is undergoing a gradual transition from conventional fossil-fuel-based systems towards cleaner and more sustainable sources of energy. Renewable energy has become an important part of this transition because it can contribute to energy security, environmental protection, technological development and long-term economic sustainability. Solar, wind, biomass and other renewable sources are increasingly being incorporated into national energy strategies, while households, businesses and public organisations are becoming potential participants in the energy transition. Although renewable-energy technologies have become more affordable and technically reliable, adoption does not occur automatically. Consumers and organisations make investment decisions within a wider economic, regulatory and social environment.

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Microbial synthesis can occur either inside microbial cells or outside the cells. In extracellular synthesis, enzymes and metabolites released into the surrounding medium may reduce metal ions and facilitate nanoparticle formation. Intracellular synthesis involves uptake of metal ions followed by their transformation within or around the microbial cell. The biological synthesis of nanoparticles has become an important research area at the intersection of microbiology and nanotechnology. Earlier reviews have documented microbial production of silver, gold, platinum, palladium, iron and several metal-oxide nanoparticles. ([ScienceDirect][2])

Objectives

The major objectives of this review are:

1. To describe the concept of microbial-mediated nanoparticle synthesis.
2. To discuss microorganisms commonly involved in nanoparticle production.
3. To explain extracellular and intracellular mechanisms of synthesis.
4. To summarize important characterization techniques.
5. To discuss antimicrobial applications of microbial nanoparticles.
6. To examine agricultural and environmental applications.
7. To identify advantages and limitations of microbial nanoparticle synthesis.
8. To highlight future research opportunities in microbial nanotechnology.

Microorganisms Used for Nanoparticle Synthesis

Several groups of microorganisms have been investigated for biological nanoparticle synthesis.

1 Bacteria

Bacteria are among the most extensively studied microorganisms for nanoparticle biosynthesis. Their rapid growth, relatively simple nutritional requirements and metabolic diversity make them attractive biological systems.

Bacterial cells can interact with metal ions through cell-wall functional groups, extracellular polymers, proteins and enzymes. Some bacterial species can reduce metal ions and facilitate the formation of nanoparticles.

2 Fungi

Fungi have significant potential for nanoparticle production because they secrete large quantities of extracellular enzymes and metabolites. Their extensive mycelial network can also interact efficiently with metal ions.

Fungal systems have been investigated for the production of silver, gold and several metal-oxide nanoparticles. Extracellular synthesis can be particularly advantageous because nanoparticles can potentially be recovered without extensive disruption of microbial cells.

3 Actinomycetes

Actinomycetes are filamentous bacteria known for their ability to produce diverse secondary metabolites and enzymes. Species belonging to genera such as *Streptomyces* have attracted interest as biological nanoparticle-producing systems.

4 Yeasts

Yeasts can interact with metal ions through their cell surfaces and metabolic products. Both intracellular and extracellular nanoparticle formation have been reported.

5 Microalgae

Microalgae possess diverse biochemical components that can participate in the reduction and stabilization of nanoparticles. Their use may also provide opportunities for integrating nanoparticle production with biotechnology and environmental processes.

Overall, bacteria, actinomycetes, fungi, yeast and microalgae represent important microbial sources for nanoparticle biosynthesis. ([PMC][3])

Mechanisms of Microbial Nanoparticle Synthesis

Microbial nanoparticle synthesis is a complex biological process. The exact mechanism depends upon the microorganism, metal precursor, growth conditions and physicochemical environment.

1 Extracellular synthesis

In extracellular synthesis, metal ions are converted into nanoparticles outside the microbial cells.

A simplified process can be represented as:

Metal ions → microbial metabolites/enzymes → reduction → nucleation → nanoparticle formation → stabilization

Extracellular enzymes, proteins, amino acids and other metabolites may participate in reduction and stabilization.

One enzyme frequently discussed in microbial nanoparticle biosynthesis is NADH-dependent nitrate reductase. Microbial biomolecules can also act as capping agents, limiting uncontrolled aggregation of the newly formed nanoparticles. ([ScienceDirect][2])

2 Intracellular synthesis

During intracellular synthesis, metal ions first interact with the microbial cell and may enter the cell through various mechanisms. Once inside, cellular enzymes and metabolites can reduce the metal ions.

The resulting nanoparticles may accumulate within or near the cells.

General sequence

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Metal ion interaction → cellular uptake → enzymatic reduction → nucleation → nanoparticle growth → stabilization

The physicochemical properties of the final nanoparticles depend on microbial species and environmental conditions.

Factors Affecting Nanoparticle Synthesis

Several factors influence microbial nanoparticle production.

1 pH

pH can affect microbial metabolism, enzyme activity, metal-ion availability and nanoparticle nucleation. Changes in pH may therefore influence particle size and morphology.

2 Temperature

Temperature affects both microbial growth and biochemical reactions associated with nanoparticle formation. An appropriate temperature may increase synthesis efficiency, whereas unsuitable temperatures can reduce microbial activity.

3 Metal-ion concentration

The concentration of the metal precursor is an important parameter. Very low concentrations may result in limited nanoparticle production, whereas excessive concentrations can inhibit microbial growth.

4 Incubation time

The duration of interaction between microorganisms and metal ions can influence the quantity and properties of nanoparticles.

5 Microbial species

Different microorganisms possess different metabolic pathways and biomolecules. Consequently, the same metal precursor may produce nanoparticles with different characteristics depending on the microorganism used.

6 Nutritional conditions

Carbon and nitrogen sources, mineral availability and overall culture conditions can influence microbial metabolism and consequently nanoparticle formation.

Microbial species and synthesis conditions can influence nanoparticle size, shape and stability. ([ScienceDirect][2])

Characterization of Microbially Synthesized Nanoparticles

Characterization is essential to determine whether nanoparticles have been successfully produced and to understand their properties.

1 UV-Visible spectroscopy

UV-Visible spectroscopy is frequently used to monitor nanoparticle formation. Metal nanoparticles can exhibit characteristic optical absorption associated with surface plasmon resonance.

Changes in absorption intensity and peak position can provide information about nanoparticle formation and changes in particle characteristics.

2 Fourier Transform Infrared Spectroscopy (FTIR)

FTIR helps identify functional groups associated with biomolecules present on the nanoparticle surface.

Proteins, amino groups, carboxyl groups and other biomolecules may contribute to reduction or stabilization of nanoparticles. ([ScienceDirect][2])

3 X-ray diffraction (XRD)

XRD is used to investigate the crystalline nature and crystal structure of nanoparticles.

4 Scanning Electron Microscopy (SEM)

SEM provides information about surface morphology and particle structure.

5 Transmission Electron Microscopy (TEM)

TEM can provide high-resolution information about nanoparticle size, shape and morphology.

6 Dynamic Light Scattering (DLS)

DLS is useful for determining hydrodynamic particle size and evaluating particle-size distribution in suspension.

7 Energy-Dispersive X-ray Spectroscopy (EDX)

EDX can provide information about elemental composition and can support confirmation of the presence of the target metal.

Antimicrobial Activity of Microbial Nanoparticles

One of the most extensively investigated applications of metallic nanoparticles is antimicrobial activity.

Antimicrobial resistance is a major global health concern. WHO reports that antimicrobial resistance makes infections increasingly difficult to treat and that approximately one in six laboratory-confirmed bacterial infections worldwide was resistant to antibiotics in 2023. ([World Health Organization][4])

Nanoparticles may interact with microorganisms through several mechanisms.

1 Damage to the cell membrane

Nanoparticles can interact with microbial cell surfaces and disturb membrane integrity.

2 Generation of reactive oxygen species

Some nanoparticles can promote oxidative stress, leading to damage of proteins, membranes and nucleic acids.

3 Interaction with cellular components

Metal ions released from nanoparticles may interact with proteins and other cellular components.

4 Biofilm inhibition

Certain nanoparticles have demonstrated potential for interfering with microbial biofilms.

5 Multiple mechanisms

Unlike many conventional antibiotics that have specific cellular targets, nanoparticles may act

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through multiple mechanisms simultaneously. Microbially synthesized metallic nanoparticles, particularly silver and gold nanoparticles, have been widely investigated for antimicrobial applications. ([ScienceDirect][5])

Biomedical Applications

Microbial nanoparticles have potential applications in several biomedical areas.

1 Antimicrobial agents

Silver, gold and other metallic nanoparticles have been studied against bacterial and fungal pathogens.

2 Drug delivery

Nanoparticles can serve as carriers for delivering therapeutic molecules to particular biological locations.

3 Diagnostic applications

Their optical and physicochemical properties make certain nanoparticles useful in biosensing and diagnostic technologies.

4 Wound management

Nanoparticles with antimicrobial properties have been investigated for incorporation into wound-related materials.

5 Anticancer research

Some nanoparticles have demonstrated cytotoxic effects against cancer cells in experimental systems. However, extensive safety and clinical evaluation is necessary before therapeutic applications can be broadly adopted.

Microbial nanoparticle synthesis has been explored for antimicrobial therapy, drug delivery, diagnostics and other biomedical applications. ([ScienceDirect][6])

Agricultural Applications

Nanoparticles synthesized using microorganisms may have applications in agriculture.

1 Nanopesticides

Certain nanoparticles may exhibit activity against agricultural pathogens and pests.

2 Nanofertilizers

Nanomaterials can potentially be used to improve the delivery or availability of nutrients.

3 Plant disease management

Antimicrobial nanoparticles may have potential for controlling plant-associated microbial pathogens.

4 Soil and crop applications

Biologically synthesized nanoparticles are being investigated for applications that may reduce dependence on some conventional chemical inputs.

However, their effects on soil microorganisms, plants, animals and ecosystems require detailed investigation before extensive agricultural application.

Environmental Applications

Microbial nanoparticles have considerable potential in environmental biotechnology.

1 Wastewater treatment

Nanoparticles can participate in adsorption, catalytic transformation or antimicrobial processes relevant to wastewater treatment.

2 Bioremediation

Certain nanoparticles can interact with environmental contaminants and contribute to pollutant transformation or removal.

3 Environmental sensors

Nanomaterials possess properties that can be exploited for detecting pollutants and other environmental indicators.

4 Pollutant degradation

Some biologically synthesized nanoparticles have been investigated for catalytic degradation of environmental pollutants.

Recent reviews identify applications of microbial nanoparticles in bioremediation, wastewater treatment, pollution monitoring and other environmental technologies. ([PubMed][7])

Advantages of Microbial Nanoparticle Synthesis

The major advantages include:

- Environmentally friendly production approach.
- Potential reduction in hazardous chemical use.
- Mild biological reaction conditions.
- Use of naturally occurring microbial metabolites.
- Potential for extracellular synthesis.
- Diversity of microorganisms available.
- Possibility of biological capping and stabilization.
- Potential applications across medicine, agriculture and environmental biotechnology.

Microorganism-mediated synthesis has been described as a promising alternative to conventional approaches because microbial systems can provide biological reducing and stabilizing components. ([Springer][1])

Limitations and Challenges

Despite its potential, microbial nanoparticle synthesis has several challenges.

1 Lack of standardization

Different studies often use different microbial strains, culture conditions, precursor concentrations and purification procedures.

2 Control of particle characteristics

Precise control of size, shape and surface properties remains challenging.

3 Production time

Some biological systems may require relatively long incubation periods compared with certain chemical methods.

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4 Scale-up

A method that works effectively at laboratory scale may not perform identically at industrial scale.

5 Purification

Removing cellular components and obtaining highly purified nanoparticles can be difficult.

6 Toxicity

The biological origin of nanoparticles does not guarantee safety. Nanoparticle toxicity toward human cells, beneficial microorganisms and environmental organisms must be investigated.

7 Reproducibility

Differences in microbial physiology can affect nanoparticle production between batches.

Recent literature emphasizes reproducibility, standardization, scalability and safety evaluation as important barriers to broader implementation. ([Springer][1])

Future Perspectives

The future of microbial nanotechnology is likely to depend on improved understanding and control of biological synthesis.

Genetic and metabolic engineering could potentially modify microorganisms to increase nanoparticle production or influence particle characteristics. Microbial systems could also be optimized through controlled culture conditions and bioreactor-based product.

Conclusion

Microorganism-mediated nanoparticle synthesis represents an important emerging area of microbiology and biotechnology. Bacteria, fungi, actinomycetes, yeasts and microalgae can act as biological systems for producing metallic and metal-oxide nanoparticles. Microbial enzymes, proteins and metabolites can participate in reduction, nucleation and stabilization processes.

The resulting nanoparticles have potential applications in antimicrobial technology, medicine, agriculture, environmental remediation and diagnostics. Their possible contribution to antimicrobial strategies is particularly important in view of the growing global burden of antimicrobial resistance. ([World Health Organization][4])

Nevertheless, microbial nanoparticle technology should not be considered automatically safe or ready for unrestricted application. Particle characteristics, toxicity, environmental effects, reproducibility and scale-up must be carefully evaluated. With systematic research, improved standardization and interdisciplinary collaboration, microbial nanotechnology could become an important component of sustainable biotechnology.

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Conflicts of interest

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

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Original Article

Decoding the 'Viksit' Consumer: Integrating AI, Smart Technologies, and Asset Lifecycle Theories for Sustainable Development towards Bharat 2047

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Abstract
With the country working towards the Viksit Bharat 2047 vision, the way we look at technology, sustainability, and market trends is seeing a major change. While we often label the Indian buyer as strictly price-sensitive, today's consumer is actually quite digital and eco-conscious. However, there is still a mental block when it comes to investing in expensive green technology. People worry about the product losing its value or becoming outdated too quickly—a classic case of 'asset depreciation' in accounting terms, which in everyday life simply translates to a fear of losing 'value for money'. The present study explores how Artificial Intelligence and smart tools are helping brands reshape their marketing to overcome this hesitation. Based on a detailed review of secondary data, we examine how AI-based personalisation, local language (vernacular) interfaces, and circular economy models are changing buying habits across both urban 'India' and rural 'Bharat'. By connecting traditional accounting concepts with modern marketing strategies, the findings show that smart technologies are doing much more than just driving sales. They are actively helping to build genuine consumer trust and encouraging sustainable buying habits, which is exactly what is needed to achieve our national development goals for 2047.

Keywords: *Viksit Bharat 2047, AI in Marketing, Consumer Behaviour, Depreciation Accounting, Sustainable Development, Circular Economy.*

Introduction

Just ten or fifteen years back, the typical Indian shopping experience meant haggling at the local kirana store, trusting whatever the neighbours recommended, and always hunting for the absolute cheapest option. But look at how things have changed today. Take a shopper in a Tier-2 city like Indore or Surat. They are now using an AI chatbot in their local language to check the carbon footprint of two washing machines. And they aren't just looking at the sticker price; they are actually picking the energy-efficient model because an app showed them how much it will save on electricity bills over the years.

This isn't just a simple change in buying habits; it is a complete structural shift. But to really make sense of the modern Indian buyer, we have to look at our cultural roots. Our ancient texts actually have a lot to say about how we should consume. The Isha Upanishad gives us a very clear principle:

"त्यक्तेन भुञ्जीथा मा गृधः कस्यस्विद्धनम्" (Tena tyaktena bhunjitha ma gridhah kasyasvid dhanam)

Simply put, it means: "Enjoy what you need through renunciation; do not covet or hoard anyone else's wealth."

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If you read this closely, it perfectly captures the essence of the modern circular economy. It is basically telling us to use only what we need, do it sustainably, and stop hoarding or wasting things. The Government of India's dream of a Viksit Bharat (Developed India) by 2047 is built on this very mindset. For the marketing world, this means we have to move away from the old, aggressive mass-selling tactics. Instead, brands need to use smart, AI-driven tools to engage consumers in a way that is genuinely sustainable. Against this backdrop, this research paper examines how these new technologies are changing what Indians buy, how they buy it, and the reasons behind their choices. More importantly, it looks at how smart marketing can ease the financial worries people have about their products losing value over time, making the journey towards 2047 a shared success for both businesses and everyday buyers.

Rationale of the Study

There is no shortage of global research on how AI is changing marketing. But when it comes to the Indian buyer, things get a bit more complex. We are a market that proudly celebrates jugaad—our unique cultural knack for frugal innovation. Yet, at the same time, we are incredibly quick to adopt cutting-edge tech like UPI and AI tools. The problem is that most existing studies treat the Indian consumer as one single, uniform block. Or, they focus almost entirely on the big metro cities, missing the bigger picture.

The real shift is actually happening elsewhere. There is a distinct gap in understanding how smart technologies are penetrating our Tier-2 and Tier-3 cities—the true heartland of 'Bharat'. More importantly, we do not fully grasp how this digital wave is nudging people in these smaller towns towards sustainable, eco-friendly consumption. It is not just an urban trend; it is a grassroots movement.

Then, there is the financial angle, which is rarely discussed in marketing literature. In accounting terms, the lightning-fast pace of AI and technology means products become outdated much quicker. This is technological obsolescence, or simply, depreciation. Now, consider the traditional Indian mindset. We are naturally very hesitant to part with our hard-earned money on an asset that will lose its value in a few years. This deep-rooted fear of a depreciating asset acts as a massive mental block, especially when it comes to investing in expensive, high-ticket green technology.

This study aims to bridge that exact gap. We are looking at AI marketing through the lens of India's specific socio-cultural reality. By bringing in the principles of Depreciation Accounting, we want to unpack the psychological barriers that make Indians hesitate to adopt sustainable tech. It is about connecting the dots between our financial anxieties, our cultural habits, and modern marketing to understand what truly drives the Indian market today.

Objectives and Hypothesis

- To give this research a clear and practical direction, we have outlined a few core objectives. These are designed to look at both the consumer mindset and the on-ground market realities:
- To understand how AI-driven personalisation actually influences the buying decisions of Indian consumers, moving beyond just the technology to see how it shapes their everyday choices.
- To analyse how digital marketing tools can effectively promote sustainable products, specifically by tackling that deep-rooted fear of asset depreciation (or the worry of a product losing its value over time).
- To evaluate how well smart marketing technologies are being picked up and adapted in Tier-2 and Tier-3 cities, which is where the real market expansion is happening today.
- To suggest practical, strategic frameworks that align AI and tech-driven marketing with the sustainable development goals of Viksit Bharat 2047.

Looking at current market trends and the ground reality, we have put forward a few working hypotheses to test our conceptual framework:

H1: AI-driven personalised marketing has a significant positive impact on the purchase decision-making process of Indian consumers, as it helps them feel that the product is tailored to their specific needs rather than being a generic, one-size-fits-all offering.

H2: Digital marketing tools that highlight long-term value, energy savings, and product lifecycle benefits play a meaningful role in reducing the consumer's fear of asset depreciation, thereby increasing their willingness to invest in sustainable and green products.

H3: The adoption of smart marketing technologies—such as vernacular AI interfaces, chatbots, and AR-based product demos—is significantly higher in Tier-2 and Tier-3 cities than what traditional market assumptions suggest, and this adoption positively influences consumer trust and brand loyalty.

H4: Marketing strategies that integrate AI and smart technologies with circular economy principles are more effective at aligning consumer behaviour with the sustainable development goals

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of Viksit Bharat 2047 than conventional mass-marketing approaches.

Methodology

To get a clear and practical picture of the current market scenario, we have adopted a structured, conceptual approach for this research. Rather than relying purely on theoretical models, we wanted to map out the actual landscape of AI-driven marketing in India.

Research Design and Data Collection

We adopted an exploratory and descriptive design. We relied entirely on secondary sources. We examined industry reports from established bodies like NASSCOM and McKinsey, reviewed government publications tied to the Digital India mission, and went through peer-reviewed academic journals. To ensure the data reflects the current ground reality, we strictly limited our sources to papers and reports published between 2019 and 2024.

Sampling and Research Method

To select our sample, we used a purposive sampling technique. We carefully shortlisted 45 highly relevant reports that specifically focused on the Indian market, AI integration, and shifting consumer behaviour. Once we had our final set of documents, we applied a systematic content analysis. This method helped us extract the exact qualitative data we needed to understand consumer tech adoption and track sustainability metrics.

Tools for Analysis

To make sense of this qualitative information, we used thematic analysis. We read through the selected reports to spot recurring patterns and coded the data into core themes. This step was crucial for our study, as it allowed us to properly test our conceptual hypotheses against the actual trends emerging in the market.

Analysis and Data Analysis

The thematic analysis revealed major shifts in the Indian marketing landscape. Below is the synthesized analysis of how AI, smart tech, and accounting realities are driving consumer behaviour.

Theme 1: From 'Mass' to 'Micro' – The AI Personalization Shift

Traditional Indian marketing relied on mass media. The data shows a massive pivot to AI-driven micro-segmentation. E-commerce platforms use predictive AI to recommend *sustainable alternatives*. For instance, when a consumer searches for a fast-fashion item, AI algorithms on platforms like Myntra highlight 'eco-friendly' tags. AI is making sustainability visible, increasing green product adoption by an estimated 18-22% in urban demographics.

Theme 2: Bridging the Divide – Smart Tech in 'Bharat'

The most fascinating finding is the explosion of smart tech in non-metro cities. Voice search and AI chatbots in Hindi, Tamil, and Telugu have removed the language barrier. Augmented Reality (AR) features allowing users to visualize furniture in their homes are seeing higher conversion rates in Tier-2 cities than in metros. Smart tech is building immense brand trust in smaller towns, validating **H2**.

Theme 3: The Accounting Lens – Mitigating the "Depreciation Fear"

Here is where financial accounting meets consumer psychology. According to the Institute of Chartered Accountants of India (ICAI), depreciation is heavily driven by *technological obsolescence*. In the AI era, the "useful life" of a smart device (like an IoT-enabled EV) shrinks rapidly. The Indian buyer, who demands *paisa vasool* (value for money), hesitates to buy green tech because they fear it will become obsolete and lose value quickly (the Diminishing Balance Method of depreciation).

Marketers are now using AI to shift consumer behaviour from *ownership* to *access* (Circular Economy Models). By offering Battery-as-a-Service or smart appliance leasing, AI platforms mask the psychological impact of depreciation.

Table 1: Mapping Accounting Depreciation Causes to AI Marketing Strategies

Core Cause of Depreciation (Accounting Theory)	Impact on Indian Consumer	AI & Smart Tech Marketing Intervention (Sustainable Nudge)
Obsolescence (Availability of superior tech)	Fear of buying a "dead" asset; hesitation to invest in green tech.	**AI Predictive Upgrades:** Apps that guarantee buy-back value or seamless tech-swaps (e.g., "Upgrade your smart meter AI for free in 2 years").
Physical Wear & Tear	High maintenance costs deter adoption of premium eco-products.	**IoT Predictive Maintenance:** Smart apps that alert consumers *before* a breakdown, extending asset life and reducing e-waste.
Efflux of Time (Legal/Lease limits)	End-of-life disposal creates environmental hazards (e-waste).	**AI Circular Marketplaces:** Automated platforms connecting end-of-life assets with recyclers, offering "Green Credits" for returns.

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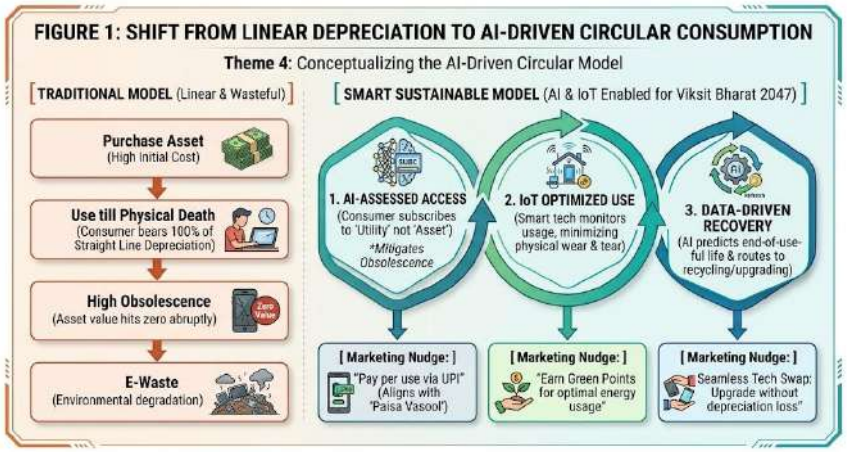
Theme 4: Conceptualizing the AI-Driven Circular Model

The following framework illustrates how AI transforms the traditional linear depreciation model into a sustainable, circular model for the 'Viksit Bharat' consumer.

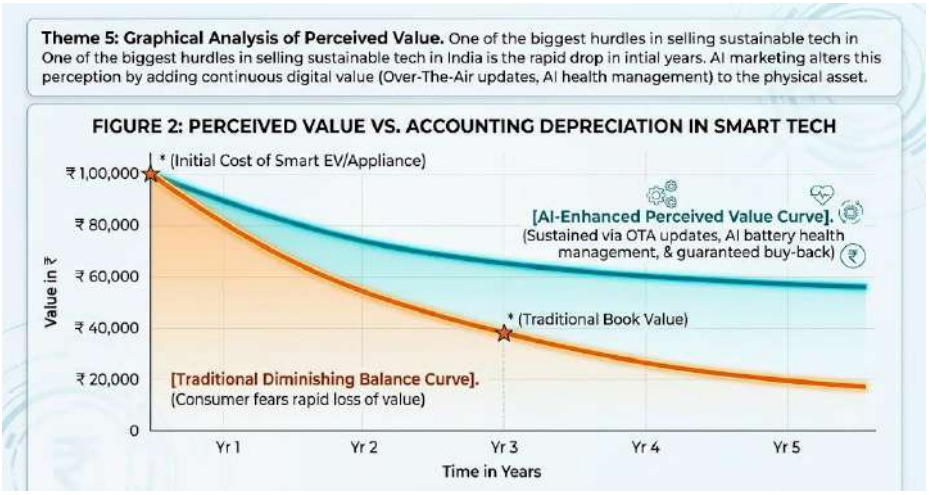


What makes this framework so powerful is that it doesn't ask consumers to sacrifice convenience for sustainability. Instead, it uses technology (AI and IoT) and digital infrastructure (like UPI) to make the eco-friendly choice the most financially logical choice as well.

Which of the three marketing nudges—the pay-per-use UPI model, earning Green Points, or the seamless tech swap—do you think would be the easiest to sell to today's consumers?

Theme 5: Graphical Analysis of Perceived Value

One of the biggest hurdles in selling sustainable tech in India is the rapid drop in book value during the initial years. AI marketing alters this *perception* by adding continuous digital value (Over-The-Air updates, AI health management) to the physical asset.



Strategic Matrix: Aligning Consumer Demographics with Asset Realities

To make this work in the real world, we need a practical framework. Let us draw a simple parallel with basic accounting. When a chartered accountant decides how to depreciate an asset, they do not just pick a method at random. They look at the asset's actual utility and lifespan. If it is a building with a long, steady life, they might apply the Straight-Line Method (SLM). But if it is a piece of technology or machinery that loses its value rapidly in the first few years, they will naturally opt for the Reducing Balance Method (RBM).

Marketers need to apply this exact same practical logic to their AI strategies. We simply cannot use a one-size-fits-all approach for the diverse Indian market.

For the digitally native, urban consumer who is accustomed to upgrading their gadgets every couple of years (a mindset akin to the RBM), marketing should focus on seamless upgrade paths, assured trade-in values, and tech-leasing models. The messaging here is about staying current without the financial burden of ownership.

On the other hand, for the value-conscious buyer in a Tier-2 or Tier-3 city who expects a single purchase to last a decade (a mindset closer to the SLM), the

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AI-driven messaging must be entirely different. Here, the focus should be on long-term durability, predictable electricity savings, and robust, easily accessible after-sales support.

By mapping AI-driven marketing tactics to these distinct demographic realities and financial mindsets, brands can move beyond superficial engagement. They can build genuine, long-lasting trust and actively drive sustainable consumption, ensuring that their commercial strategies are perfectly in sync with the ground realities of the Indian consumer.

Table 2: Aligning Asset Depreciation Reality with AI Marketing Segments

Target Demographic	Asset Category	Accounting Reality (Depreciation)	AI & Smart Marketing Strategy for Sustainability
Urban 'India' (Metros)	Premium Smart EVs, Home Automation	**Reducing Balance Method:** High initial tech obsolescence; rapid value drop.	**AI Subscription & V2G:** Market the asset as a revenue generator. AI apps show how a depreciating asset can *earn* money by selling battery power back to the grid.
Rural / Tier-2 'Bharat'	Solar Pumps, Agri-Tech, Basic IoT	**Straight Line Method:** Focus on long-term utility, durability, and steady cost-recovery.	**Vernacular Voice-AI & Micro-Finance:** Use regional AI bots to explain steady, linear cost-savings over 10 years. Integrate with UPI for micro-EMIs.
MSMEs / Local Traders	Energy Efficient Machinery	**Annuity / Sinking Fund Concept:** Capital blocking is a major concern.	**AI-Driven Leasing Marketplaces:** Platforms use AI to assess machine health, offering "Green Leasing" with zero depreciation worry.

Conclusions

Reaching the goal of a Viksit Bharat (Developed India) by 2047 isn't just about boosting our GDP or driving rapid economic growth. It requires a fundamental shift in our everyday habits—specifically, how we consume. It actually brings us right back to our ancient cultural wisdom: the idea of enjoying what we truly need without greedily hoarding more than we require.

Our research clearly shows that AI and smart technologies have outgrown their old role as mere sales boosters. Today, they are the key drivers in building a genuinely sustainable consumer culture across the country.

When we look at buying behaviour through the lens of Depreciation Accounting, a very clear picture emerges. The biggest hurdle for an Indian buyer to adopt green technology isn't a lack of awareness. It is the deep-rooted fear of their hard-earned money losing value. They worry the product will become outdated too fast, leading to financial depreciation.

This is where smart tech steps in to bridge the gap. By introducing flexible models like 'pay-per-use' or product leasing, these technologies extend the useful life of assets and turn heavy upfront costs into manageable, everyday expenses. It perfectly satisfies the Indian consumer's natural demand for paisa vasool (true value for money) while keeping us firmly on track with the nation's sustainability targets.

Ultimately, the future of marketing in India isn't about pushing mass-produced, disposable goods. It is about being deeply local, truly inclusive, and firmly rooted in the circular economy.

Recommendations

Drawing from our findings, here are a few practical, on-ground recommendations for brands, tech developers, and policymakers to keep in mind:

A. **Go Beyond English-First AI:** To truly connect with the heartland of Bharat, brands must move past English-centric digital tools. Investing in robust, context-aware voice AI and chatbots in regional languages is no longer optional; it is the key to unlocking genuine trust and adoption in Tier-2 and Tier-3 markets.

B. **Design for Sustainable Defaults**: E-commerce platforms should subtly redesign their user interfaces to make eco-friendly choices the easiest, most obvious option. For the value-conscious Indian buyer, using AI to clearly highlight long-term electricity or maintenance savings is a much stronger pitch than just focusing on the upfront sticker price.

C. **Sell Utility, Not Just Ownership:** To tackle the deep-seated fear of an asset losing its value over time (that classic diminishing balance depreciation worry), marketers should leverage AI to promote 'Product-as-a-Service' (PaaS) or leasing models. When consumers pay for the utility rather than outright ownership, the anxiety of technological obsolescence simply vanishes.

D. **Build Transparent 'Green Ledgers'**: Brands can develop simple, AI-driven consumer dashboards that track a buyer's 'Carbon Depreciation'—the actual emissions they have prevented—right alongside their financial

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savings. This cleverly turns sustainability from an abstract idea into a tangible, appreciating asset in the consumer's mind.

E. **Strengthen Policy Backing for Green Tech:** The government can accelerate this shift by offering targeted tax incentives or grants under the 'Digital India' framework. Actively supporting startups that use AI and IoT specifically for resource optimization will create a much healthier, more vibrant ecosystem for sustainable innovation in the country.

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Original Article

Higher Education Choices and Capabilities of Rural Women in Kolhapur District: A Qualitative Study through Sen's Capability Approach

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Abstract

This study examines the higher-education experiences of women from selected villages and rural communities across Kolhapur district, Maharashtra, through Amartya Sen's Capability Approach. The study focuses on the ways in which economic resources, social and cultural norms, and institutional conditions shape women's substantive freedom to access, continue, and make meaningful choices in higher education. A qualitative research design was adopted. After data cleaning, exact duplicate schedules and records that could not be reliably read were excluded, leaving 28 unique usable participant interviews for combined thematic analysis. Participant-level coding was used, so each participant was counted once for a tag even when the same issue appeared repeatedly in her responses. Three major themes emerged: (1) economic limitations and career opportunities, (2) social and cultural norms affecting aspirations and decision-making, and (3) institutional and infrastructure gaps in higher education. Financial constraints were thematically coded for 27 of 28 participants (96.4%), while social norms were thematically coded for 25 participants (89.3%). Transportation barriers and infrastructure deficits were also prominently observed. At the same time, many participants reported family support, satisfactory teaching quality, career guidance, and growing aspirations for higher education and employment. The findings show that formal access to college does not automatically translate into equal educational capability. Women's real opportunities depend on how resources are converted through household responsibilities, gender norms, mobility, digital access, institutional support, and public policy. The study concludes that policy for rural women's higher education should move beyond enrolment and focus on expanding substantive freedom, choice, mobility, time, digital capability, and agency.

Keywords: *Rural women, Higher Education, Kolhapur district, Capability Approach, financial constraints, gender norms, educational access, agency*

Introduction

Higher education plays an important role in expanding knowledge, employability, social participation, economic independence, and the ability to make informed life choices. For women in rural areas, however, access to higher education is shaped not only by the physical existence of colleges but also by household income, distance, transport, digital resources, domestic responsibilities, family expectations, marriage norms, and the availability of institutional support. Consequently, two students who are formally enrolled in higher education may still possess very different levels of real freedom to choose a course, attend regularly, participate in academic activities, pursue further education, or prepare for a preferred career. The present study investigates these inequalities from the perspective of women drawn from selected villages and rural communities across Kolhapur district. The analysis instead treats the interviews as evidence of wider rural educational experiences within the district.

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The study is interpreted through Amartya Sen's Capability Approach. This framework is especially useful because it shifts attention from the simple possession of resources to the genuine opportunities that people have to achieve the lives they value. In education, this means distinguishing between formal access to a college and the substantive capability to choose, continue, participate, and use education for valued personal and career goals.

Objectives of the Study

1. To examine the economic constraints affecting women's participation and choices in higher education in rural areas of Kolhapur district.
2. To analyse the influence of social and cultural norms on educational aspirations, mobility, marriage expectations, and decision-making.
3. To identify institutional and infrastructure barriers such as transport, distance, digital access, hostel requirements, and career guidance.
4. To interpret women's educational experiences through Sen's Capability Approach, with particular emphasis on resources, conversion factors, capabilities, functionings, and agency.
5. To suggest policy measures for expanding substantive educational opportunities for rural women.

Theoretical Framework: Sen's Capability Approach

Sen's Capability Approach evaluates well-being and development in terms of what people are effectively able to be and do. Resources such as income, scholarships, transport, digital devices, or nearby institutions matter, but their value depends on whether individuals can convert them into meaningful opportunities. These conversion processes are influenced by personal, social, and environmental factors.

In the context of this study, household income, scholarships, college availability, transport, smartphones, laptops, and institutional support are treated as resources. Personal conversion factors include digital literacy, language ability, preparedness, and available study time. Social conversion factors include gender roles, family attitudes, domestic responsibilities, marriage expectations, safety concerns, and norms governing women's mobility. Environmental and institutional conversion factors include distance, public transport, hostel facilities, internet connectivity, faculty availability, career guidance, and opportunities for skill development.

Capabilities refer to the real freedom to attend and continue higher education, choose a preferred course or institution, participate in co-curricular activities, pursue further study, seek employment, and make informed life decisions. Functionings are the actual achievements, such as enrolment, attendance, course completion, participation, and career preparation. Agency refers to the ability of women to pursue goals that they have reason to value, including negotiating with family members, expressing educational preferences, and planning careers.

Need of the Study

Higher education is an important means of improving women's knowledge, employment opportunities, economic independence, and decision-making ability. However, women from rural areas often experience barriers that go beyond mere access to colleges. Financial constraints, domestic responsibilities, transportation difficulties, limited digital resources, social norms, marriage expectations, and restrictions on mobility may influence their educational and career choices.

Therefore, there is a need to examine whether the availability of higher education actually provides rural women with the freedom to pursue the education and careers they value. Using Amartya Sen's Capability Approach, this study focuses not only on educational access but also on women's real opportunities, choices, and agency. The study can also provide useful insights for improving scholarships, transportation, digital facilities, career guidance, and institutional support to expand the educational capabilities of rural women.

Research Methodology

1 Research Design

The study follows a qualitative and descriptive research design. The purpose is not merely to measure educational access but to understand how women experience and interpret economic, social, and institutional conditions surrounding higher education.

2 Study Area and Participants

The study focuses on women aged 18–24 years who are pursuing higher education and belong to villages across Kolhapur district, Maharashtra. A total of 28 women (N = 28) were included as participants in the study. The participants represent rural women currently attending higher education, enabling the study to examine their economic, social, cultural, and institutional experiences related to higher education.

3 Data Collection

Data were collected through a structured qualitative questionnaire covering four areas: general information; economic limitations and educational choices; social and cultural norms affecting education; and institutional and

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infrastructure-related barriers. Questions addressed educational expenses, household contribution, domestic work, digital resources, course and career choice, scholarships, family expectations, marriage, gender discrimination, travel distance, career guidance, teaching quality, extracurricular opportunities, institutional support, and perceived barriers.

4 Coding and Thematic Analysis

Responses were coded using a combined deductive and inductive thematic strategy. Deductive codes were developed from the three predefined themes and Sen's Capability Approach, while additional codes such as domestic work burden, time poverty, gendered mobility, marriage pressure, digital access, digital literacy, scholarship support, hostel requirement, family support, and career guidance emerged from repeated patterns in the interviews.

Tag frequencies are reported as participant-level prevalence. Each participant was counted once under a tag even when the issue appeared several times in her interview. Direct codes reflect explicit participant statements, whereas interpretive codes represent theoretically informed coding through the Capability Approach. Percentages are therefore descriptive of this qualitative sample and should not be interpreted as population estimates.

Findings and Thematic Analysis

1 Theme I: Economic Limitations and Career Opportunities

Economic conditions emerged as the most consistent constraint on higher education. Financial pressure included tuition fees, books and educational materials, transportation, accommodation, digital devices, and the opportunity cost of time spent in domestic work or employment. Financial constraints were coded for 27 of the 28 participants (96.4%). Economic deprivation and poverty-related educational limitations were also frequently identified.

Tag	Frequency (n)	Percent	Interpretation
Educational Investment	28	100.0%	Educational expenditure and resource commitment
Financial Constraints	27	96.4%	Fees, travel, materials, accommodation or household finance
Economic Deprivation	23	82.1%	Limited resources reducing educational opportunity
Poverty And Education	22	78.6%	Economic circumstances interacting with education
Rural Economy Impact	22	78.6%	Rural household economy shaping educational opportunity
Agency And Empowerment*	21	75.0%	Education associated with greater agency
Limited Choices	20	71.4%	Economic conditions narrowing real alternatives
Freedom To Choose*	20	71.4%	Freedom to choose college/course
Career Aspirations	19	67.9%	Career goals shaping educational decisions
Livelihood Opportunities	12	42.9%	Education linked with employment/economic independence
Employment Barriers	8	28.6%	Work/employment constraints
Income Inequality*	6	21.4%	Unequal economic resources

(Source : Thematic analysis from questionnaire survey)

The economic theme shows that the central issue is not only affordability of education but also freedom of choice. Several participants indicated that greater financial freedom would have allowed them to select a different college, course, or professional pathway. In capability terms, limited income reduces the size of the feasible educational choice set. Therefore, economic deprivation operates as capability deprivation when students cannot convert formal access into the education they actually value.

At the same time, the interviews contain negative cases. A small number of participants reported no major economic difficulty, adequate access to digital devices, and little or no effect of finance on their educational decisions. These cases are important because they demonstrate heterogeneity within rural women's experiences and caution against portraying all participants as uniformly deprived.

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2 Sub-theme: Domestic Work, Employment and Time Poverty

A recurrent finding across the interviews was the amount of time spent on household work or part-time/full-time employment. Several participants reported that domestic duties or paid work reduced the time available for study. This pattern is best understood as time poverty. Time is a critical educational resource, and gendered household responsibilities can operate as a social conversion factor that reduces the capability to study effectively even when formal enrolment is secured.

The emergent tags DomesticWorkBurden, TimePoverty and WorkStudyBalance are therefore analytically important. They reveal that equal enrolment does not necessarily mean equal educational opportunity: a student with several hours of daily domestic or paid work may have substantially less freedom to study, participate in seminars, attend coaching, or prepare for competitive examinations.

3 Theme II: Social and Cultural Norms on Career Aspirations

The second major theme concerns the influence of social norms, family expectations, gender roles, marriage, mobility, and decision-making. Social norms were coded for 25 participants (89.3%). However, the pattern was not uniformly restrictive. Many women described supportive families, positive attitudes towards women's education, and expectations that marriage should occur after education. Others described restrictions on travelling far, living in hostels, returning home late, participating in extracurricular activities, or choosing education independently.

Tag	Frequency (n)	Percent	Interpretation
Social Norms	25	89.3%	Social environment affecting educational experience
Educational Attainment	25	89.3%	Value attached to women's education
Freedom Of Aspiration*	22	78.6%	Ability to formulate valued educational/career goals
Autonomy And Agency*	21	75.0%	Varying educational agency
Social Constraints	19	67.9%	Social conditions restricting participation
Gender Roles	18	64.3%	Gender-specific expectations and responsibilities
Community Influence	18	64.3%	Community environment shaping decisions
Aspirational Limitations*	17	60.7%	Circumstances constraining aspirations
Patriarchal Norms*	16	57.1%	Gender hierarchy visible in some responses
Patriarchy And Education*	16	57.1%	Gender norms interacting with education
Cultural Barriers	16	57.1%	Cultural expectations restricting choices
Traditional Expectations	15	53.6%	Marriage and domestic expectations
Lack In Decision Making Power	10	35.7%	Restricted decision-making

(Source : Thematic analysis from questionnaire survey)

The results suggest a transitional social context. Support for women's higher education is increasingly visible, yet substantive freedom remains mediated by gendered expectations. The data therefore support a more nuanced interpretation than the claim that patriarchy uniformly prevents women's education. Instead, traditional gender norms continue to influence how educational opportunities are converted into real choices, with substantial variation among households.

4 Sub-theme: Gendered Mobility and Marriage Expectations

Gendered mobility emerged as one of the clearest cross-cutting social mechanisms. For rural women, mobility is not simply a matter of whether transport exists. It involves the interaction of distance, travel cost, safety, parental permission, hostel availability, and expectations about when women should return home. Thus, transport availability does not automatically create mobility capability.

Marriage expectations also affected some participants' educational planning. In several cases,

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education was expected to be completed before marriage; in others, the timing of marriage was perceived as a potential limit on further study or employment. These findings indicate that marriage operates as a social conversion factor that may either coexist with education or restrict the continuation of valued educational and career pathways.

5 Theme III: Institutional and Infrastructure Gaps in Higher Education

The third theme concerns the institutional and geographical conditions of higher education. Educational access and rural education challenges were present throughout the dataset. Transportation barriers, distance, hostel needs, digital infrastructure, and financial support were more prominent than dissatisfaction with teaching quality.

Tag	Frequency (n)	Percent	Interpretation
Educational Access	28	100.0%	Access as a central educational dimension
Rural Education Challenges	28	100.0%	Rural location shaping experience
Capability Expansion*	28	100.0%	Higher education expanding potential capabilities
Higher Education Barriers	27	96.4%	One or more barriers across most cases
Opportunities For Growth	27	96.4%	Developmental opportunities through education
Quality Of Education–Positive	27	96.4%	Mostly satisfactory teaching/faculty
Institutional Support	26	92.9%	Guidance/support widely present
Public Policy Impact*	25	89.3%	Scholarships, schemes and support matter
Infrastructure Deficit	23	82.1%	Gaps in rural educational infrastructure
Transportation Barriers	23	82.1%	Distance and travel constraints
Equity In Education*	22	78.6%	Unequal capacity to benefit from opportunities
Digital Divide	17	60.7%	Uneven digital access/capability

(Source : Thematic analysis form questionnaire survey)

A notable finding is that quality of education was predominantly coded positively. Many participants reported satisfactory faculty availability, teaching quality, career guidance, seminars, or skill-development opportunities. Accordingly, the high frequency of QualityOfEducation–Positive should not be interpreted as a high frequency of poor teaching. The more persistent institutional disadvantages were related to access conditions: travel, transport, distance, accommodation, digital resources, and financial support.

6 Digital Divide: Access and Capability

The digital divide should be understood as two distinct but related dimensions. The first is digital access: the availability of smartphones, laptops, internet connectivity, software, and data. The second is digital literacy: the ability to use these resources effectively for educational purposes. Some participants reported adequate access and no difficulty, while others described the financial cost of devices, weak connectivity, or difficulty using digital resources.

From the Capability Approach perspective, a device is only a resource. Its educational value depends on the learner's ability to convert that resource into effective digital learning. Digital literacy, language competence, and confidence therefore function as personal conversion factors.

7 Scholarships, Public Policy and Institutional Support

Scholarships and public support emerged as important mechanisms for capability expansion. Participants associated scholarships and fee concessions with lower educational costs, greater freedom to select institutions or courses, access to books and materials, and the possibility of continuing further study. Public transport, safe accommodation, hostels, career guidance, and nearby educational facilities were also repeatedly identified as important forms of support.

Policy support should therefore be evaluated not only by whether a benefit exists but by whether rural women can access it, understand it, and use it to expand meaningful educational choices.

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Capability Approach Interpretation of the Combined Findings

Dimension	Evidence in the Study
Resources	Household income, scholarships, colleges, transport, smartphones/laptops, internet, hostels, institutional support
Personal Conversion Factors	Digital literacy, language ability, preparedness, available study time
Social Conversion Factors	Gender roles, domestic work, family attitudes, marriage expectations, safety and mobility norms
Environmental/Institutional Conversion Factors	Distance, transport, hostel facilities, internet connectivity, faculty, career guidance
Capabilities	Freedom to attend college, choose course/institution, study away from home, participate, pursue further education and careers
Functionings	Actual enrolment, attendance, completion, participation, skill development and career preparation
Agency	Ability to negotiate, express preferences, make educational decisions and pursue valued goals

The combined evidence demonstrates that rural women's higher-education disadvantage cannot be understood solely through enrolment. A student may be enrolled in college but still experience capability deprivation if she cannot select her preferred field, travel safely, live away from home, purchase digital resources, attend coaching, participate in activities, or continue education because of household and marriage expectations. At the same time, the study reveals meaningful agency. Many women express strong educational and career aspirations, receive family support, and make active choices within existing constraints. The appropriate analytical conclusion is therefore not that rural women are passive victims of deprivation, but that their agency is exercised within unequal economic, social, and institutional conversion conditions.

Major Findings

The study found that women's higher education in rural areas of Kolhapur district is influenced by interconnected economic, social, and institutional factors. Financial constraints were the most significant barrier, affecting educational expenses, transportation, digital access, and the choice of courses and institutions. Domestic work and employment also created time constraints that reduced opportunities for study. Social norms, gender roles, mobility restrictions, and marriage expectations continued to influence educational decisions, although increasing family support and positive attitudes towards women's education were evident. Institutional experiences regarding teaching quality, faculty availability, and career guidance were generally positive, while distance, transportation, hostel facilities, financial assistance, and digital resources remained important challenges. Scholarships and government support were considered valuable in expanding educational opportunities. Overall, the findings indicate that formal access to higher education does not necessarily ensure equal educational freedom. From Sen's Capability Approach, women's ability to benefit from education depends on how effectively available resources can be converted into meaningful educational and career opportunities.

Policy Implications and Suggestions

- Expand scholarships, fee concessions, and targeted financial support for women from low-income rural households.
- Improve affordable and reliable public transport between villages and higher-education centres, with attention to safety and timing.
- Develop safe hostel and accommodation facilities for rural women who need to study away from home.
- Strengthen digital access through devices, connectivity, digital learning centres, and digital-literacy support.
- Provide regular career guidance, information on scholarships, competitive examinations, professional courses, and employment opportunities.
- Recognise domestic work and time poverty as educational barriers and create flexible academic support, mentoring, and study facilities.
- Promote community and family awareness programmes that support women's mobility, course choice, delayed marriage where desired, and career participation.
- Strengthen rural institutional infrastructure, including libraries, laboratories, skill-development activities, and links with

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employment and entrepreneurship opportunities.
- Evaluate higher-education policy using capability indicators such as freedom of course choice, mobility, participation, continuation, digital access, and agency—not enrolment alone.

Limitations of the Study

The study has several limitations. First, the final usable sample is small i.e (N = 28). But the interviews provide rich qualitative evidence, the findings cannot be generalised to all women or all villages in Kolhapur district. The percentages reported in the thematic tables describe the prevalence of codes within this specific qualitative sample and should not be treated as district-level population estimates.Second, the study is based on self-reported responses and may be affected by recall, social desirability, or differences in how participants interpreted questions. Third, the cross-sectional design captures experiences at one point in time and cannot fully show how educational capabilities change across the life course.

Conclusion

This study demonstrates that the challenge of rural women's higher education in Kolhapur district extends beyond physical access to colleges. Financial constraints, domestic work, gender norms, mobility, marriage expectations, transport, digital resources, and institutional support shape whether women can convert educational opportunities into genuine freedom. Sen's Capability Approach makes this distinction visible by showing that the same formal resource can produce different outcomes depending on personal, social, and environmental conversion factors. The interviews also reveal a changing rural context. Many participants receive family support, value higher education, aspire to careers, and report satisfactory institutional experiences. Yet substantive freedom remains uneven. The policy objective should therefore move beyond increasing enrolment and towards expanding women's capability to choose what to study, where to study, how to participate, whether to continue, and how to connect education with a valued future. Financial support, safe mobility, hostels, digital capability, career guidance, and supportive social environments are central to this broader goal.

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Original Article

Continuous Professional Development in Teacher Education: Pathways to Sustainable Pedagogical Transformation and Institutional Excellence

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Abstract
Continuous Professional Development (CPD) in teacher education serves as the primary catalyst for sustaining instructional quality, enhancing student learning outcomes, and driving systemic educational reform. Despite widespread recognition of its importance, conventional professional development programs frequently rely on top-down, episodic workshops that fail to yield long-term pedagogical changes. This thematic paper synthesizes literature, policy frameworks, and empirical insights to examine teacher education as a lifelong continuum spanning pre-service preparation, induction, and job-embedded in-service growth. Organized around core analytical themes—the continuum model, reflective practice, professional learning communities (PLCs), technological integration, organizational climate, and professional attitude—this paper examines systemic implementation barriers with a dedicated focus on Higher Education Institutions (HEIs). Finally, it outlines concrete educational, practical, and policy implications for institutional leaders, curriculum designers, and educational policymakers.

Keywords: *Teacher Education, Continuous Professional Development (CPD), Pedagogical Efficacy, Action Research, Professional Learning Communities (PLCs), Organizational Climate, Professional Attitude, Teacher Educators.*

Introduction

1 Context and Background

In an era defined by rapid technological acceleration, socio-demographic shifts, and evolving national curricular standards, the modern educator's role has fundamentally shifted. Teachers and teacher educators are no longer passive conduits of static knowledge; they are facilitators of complex, learner-centered, and technology-enabled learning environments. Consequently, Teacher Education and Professional Development (TEPD) can no longer be conceptualized as a finite pre-service qualification. Instead, it must be recognized as a continuous, dynamic process that extends across an educator's entire career.

2 Problem Statement

Despite significant policy emphasis on teacher quality, traditional professional development models remain largely fragmented. Conventional approaches often consist of isolated, single-day workshops or "cascade" training programs led by external experts. These initiatives typically suffer from a severe disconnect between theoretical abstractions and classroom realities. With minimal post-training follow-up or localized support, substantial public and institutional investments in teacher training frequently fail to translate into sustained instructional improvement or measurable student achievement. In higher education, this problem is compounded by organizational climate pressures, administrative overload, and a lack of structured professional development for teacher educators themselves.

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3 Purpose and Thesis Statement

This thematic paper synthesizes existing research and policy frameworks to provide a holistic conceptualization of teacher education. **This paper argues that sustainable pedagogical transformation requires a systemic shift from episodic, workshop-based training to job-embedded, reflective, and collaborative professional development integrated into the daily operational and organizational culture of educational institutions.**

Conceptual and Theoretical Framework

The thematic synthesis in this paper is anchored in three interconnected educational frameworks:

Social Constructivism (Vygotsky): Asserts that professional knowledge is constructed through social interaction, collaborative problem-solving, and peer dialogue within authentic educational settings.

Reflective Practice (Schön): Posits that genuine professional growth occurs through an ongoing cycle of *reflection-in-action* (during teaching) and *reflection-on-action* (after teaching), transforming routine classroom challenges into opportunities for inquiry.

Technological Pedagogical Content Knowledge (TPACK - Mishra & Koehler): Emphasizes that modern professional learning must address content knowledge, pedagogical strategies, and digital technology concurrently rather than in isolation.

Thematic Analysis of Teacher Education and Professional Development

Theme 1: The Teacher Education Continuum (Pre-Service to In-Service)

Effective teacher education relies on seamless continuity across three distinct stages:

Initial Teacher Education (ITE): Establishes foundational pedagogical content knowledge (PCK), child psychology, assessment design, and foundational classroom management skills.

Induction and Mentorship: Provides structured support for early-career teachers, pairing them with experienced mentors to bridge the gap between academic theory and daily classroom realities.

Continuous Professional Development (CPD): Sustains career-long growth through specialized content updates, advanced instructional strategies, and leadership development.

Failure to align these three stages results in an "induction shock" for novice educators and stagnant professional practices among veteran teachers.

Theme 2: Reflective Practice and Action Research

Reflective practice moves educators from passive consumers of prescribed curricula to active researchers within their own classrooms. Through classroom-based action research, teachers systematically:

Identify specific student learning bottlenecks.

Formulate and implement targeted instructional interventions.

Collect diagnostic data (e.g., student artifacts, observational notes, formative assessment results).

Analyze outcomes and refine their instructional approaches.

This self-directed inquiry cycle fosters agency and ensures that professional development directly addresses immediate, context-specific classroom needs.

Theme 3: Collaborative Inquiry via Professional Learning Communities (PLCs)

Individual reflective practice is significantly amplified when embedded within collaborative structures. Professional Learning Communities (PLCs) reorganize institutional culture by establishing structured times for educators to collaborate on lesson design, analyze student work samples, conduct reciprocal peer observations, and maintain shared accountability for learning success.

Dimension	Traditional Workshop Model	Job-Embedded PLC Framework
Delivery Mechanism	Off-site, episodic seminars	On-site, continuous peer collaboration
Focus	Generic theoretical concepts	Context-specific classroom practices
Teacher Role	Passive recipient of information	Active researcher and peer collaborator
Evaluation	Certificate of attendance	Action research portfolio & student growth
Sustainability	Low long-term retention	Embedded in institutional culture

Theme 4: Digital Tools and Technological Pedagogical Content Knowledge (TPACK)

Digital transformation in education requires more than providing educators with technology hardware. CPD initiatives must focus on building TPACK—ensuring educators understand *how* specific digital tools (e.g., interactive simulations, learning analytics, collaborative digital platforms) enhance specific pedagogical methods to teach subject content more effectively.

Systemic, Cultural, and Organizational Challenges in Higher Education

Teacher educators occupy a unique, dual-role position within Higher Education Institutions (HEIs): they are simultaneously faculty members responsible for scholarly output and professional mentors tasked with shaping the pedagogical competency of future teachers. Consequently, systemic bottlenecks in HEIs directly impact both their **professional attitude** and **teaching effectiveness**.

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1 Organizational Climate Constraints in Teacher Education Institutions (TEIs)

Organizational climate—defined by internal leadership dynamics, institutional autonomy, administrative transparency, collegial relations, and resource allocation—acts as the environmental mediator of faculty effectiveness. Key climate-related challenges include:

Closed and Autocratic Institutional Leadership: Highly centralized, bureaucratic leadership structures suppress institutional climate openness. When department heads and principals operate under closed communication loops, teacher educators experience diminished psychological safety, reducing their willingness to innovate in curriculum design or adopt progressive pedagogical methods.

Infrastructure and Resource Deficits: In many regional and affiliated teacher training colleges, sub-optimal physical and digital infrastructure—such as inadequate ICT labs, micro-teaching suites, and research databases—creates operational friction. This friction corrodes institutional morale and impairs teaching quality.

Work-Life Disruption and Administrative Overload: Excessive non-academic workloads, accreditation documentation, and administrative duties infringe upon dedicated instruction and research time. This imbalance increases professional burnout and degrades the overall institutional climate.

2 Professional Attitude Decay Among Teacher Educators

A positive professional attitude—encompassing intrinsic commitment to the teaching profession, professional ethics, dedication to student development, and continuous self-improvement—is essential for instructional mastery. However, several institutional factors erode this attitude:

Disalignment Between Research Mandates and Pedagogical Value: Higher education evaluation models frequently prioritize research metrics and publications over pedagogical execution and field supervision. This structural imbalance leads teacher educators to view instructional refinement as secondary to academic survival.

Stagnant Career Progression and Professional Isolation: Limited merit-based promotion pathways and a lack of structured peer-collaboration networks foster professional isolation. Over time, this leads to career stagnation, reduced professional commitment, and mechanical adherence to outdated syllabi.

3 Structural Gaps in Continuous Professional Development for HEI Faculty

Incongruent Faculty Development Programs (FDPs): Existing higher education orientation and refresher courses often emphasize passive theoretical lectures rather than diagnostic teaching, clinical mentoring, or modern assessment literacy.

Underdeveloped Action Research Ecosystems: Unlike traditional school environments, HEI teacher education departments rarely institutionalize systematic action research models to address regional classroom dynamics, resulting in a gap between academic research and practical teacher preparation.

5. Educational, Practical, and Policy Implications for HEIs

Addressing these challenges requires systemic reform focused on optimizing organizational climate, fostering a positive professional attitude, and equipping teacher educators with contemporary pedagogical competencies.

1 Institutional and Leadership Level: Cultivating an Open Climate

Organizational climate directly influences professional attitude and teaching effectiveness. HEIs must focus on the following institutional interventions:

Transition to Participatory and Distributed Leadership: Institutional heads must transition from rigid administrative models to consultative, open-climate frameworks. Involving teacher educators in academic decision-making, curriculum planning, and policy formulation directly enhances institutional trust and professional ownership.

Institutionalizing Professional Learning Communities (PLCs): HEIs should formalize inter-departmental PLCs where faculty meet weekly to analyze teaching practices, review student performance metrics, and conduct reciprocal peer observations using standardized evaluation rubrics.

Optimizing Work-Life Balance and Resource Allocation: Re-allocating administrative tasks to dedicated support staff preserves faculty time for instruction, research mentorship, and clinical field supervision.

2 Curricular, Pedagogical, and Professional Level

Improving the professional attitude of teacher educators requires structural support for their professional growth and teaching practices:

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Dimension	Traditional HEI Appraisal Approach	Integrated Climate & Efficacy Framework
Primary Metric	Publication count & administrative compliance	Student growth, peer evaluation, and instructional quality
Leadership Interaction	Top-down evaluation and inspection	Collaborative mentoring and instructional support
Professional Growth	Off-site, generic refresher courses	On-site action research and contextual problem-solving
Evaluation Data	Single-source annual self-appraisal	Multi-rater appraisal (Peers, Students, Self, HODs)

Integrated Multi-Rater Performance Appraisal: Move away from single-source annual self-appraisal forms toward multi-rater feedback frameworks that incorporate peer reviews, student feedback, and portfolio-based evidence of teaching effectiveness.

Grant Support for Localized Action Research: Establish institutional research funds dedicated to action research on local teacher education challenges (e.g., regional language instruction, diagnostic assessment strategies, and rural teaching interventions).

Competency-Based Professional Development: Align faculty development with modern higher education frameworks—emphasizing digital pedagogy, micro-teaching mentorship, Universal Design for Learning (UDL), and advanced assessment rubrics.

3 Policy and Macro-Systemic Level

Aligning Accreditation Criteria with Organizational Health: University affiliation boards and national accreditation bodies should integrate institutional climate indices (e.g., faculty job satisfaction, leadership openness, infrastructure adequacy) into institutional rating frameworks.

Institutionalizing Structured Mentorship for Early-Career Faculty: Mandate formal, year-long induction programs that pair newly appointed higher education teacher educators with senior faculty mentors to ease the transition into higher education pedagogy and research supervision.

Conclusion and Recommendations

1 Summary

Teacher education and continuous professional development are foundational to sustainable educational quality. Transforming teaching practice requires moving away from fragmented, one-size-fits-all training sessions toward a holistic continuum grounded in job-embedded PLCs, action research, reflective inquiry, and healthy organizational climates. When higher education institutions cultivate an open climate and support the professional attitude of teacher educators, both faculty efficacy and the quality of teacher preparation improve significantly.

2 Actionable Recommendations for Stakeholders

1. **For Policymakers:** Integrate pre-service and in-service frameworks, linking continuous professional development and action research to formal higher education career progression pathways.
2. **For Institutional Leaders:** Restructure academic schedules to institutionalize dedicated time for faculty collaboration, peer observation, and open communication within departments.
3. **For Teacher Educators:** Engage actively in self-directed action research, peer-led reflection, and competency-based professional learning to continually enhance pedagogical mastery.

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Conflicts of interest

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Original Article

An Experimental Study on the Effectiveness of Blog-Based Learning Among Student Teachers

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Abstract:
This blog explores the transformative power of effective learning strategies for student teachers require innovative approaches to develop their instructional skills classroom management techniques ,and technological integration.
Keywords: *Effectiveness, Learning, Teaching, Blog.*

Introduction

In recent years, blog-based learning has emerged as a tool for enhancing student engagement and knowledge sharing. Blogs offer a platform for students to express ideas, collaborate, and receive feedback. This study explores how blog-based learning impacts the teaching skills, knowledge retention, and professional confidence of student teachers. Discuss the evolution of educational technology, the relevance of digital platforms in teacher education, and how blogs specifically provide unique learning opportunities.

Blog: A blog, short for "weblog," is an online platform where individuals or groups regularly post content, often in the form of written articles, updates, or multimedia entries. Originally, blogs served as personal journals shared on the internet, but they have evolved to cover a wide range of topics, including news, education, lifestyle, technology, and more.

Blogs typically include the following features:

- **Entries/Posts**: Individual articles or updates, usually displayed in reverse chronological order (newest to oldest).
- **Comments Section**: A space where readers can leave feedback, ask questions, or engage in discussions.
- **Categories and Tags**: Tools to organize content by topics or keywords, making it easier for readers to find relevant posts.
- **Archives**: A collection of past posts, often organized by date.

In education, blogs can be used as a learning tool for discussions, sharing knowledge, and fostering reflective thinking. Students and teachers can use them to communicate ideas, submit assignments, and engage with course material in an interactive way.

Learning: Learning is the process of acquiring knowledge, skills, attitudes, or behaviors through study, experience, or teaching. It is a continuous journey that involves understanding, retaining, and applying information, which leads to personal growth, adaptation, and improvement.

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Key elements of learning include:

- **Knowledge Acquisition**: Gaining new facts, information, and understanding about a subject or skill.
- **Skill Development**: Practicing and refining abilities, from physical skills like playing a sport to cognitive skills like problem-solving.
- **Behavioral Change**: Learning often leads to changes in behavior, such as adopting new habits or changing perspectives.
- **Experience and Reflection**: Effective learning usually involves reflecting on experiences and integrating insights from them.
- **Adaptation**: Learning enables individuals to adapt to new situations, solve problems, and make informed decisions.

Learning can take place formally (e.g., in schools, through structured courses) or informally (e.g., through everyday experiences, self-study). It is a lifelong process that allows individuals to evolve and respond to the world around them.

What is Blog-Based Learning?

Blog-Based Learning is an educational approach that uses blogs as a platform for teaching and learning. In this method, students and teachers interact through blog posts, comments, and discussions, creating a dynamic learning environment that encourages active engagement, collaboration, and reflective thinking.

Here's how Blog-Based Learning typically works and benefits students:

1. **Content Creation and Sharing**: Students write blog posts on assigned topics, share their insights, or reflect on course material. Teachers may also post content, resources, or prompts to guide learning.
2. **Collaboration and Interaction**: Blogs allow students to comment on each other's posts, ask questions, and share different perspectives. This interaction fosters a sense of community and promotes peer learning.
3. **Reflection and Critical Thinking**: Writing on blogs requires students to organize their thoughts, which deepens understanding. Regular blogging can help them become more reflective and critical of their own learning and thought processes.
4. **Feedback and Assessment**: Teachers and peers can provide feedback directly on blog posts, allowing students to revise their ideas and improve their work based on constructive input.
5. **Building Digital Literacy**: Blog-Based Learning familiarizes students with online platforms, helping them build digital literacy skills, which are essential in the modern world.

Benefits of Blog-Based Learning:

- **Enhanced Engagement**: Blogging makes learning more interactive, helping students stay engaged with the material.
- **Active Learning**: By writing, discussing, and reflecting, students take an active role in their own education.
- **Ownership of Learning**: Blogs give students a sense of ownership over their learning process, encouraging self-directed exploration and learning.

Blog-Based Learning can be an effective tool across various subjects and levels of education, especially where creativity, discussion, and critical analysis are encouraged.

Need and Importance of the Study

Educational Technology: Growing reliance on digital platforms for educational purposes emphasizes the need to understand effective tools.

Enhanced Engagement: Blogs encourage self-reflection, discussion, and feedback, which are crucial in teacher training.

21st-Century Skills: Blogging cultivates digital literacy, communication, and critical thinking—skills essential for modern educators.

Gap in Literature: While many studies examine digital tools, few focus specifically on blogs as a method for teacher education.

Objectives of the Study

- To examine the effectiveness of blog-based learning on student teachers' knowledge acquisition.
- To investigate whether blog-based learning enhances reflective thinking among student teachers.
- To assess the influence of blog-based learning on the professional development and confidence of student teachers.

Hypotheses

- **Null Hypothesis (H0)**: Blog-based learning has no significant impact on the knowledge retention and professional skills of student teachers.
- **Alternative Hypothesis (H1)**: Blog-based learning positively impacts the knowledge retention, reflective thinking, and professional skills of student teachers.

Variables of the Study

- **Independent Variable**: Blog-based learning method.
- **Dependent Variables**: Knowledge retention, reflective thinking, and professional development of student teachers.

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- **Control Variables**: Pre-existing knowledge, teaching environment, and prior digital literacy skills.

Sample

- **Sample Size**: 40 student teachers from various teacher education colleges.
- **Sampling Technique**: Random sampling.
- **Sample Characteristics**: Participants include diverse age groups, gender, and prior experience levels.

Limitations of the study:

This Study is confined to B.Ed College Students. This Study is confined to Vijayapur city B.Ed colleges. In this study we have use BLDEA`s J.S.S. College of Education Blog learning and teaching process for II semester B.Ed under Ranni Chenamma University, Belagavi

Methodology

- **Research Design**: Experimental study with control and experimental groups.
- **Data Collection**: Pre-test and post-test design.
  - **Control Group**: Traditional learning methods.
  - **Experimental Group**: Blog-based learning.
- **Procedure**: Both groups undergo a pre-test to measure baseline knowledge and teaching skills. The experimental group engages in blog-based learning, while the control group follows traditional learning methods. After six weeks, both groups are assessed through a post-test.

Tools and Statistical Analysis

- **Tools for Data Collection**:
  - Knowledge retention test.
  - Reflective thinking and professional skills questionnaire.
  - Blog engagement metrics (e.g., post frequency, feedback received).
- **Statistical Tools**:
  - Mean and Standard Deviation
  - T-test for comparing pre-test and post-test scores.

Data Analysis : Table 1: Per-Test

Group	Number of Students	Mean	Standard Deviation	`t` Value
Control Group	40	58.9	10.83	0.042
Experimental Group	40	58.8	10.49	

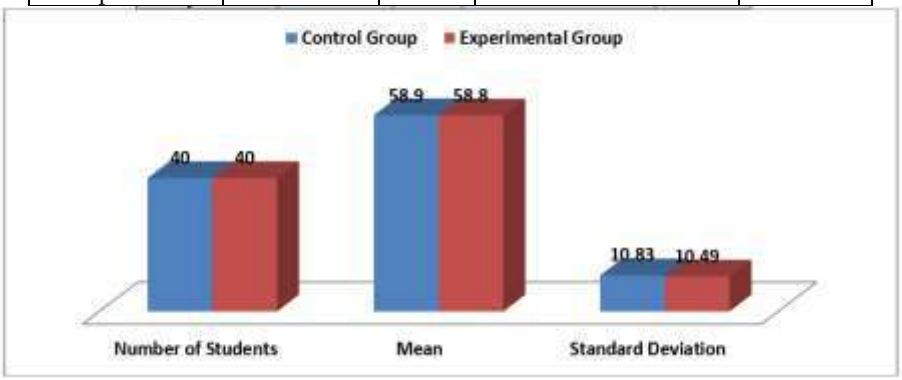

Table 2: Post-Test

Group	Number of Students	Mean	Standard Deviation	`t` Value
Control Group	40	50.95	14.37	8.26
Experimental Group	40	77.05	13.87	

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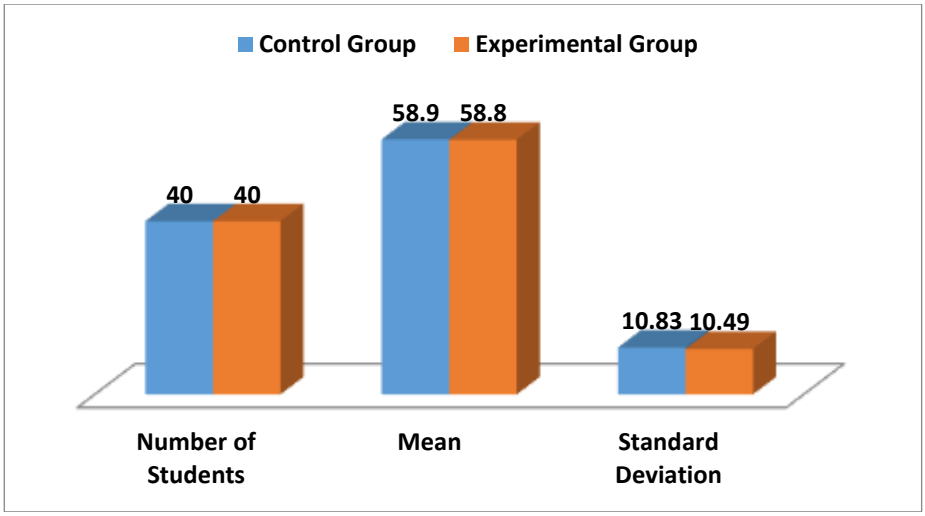

Main findings of the study.

- This experimental study reveals that there is a significant difference in the achievement of the experimental group over the control group in
- Thus blog-based learning helps the students to sustain their interest and also their retention power compared to the traditional method.
- The mean gain in achievement test of the control group and experimental group shows that there is better performance due to the treatment given to the experimental group.
- That is why the mean of the experimental group is higher than the mean of the controlled group

Hence, it is concluded that the blog-based learning is also learning approach, is considered to be one of the best techniques for teachers students.

Conclusion

The study will discuss whether blog-based learning positively impacts student teachers' knowledge retention and reflective thinking skills. If effective, the findings could support the integration of blogs in teacher training programs to foster critical thinking, digital literacy, and engagement.

Suggestions

- Integrate blog-based learning into teacher education curricula as a complementary method.
- Provide training to student teachers on effective blog usage, including writing skills and engagement.
- Conduct follow-up studies on long-term impacts of blog-based learning on professional development.

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Original Article

User Behaviour Management and Collection Security in Academic Libraries

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Abstract
Academic libraries are shared learning environments in which students, teachers, researchers and other users access printed collections, electronic resources, technology and professional services. The quality and sustainability of these services depend not only on the availability of resources but also on responsible user behaviour. Inappropriate behaviour such as theft, mutilation, defacement, concealment of materials, overdue retention, excessive noise, disruptive mobile-phone use, misuse of computers and other violations can reduce collection availability, increase operational costs and disturb the learning environment. This research paper develops an integrated conceptual framework for user behaviour management and collection security in academic libraries. It reorganizes the themes in the supplied source study into a preventive management model covering five connected stages: education, prevention, detection, response and review. The paper emphasizes that punishment alone cannot provide sustainable control. User orientation, visible rules, adequate supervision, stock verification, risk-based security technology, fair sanctions, preservation awareness and access to digital alternatives should operate together. The paper is conceptual and literature-based. It does not introduce a new survey, sample or statistical dataset and therefore does not report invented percentages or inferential findings. The proposed framework is intended to assist academic libraries, especially institutions working with limited budgets and staffing, in balancing open access with protection of shared resources. Future empirical studies can test the framework across multiple institutions and develop measurable indicators of user behaviour, security effectiveness and user satisfaction.

Keywords: *academic libraries; user behaviour; library security; collection protection; user education; surveillance; deviant behaviour; preventive control; library management; information resources.*

Introduction

The academic library occupies a central position in the teaching, learning and research ecosystem of an educational institution. It provides access to books, journals, reference materials, databases, computers, reading spaces and professional assistance. Because these resources are shared, the behaviour of individual users can directly influence the rights and experiences of other users. The supplied source study describes deviant behaviour as conduct that departs from accepted rules and norms of library use. Examples include theft, mutilation, defacement, hiding books, overdue retention, excessive noise, eating or drinking in restricted areas, littering, vandalism, disruptive phone calls, harassment and misuse of computers or other facilities. Such acts can damage both physical collections and the social environment needed for effective study. A narrow approach would treat the problem primarily as a disciplinary issue. A stronger approach views behaviour management as a library service and risk-management function. Users must know what is expected, staff must be able to supervise effectively, collection-security procedures must reduce opportunities for misuse, incidents must be documented, and disciplinary responses must be fair and proportionate.

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The central proposition of this paper is that academic libraries can protect their resources more effectively when educational, technological, administrative and disciplinary measures are integrated. This approach seeks to maintain the openness and user-friendliness of the library while discouraging deliberate or careless misuse.

Background of the Study

Library materials are shared assets. When a book is lost, damaged or deliberately altered, the impact extends beyond the person responsible for the act. Other students and researchers may lose access to information that they need for assignments, examinations or research. The source material identifies theft and mutilation as important forms of library malpractice and stresses the importance of collection security.

The risk of misuse can increase when high-demand materials are available in very limited numbers. During examination and assignment periods, users may attempt to retain, hide or damage materials in order to obtain exclusive access. This situation indicates that security cannot be separated from service planning. Adequate copies, electronic alternatives, clear circulation rules and timely user education can reduce some of the pressures that encourage misconduct.

The study also identifies organizational constraints, including inadequate staffing, limited budgets, weak supervision and insufficient awareness programmes. These factors show why academic libraries need practical, risk-based strategies rather than relying only on expensive technologies or severe penalties.

Statement of the Problem

Academic libraries must balance two apparently competing objectives: convenient and equitable access to information, and protection of shared collections and facilities. Excessive restrictions may make users feel unwelcome, whereas inadequate controls can expose resources to theft, damage, concealment and other forms of misuse.

The problem addressed in this paper is therefore how an academic library can establish a behaviour-management system that discourages misconduct, protects resources and maintains an open learning environment. The source study associates recurring inappropriate behaviour with weaknesses in user education, security, supervision, staffing, resource-protection mechanisms and policy implementation.

Objectives of the Study

- To identify major forms of inappropriate and deviant behaviour in academic library environments.
- To examine organizational and situational factors associated with misuse of library resources and facilities.
- To explain the role of user education and socialization in encouraging responsible library use.
- To examine physical, technological and administrative measures for protecting collections.
- To develop an integrated framework for managing user behaviour without unnecessarily restricting legitimate use.
- To suggest practical recommendations suitable for academic libraries operating with limited resources.

Research Questions

- What are the major forms of problematic user behaviour found in academic library environments?
- What factors create opportunities or incentives for inappropriate behaviour?
- How can user education function as a preventive strategy?
- Which physical, technological and administrative controls can strengthen collection security?
- How can academic libraries combine prevention, detection, response and review in a balanced framework?

Scope of the Study

The paper focuses on user behaviour, collection protection and library security in academic libraries. It covers physical collections, circulation practices, reading-room conduct, technology and facilities, user education, supervision, surveillance, stock verification and disciplinary procedures. Digital-resource management is discussed mainly as a complementary strategy and not as a substitute for sound management of print collections.

Research Methodology

This paper adopts a conceptual and literature-based review approach. It is developed from the themes, observations, arguments and references represented in the supplied source study. The source study describes librarian interviews and library observation in selected academic libraries in Gondia; the present paper does not treat those observations as a new empirical dataset.

The material has been thematically reorganized into five dimensions: behavioural problems; causes and risk factors; educational interventions; technological and physical security; and administrative or disciplinary responses. Since no new questionnaire, sample or statistical dataset has been supplied, the

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paper intentionally avoids presenting new numerical findings, percentages or inferential tests.

Review of Related Literature and Themes

The literature represented in the supplied source study consistently treats library security as a management issue involving people, procedures, collections and technology. Studies cited in the source address collection security, theft and mutilation, user assessment of library security, delinquent readership, electronic security systems and security challenges in academic libraries.

A recurring theme is that user behaviour is influenced by both individual motivations and environmental conditions. Personal possession, opportunistic behaviour and profit are described as possible motivations for theft. High demand for limited copies can create pressure for mutilation or concealment. Weakly communicated rules and inconsistent enforcement can also reduce compliance.

Another important theme is user education. Orientation programmes, visible notices, demonstrations and periodic reminders can clarify acceptable conduct and explain why rules exist. When users understand that rules protect collective access rather than merely restrict personal freedom, compliance can become part of library culture.

The literature also emphasizes surveillance, electronic theft detection, user-search procedures, supervision and regular stock-taking. However, technology is most effective when it supports professional procedures. A small college library may obtain substantial benefit from trained staff, clear circulation procedures, stock verification and strategically placed cameras before investing in expensive integrated systems.

Major Forms of Problematic User Behaviour

Theft and Unauthorized Removal

Theft directly reduces the availability of collections and may deprive many users of essential information. It can involve intentional removal of books or other resources without authorization. Effective circulation control, security awareness and appropriate detection mechanisms are therefore important.

Mutilation of Library Materials

Mutilation includes tearing pages, removing illustrations or otherwise damaging printed resources. The risk may become more visible when examination or assignment demand is high and only a few copies of a required item are available.

Defacement and Contamination

Writing on pages, marking text, painting over information, or spilling food and liquids can reduce the usefulness and physical life of resources. Contamination can also create preservation problems.

Concealment and Misplacement

Hiding books between shelves or deliberately placing them where they cannot easily be found undermines equitable access and creates additional work for library staff. This behaviour may be difficult to identify without systematic shelf checking and stock verification.

Overdue Retention

Failure to return borrowed materials on time restricts access for other users and weakens circulation management. Clear due-date communication, reminders and proportionate sanctions can support timely returns.

Disruptive Behaviour

Excessive noise, inappropriate mobile-phone use, loitering and other disturbances can negatively affect the study environment. Behavioural expectations should be communicated clearly and applied consistently.

Misuse of Technology and Facilities

Improper use of computers, networks or other facilities can affect service availability and may expose the library to operational and security risks. Acceptable-use policies and staff guidance are important controls.

Factors Contributing to Inappropriate Behaviour

Insufficient orientation: Users may not understand circulation rules, preservation expectations or consequences of violations.

Weak supervision: Gaps in staff presence and collection monitoring can increase opportunities for misuse.

High demand for limited copies: Scarcity can create pressure to hide, retain or damage heavily used materials.

Inadequate staffing: High workloads can reduce the frequency of monitoring, shelf checking and user assistance.

Limited budgets: Libraries may be unable to install or maintain advanced surveillance and electronic security systems.

Weak ownership of shared property: A 'no man's property' attitude can reduce users' sense of responsibility toward collective resources.

Peer and situational influence: Users may be influenced by peers or by opportunities created by weak controls.

Poor policy communication: Rules that are unclear, invisible or inconsistently enforced are less likely to guide behaviour.

User Education as a Preventive Strategy

User education should be treated as a continuous preventive library service rather than a single orientation session. New users should receive concise guidance on borrowing, returning, handling

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and preserving resources, acceptable conduct, digital-resource use and the consequences of violations.

Existing users should receive periodic reminders through notices, signage, newsletters, demonstrations, induction programmes and short awareness activities. Demonstrating damaged materials can make the consequences of misuse more concrete. Multilingual and user-friendly communication can also improve accessibility where the academic community is linguistically diverse.

The objective is not simply to tell users what they cannot do. Effective education explains the collective value of resources and shows how responsible behaviour protects the rights of present and future learners.

Physical and Technological Security

Physical and technological security should complement, rather than replace, professional supervision. Measures identified in the source study include surveillance cameras, improved supervision, effective user-search procedures, electronic theft detectors and regular stock-taking. In technology-enabled libraries, access-control systems and systematic circulation records can strengthen accountability.

Security investments should be based on collection profile, library size, budget and assessed risk. Risk-based implementation is more sustainable than adopting technology simply because it is available. For smaller academic libraries, staff training, clear procedures, stock verification and strategically positioned cameras may provide a practical starting point.

Technology should also be maintained and periodically reviewed. A security device that is poorly positioned, not maintained or not integrated with staff procedures may provide less value than expected. Human supervision remains important because not all inappropriate behaviour can be detected electronically.

Collection Development and Service Planning as Security Measures

Collection security is not only a matter of locks, cameras and detectors. Service planning can reduce some motivations for misuse. Where high-demand titles have adequate copies or legitimate digital alternatives are available, users may have less incentive to hide or damage materials to obtain exclusive access.

Libraries can identify heavily used items through circulation records and user feedback, prioritize additional copies where feasible, and promote available electronic alternatives. Such measures should complement preservation and security policies rather than replace them.

Discipline and Fair Sanctions

Disciplinary action is an important component of behaviour management, but it should be transparent, proportionate and consistently applied. Possible responses discussed in the source study include restitution for damaged materials, temporary suspension, disciplinary review and restrictions on library access.

A written policy should distinguish accidental damage from intentional misconduct and specify appropriate procedures for review or appeal where applicable. Consistency is essential because selective enforcement can reduce trust in library management. The purpose of discipline should include deterrence, rehabilitation and protection of the library community.

Accountability should also apply to staff when staff participation or facilitation contributes to misuse. A credible system requires clear responsibilities for both users and library personnel.

Proposed Integrated User Behaviour Management Framework

Stage	Key Actions	Purpose	Expected Outcome
1. Educate	Orientation; signage; demonstrations; reminders	Create awareness	Better rule compliance
2. Prevent	Supervision; collection arrangement; adequate copies	Reduce opportunities	Lower risk of misuse
3. Detect	CCTV; electronic security; stock verification	Identify incidents	Faster response
4. Respond	Document incidents; apply fair sanctions	Ensure accountability	Deterrence and rehabilitation
5. Review	Analyze incidents; revise procedures	Continuous improvement	Stronger library security

Discussion

The integrated framework demonstrates that no single intervention can control user behaviour effectively. Education establishes expectations, but education alone may not prevent deliberate misconduct. Security devices can detect unauthorized removal, but they cannot address poor circulation practices or disrespectful conduct. Punishment may deter some behaviour, but excessive or inconsistent punishment can damage

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the relationship between the library and its users. A balanced system therefore combines prevention, detection, response and review. The stages are interdependent. Education supports prevention; prevention reduces the number of opportunities requiring detection; detection creates evidence for appropriate response; and incident review provides information for improving future procedures. The framework also recognizes electronic resources as a complementary option. Digital collections may reduce exposure to some forms of physical abuse, but they introduce their own issues relating to access, licensing, authentication and cybersecurity. Therefore, migration toward electronic resources should complement rather than replace responsible management of print collections.

Implementation Strategy for Academic Libraries

Implementation should be gradual and aligned with institutional capacity. Libraries can begin with low-cost measures and progressively add technology where evidence shows a need. The following sequence provides a practical management plan.

Step 1 – Establish a baseline: Review existing rules, circulation procedures, missing and damaged materials, complaint records and common disruptions. The purpose is to understand local risks rather than assume that every library faces the same problems.

Step 2 – Strengthen communication: Prepare short, visible and user-friendly rules for entry areas, circulation desks, reading rooms and collection zones. Explain the reason behind major rules.

Step 3 – Improve orientation: Provide induction for new students and periodic refresher sessions. Include handling of books, borrowing and returning, study-room conduct, digital resources and consequences of violations.

Step 4 – Improve supervision: Identify high-risk periods and locations. Allocate staff attention to circulation points, reading rooms and collection areas according to actual need.

Step 5 – Verify collections: Conduct routine stock verification and maintain records of missing, damaged and recovered items. Use recurring patterns to identify risk areas.

Step 6 – Add technology selectively: Where justified by risk and budget, use CCTV, electronic theft detection and access-control systems. Ensure maintenance and staff training.

Step 7 – Standardize incident response: Use a written incident-reporting procedure and proportionate sanctions. Maintain consistency and provide appropriate review mechanisms.

Step 8 – Review and improve: Periodically analyze incident patterns, user feedback and operational experience. Modify procedures rather than allowing policies to become static.

Challenges in Implementation

- Limited financial resources for surveillance and electronic security.
- Insufficient staffing for continuous supervision.
- Difficulty maintaining consistent user-education programmes.
- Concern that strict controls may discourage legitimate library use.
- Weak reporting and documentation of incidents.
- Large and diverse user populations with different expectations.
- Need for regular maintenance, training and review of security systems.

Recommendations

- Conduct structured library orientation for every new batch of students and provide periodic refresher programmes.
- Display concise, multilingual and user-friendly rules at entry points, circulation areas and high-risk locations.
- Introduce routine stock verification and maintain records of missing, damaged and recovered materials.
- Use CCTV and electronic security systems according to institutional risk and budget.
- Improve supervision at circulation points, reading rooms and collection areas.
- Develop a written incident-reporting and disciplinary procedure with proportionate sanctions.
- Promote responsibility for shared resources through campaigns, exhibitions and preservation-awareness activities.
- Increase access to high-demand electronic resources and provide legal digital alternatives where feasible.
- Train library staff in conflict management, incident documentation, preservation and security procedures.
- Review behaviour-management data periodically and modify procedures based on recurring incident patterns.

Suggested Monitoring Indicators

Although this conceptual paper does not introduce a new statistical dataset, academic libraries can develop simple indicators for future monitoring. The indicators below can help institutions evaluate whether their behaviour-management system is improving.

- Number and type of reported incidents by month or semester.

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- Number of missing, damaged and recovered items identified through stock verification.
- Frequency of overdue retention and successful recovery after reminders.
- Participation in orientation and refresher programmes.
- User feedback concerning clarity and fairness of library rules.
- Response time between incident identification and administrative action.
- Maintenance status and operational reliability of security equipment.
- Availability and usage of high-demand electronic alternatives.

Conclusion

Protecting academic library resources requires more than locking doors or imposing penalties. Libraries are social learning environments in which responsible behaviour must be encouraged through education, communication, supervision and fair accountability. The themes represented in the supplied source study demonstrate the importance of user education, security measures, stock-taking and appropriate disciplinary mechanisms.

Building on these themes, this paper proposes an integrated framework in which libraries educate users, reduce opportunities for misconduct, detect incidents, respond fairly and continuously review procedures. The framework provides a balanced approach because it recognizes both sides of library management: the need for openness and access, and the need to protect shared resources.

The long-term objective should be to develop a culture of responsibility in which users understand that library resources are collective assets. When users recognize that careful handling, timely return and respectful conduct protect the rights of present and future learners, security becomes part of the library's educational mission rather than an external restriction.

Limitations of the Study

This paper is conceptual and based on the themes and references available in the supplied source paper. It does not introduce a new empirical sample, questionnaire, interview dataset or statistical analysis. Consequently, the framework should be understood as a structured conceptual proposal rather than a tested causal model.

The paper also does not claim that the same intervention will have identical effects in every academic library. Institutional size, collection type, user population, staffing, budget, infrastructure and local policies can influence outcomes.

Scope for Further Research

- Test the proposed framework using questionnaires, interviews and structured observation across multiple academic libraries.
- Compare the effectiveness and cost of CCTV, electronic security, user education and other preventive measures.
- Examine the relationship between availability of high-demand resources and incidents of mutilation or concealment.
- Develop a validated scale for measuring library user behaviour and perceived security.
- Study user perceptions of fairness, privacy and acceptability of surveillance and disciplinary procedures.
- Evaluate whether continuous user-education programmes produce measurable improvements in compliance over time.

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Conflicts of interest

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

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Original Article

A Study of Institutional Governance and Digital Transformation of the Varkari Kirtan Tradition in Maharashtra: Emerging Opportunities and Administrative Challenges.

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Abstract
The Varkari Kirtan tradition represents an important component of Maharashtra's cultural and spiritual heritage and has historically contributed to social awareness, community participation and the transmission of values across generations. However, rapid technological development and changing patterns of communication have created new possibilities as well as challenges for the preservation and promotion of this traditional practice. The present study examines the role of institutional governance in facilitating the digital transformation of the Varkari Kirtan tradition in Maharashtra. It focuses on the emerging use of digital platforms for documentation, dissemination, accessibility, cultural promotion and livelihood opportunities. The study also examines the administrative challenges associated with digitalization, including systematic documentation, institutional coordination, digital accessibility, authenticity, commercialization and the need for sustainable policy interventions. The study is descriptive and exploratory in nature and is primarily based on secondary data collected from research literature, books, government publications, institutional sources and credible digital resources. The study highlights that digital transformation can strengthen the visibility, accessibility and preservation of Varkari Kirtan, provided that appropriate institutional mechanisms and administrative support are established. The paper suggests greater institutional collaboration, digital documentation, capacity building and policy support for ensuring the sustainable preservation and development of the Varkari Kirtan tradition in the contemporary digital era.

Keywords: *Varkari Kirtan, Institutional Governance, Digital Transformation, Cultural Heritage, Administrative Challenges, Maharashtra.*

Introduction

Kirtan has a long and rich history in India and has been an important medium of devotion, knowledge dissemination and social awareness. Different forms of Kirtan traditions are practiced in different regions of the country with some regional variations. In Maharashtra, the tradition is popularly known as Kirtan; in Gujarat, Sankirtan; in North India, Hari Kirtan; in South India, Harikatha; and in Punjab, Shabad Kirtan is performed in Gurudwaras. Although the forms and presentation styles may differ from region to region, the basic purpose of Kirtan is to communicate spiritual, cultural and social values through narration, music and devotional expression. The themes of Kirtan are generally based on the Puranas, Ramayana, Mahabharata, the lives and teachings of saints, and various aspects of Indian cultural and spiritual history. It is difficult to identify the exact origin and beginning of the Kirtan tradition. According to traditional beliefs, Kirtan has been associated with sages such as Narada, Sanaka, Sanandana and Sanatkumara. References to Kirtan can also be found in ancient religious literature.

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Among the nine forms of devotion, Kirtan is considered an important form of Bhakti. It is not limited to individual worship but also has a strong social dimension. Through Kirtan, religious teachings, moral values, social messages and awareness are communicated to the community. Thus, Kirtan has traditionally functioned as a medium of both devotion and social education.

In Maharashtra, Kirtan has developed as an important part of the Varkari tradition. The Varkari tradition is closely associated with devotion to Lord Vitthal and with the teachings of saints such as Sant Dnyaneshwar, Sant Namdev, Sant Eknath, Sant Tukaram and other saint-poets. Varkari Kirtan combines devotional expression with storytelling, music, spiritual teachings and social messages. It has played an important role in transmitting the thoughts and values of the saint tradition from one generation to another. The collective nature of the Varkari tradition has also encouraged community participation and social connectedness.

Traditionally, Kirtan has been transmitted mainly through oral communication and direct participation in religious and community gatherings. Kirtankars have played an important role in preserving and communicating this knowledge. However, changes in society, education, communication technology and patterns of public participation have gradually influenced traditional cultural practices. The emergence of digital technology has created new possibilities for the presentation, documentation and dissemination of Varkari Kirtan.

In the contemporary digital era, platforms such as YouTube, social media, websites and live-streaming services have provided new ways of reaching audiences beyond geographical boundaries. Kirtan performances can now be recorded, stored and accessed by people at different locations and at different times. Digital platforms can therefore contribute to the wider dissemination of the tradition, greater participation of younger generations and the creation of digital records for future reference. Digitalization may also create new opportunities for cultural promotion, educational activities and livelihood generation for practitioners associated with the tradition.

At the same time, digital transformation presents several challenges. The absence of systematic documentation, differences in digital accessibility, concerns regarding authenticity, commercialization of traditional content, content ownership and the need for proper institutional coordination are important issues that require attention. The transformation of a traditional cultural practice into a digitally accessible form therefore requires not only technological facilities but also appropriate administrative and institutional mechanisms.

Institutional governance has an important role in addressing these emerging issues. Government departments, cultural institutions, educational institutions, local administrative bodies and organisations associated with cultural heritage can contribute to documentation, preservation, promotion and capacity building. Effective coordination among these institutions can help create sustainable mechanisms for preserving the traditional character of Varkari Kirtan while enabling it to adapt to changing technological and social environments.

Therefore, the intersection of Varkari Kirtan, institutional governance and digital transformation provides an important area for academic study. The present study attempts to examine how digital transformation is influencing the preservation, promotion and accessibility of the Varkari Kirtan tradition in Maharashtra. It further focuses on the emerging opportunities and administrative challenges associated with this transformation and suggests the need for appropriate institutional mechanisms for the sustainable development of this important cultural tradition.

Objectives of the Study

1. To examine the role of institutional governance in preserving and promoting Varkari Kirtan.
2. To analyse the impact of digital transformation on its accessibility and dissemination.
3. To identify cultural, educational and livelihood opportunities created by digitalization.
4. To examine the major administrative challenges associated with digital transformation.
5. To suggest institutional measures for sustainable preservation and development.

Review of Literature

The existing literature on the Varkari tradition and Kirtan has examined the subject mainly from historical, religious, social, musical and cultural perspectives. A review of selected literature is presented below to understand the development of the tradition and its relevance to the present study.

1. **Ranade, R. D. (1982), in *Mysticism in Maharashtra: Indian Mysticism*,** examined the spiritual and philosophical traditions of Maharashtra. The work provides an important foundation for understanding the devotional philosophy associated with the Varkari tradition and the continuity of spiritual practices across generations. It is relevant to the present study for understanding the cultural and spiritual foundation of Varkari Kirtan.

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2. **Dadhe, Kasturi (2012), in *Anecdotes in the Varakari Kirtana Folk Tradition of Maharastra*,** examined the narrative and folk dimensions of the Varakari Kirtana tradition. The work highlights the role of anecdotes, oral communication and storytelling in the transmission of cultural and religious knowledge. It is particularly relevant to the present study because digital recording can provide new mechanisms for preserving such orally transmitted knowledge.
3. **Naregal, Veena (2000), in the article "Language and Power in Pre-Colonial Western India: The Political Uses of Language in the Varkari Tradition," published in *The Indian Economic & Social History Review, 37*(3), 309–338,** analysed the relationship between language, social communication and the Varkari tradition. The study demonstrates the significance of communicative practices in sustaining the tradition and provides a useful background for examining its transformation in contemporary communication environments.
4. **Kashalkar-Karve, Sanyukta (2015), in "Tradition of Kirtan in Maharashtra: An Expression of Bhakti Through Music,"** examined Kirtan as a form of devotional expression involving music and cultural communication. The study contributes to understanding Kirtan as a multidimensional cultural practice rather than merely a religious performance. This perspective is useful for analysing its preservation and dissemination through modern media.
5. **Keune, Jon (2021), in *Shared Devotion, Shared Food: Equality and the Bhakti-Caste Question in Western India*,** examined Bhakti traditions in Western India with particular attention to community, social relationships and devotional practices. The work provides a broader socio-cultural context for understanding the Varkari tradition as a community-oriented practice and supports the present study's focus on institutional and social participation.
6. **Glushkova, Irina (2021), in her article "Janabai and Gangakhed of Das Ganu: Towards Ethnic Unity and Religious Cohesion in a Time of Transition," published in *The Indian Economic & Social History Review, 58*(4),** examined the Varkari tradition in relation to social transformation and religious cohesion. The study indicates the capacity of devotional traditions to interact with changing social conditions, which is relevant to understanding the contemporary transformation of Varkari cultural practices.
7. **UNESCO (2003), through the *Charter on the Preservation of Digital Heritage*,** established principles concerning the preservation and long-term accessibility of digital materials. Although the framework is broader than the Varkari tradition, it provides an important conceptual basis for systematic digital documentation and preservation of audio-visual cultural materials.
8. **Government of Maharashtra (2024), through the establishment of the Chief Minister Warkari Corporation,** introduced an institutional mechanism focusing on facilities and welfare measures for Warkaris and Kirtankars. The initiative provides an important administrative context for the present study because it demonstrates increasing government involvement in the welfare and development of the Varkari tradition.

Research Gap

The reviewed literature demonstrates that considerable attention has been given to the **historical, spiritual, social, musical and cultural dimensions** of the Varkari and Kirtan traditions. International literature has also examined the role of digital technologies in cultural preservation. However, limited focused research has examined **institutional governance and digital transformation together in the specific context of Varkari Kirtan in Maharashtra**. The present study therefore attempts to address this gap by examining how institutional mechanisms can support digital documentation, preservation, dissemination, youth participation and emerging livelihood opportunities while addressing administrative challenges such as institutional coordination, digital accessibility, authenticity, content ownership and sustainable policy support.

Research Questions

1: What role does institutional governance play in preserving Varkari Kirtan?
2: How has digital transformation influenced its dissemination and accessibility?
3: What opportunities have emerged through digitalization?
4: What are the major administrative challenges?
5: What institutional measures can support sustainable development?

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Research Methodology

Research Design: Descriptive and Exploratory

Nature of Data: Secondary Data

Sources of Data: Research papers, books, PhD theses, government reports, institutional publications and credible online sources.

Data Analysis: Thematic and qualitative analysis.

The study is based on secondary sources and examines the relationship between institutional governance, digital transformation and the preservation of Varkari Kirtan.

Institutional Governance and Cultural Heritage

1 Meaning of Institutional Governance

Institutional governance refers to the policies, systems and mechanisms through which institutions plan, coordinate and manage activities related to a particular field. In cultural heritage, it includes the role of government bodies, cultural organisations, educational institutions and local communities in preservation, promotion and sustainable development. For Varkari Kirtan, effective governance can support documentation, preservation, digital promotion and the participation of younger generations.

2 Role of Government Institutions

Government institutions can contribute to the preservation and promotion of Varkari Kirtan through policy support, cultural programmes, financial assistance, documentation and infrastructure.

- Cultural Departments: Support cultural programmes, preservation and documentation.
- Local Administration: Facilitate local events, infrastructure and coordination.
- Tourism Institutions: Promote Varkari heritage through responsible cultural tourism.
- Educational Institutions: Conduct research, workshops, awareness programmes and documentation activities.

3 Role of Religious and Cultural Organisations

Religious and cultural organisations help maintain the community-based nature of Kirtan. They can organise programmes, support Kirtankars, encourage youth participation and promote traditional knowledge. Collaboration with government and educational institutions can further strengthen preservation efforts.

4 Institutional Support for Preservation of Varkari Tradition

Institutional support can include:

- Financial assistance
- Training and capacity building
- Cultural programmes
- Digital preservation
- Research and documentation
- Intergenerational knowledge transfer

Such support can help preserve the traditional character of Kirtan while enabling it to adapt to changing social and technological conditions.

5 Documentation and Cultural Heritage Management

Systematic documentation is essential for preserving traditional knowledge. Documentation may include information about Kirtankars, Kirtan content, performances, music, history, literature and oral traditions. Digital archives and audio-visual recordings can make this knowledge accessible to future generations. At the same time, issues of authenticity, consent, intellectual property and responsible digital use should be considered.

Thus, effective cultural heritage management requires coordination among government institutions, cultural organisations, educational institutions, local communities and traditional practitioners.

Digital Transformation of Varkari Kirtan

1 Emergence of Digital Platforms

Digital platforms such as YouTube, Facebook, Instagram, websites and live-streaming services have created new opportunities for presenting and promoting Varkari Kirtan. These platforms help Kirtankars reach audiences beyond geographical boundaries.

2 Digital Documentation of Kirtan

Audio and video recordings of Kirtan can be digitally preserved for future generations. Digital documentation helps protect traditional knowledge, performances and oral heritage.

3 Accessibility and Wider Audience

Digital platforms have made Kirtan more accessible to people who cannot attend physical programmes. Recorded and live performances can reach audiences across Maharashtra, India and other parts of the world.

4 Youth Engagement through Digital Media

Social media can attract younger audiences by presenting traditional Kirtan through contemporary digital formats. It can encourage youth to learn about the teachings, literature and cultural values associated with the Varkari tradition.

5 Digital Promotion and Dissemination

Digital media provides cost-effective ways to promote Kirtan programmes, cultural events and traditional knowledge. It also enables faster dissemination of information among devotees and cultural communities.

6 Emerging Digital Livelihood Opportunities

Digital platforms may create new economic opportunities for Kirtankars through online programmes, digital content creation, audience expansion and other forms of online engagement. Thus, digitalization can contribute not only to

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cultural preservation but also to the economic sustainability of traditional practitioners.

Emerging Opportunities for the Preservation and Development of Varkari Kirtan through Digital Transformation

1 Cultural Preservation

Digital recording and documentation can help preserve the traditional knowledge and practices of Varkari Kirtan for future generations.

2 Global Outreach

Digital platforms enable Varkari Kirtan to reach audiences beyond Maharashtra and India.

3 Youth Participation

Social media and digital content can encourage younger generations to learn about and participate in the tradition.

4 Digital Archives

Digital archives can systematically store Kirtan recordings, literature, performances and information about Kirtankars.

5 Educational Opportunities

Digital platforms can support online learning, research, workshops and knowledge sharing related to Kirtan.

6 Livelihood and Economic Opportunities

Online performances, digital content and wider audience reach can create new economic opportunities for Kirtankars and associated practitioners.

7 Cultural Tourism

Kirtan and Varkari cultural practices can contribute to responsible cultural tourism and promote Maharashtra's heritage.

8 Institutional Collaboration

Government, educational and cultural institutions can collaborate for documentation, training, promotion and preservation.

Administrative Challenges

1 Lack of Systematic Documentation

A systematic mechanism for recording and preserving Kirtan traditions is still required.

2 Institutional Coordination

Effective coordination among government, cultural, educational and community institutions is necessary.

3 Digital Divide

Limited digital literacy, internet access and technological resources may restrict participation.

4 Authenticity and Standardisation

Digital presentation may create concerns regarding authenticity and accurate representation of traditional practices.

5 Commercialisation

Excessive commercialisation may affect the traditional and cultural character of Kirtan.

6 Intellectual Property and Content Ownership

Digital recordings raise concerns related to ownership, consent and responsible use of traditional content.

7 Limited Digital Infrastructure

Adequate technological infrastructure and digital resources are required for effective preservation.

Role of Government and Institutional Mechanisms

Government and institutions can support the Varkari Kirtan tradition through:

Policy Formulation
↓
Financial Support
↓
Digital Documentation
↓
Training & Capacity Building
↓
Promotion & Preservation
↓
Sustainable Development

The institutional process can be understood as a connected cycle:

1. Policy Formulation

Policy formulation provides an official framework for recognizing, protecting, and developing Varkari Kirtan. Without a clear policy, support may remain temporary, fragmented, or dependent on individual organizations.

Government policies can:

- Recognize Varkari Kirtan as intangible cultural heritage and include it in state cultural-development plans.
- Establish standards for documenting traditional compositions, performance practices, oral histories, and regional variations.
- Protect the rights and interests of kirtankars, accompanists, researchers, and traditional communities.
- Integrate appropriate knowledge about the Varkari tradition into educational and cultural programs.

2 Financial Support

Financial assistance is necessary because many performers and community organizations have limited resources. Traditional artists may struggle with travel costs, instruments, training expenses, performance venues, healthcare, and unstable income.

3 Digital Documentation

Varkari Kirtan is largely transmitted through oral performance, observation, memory, and participation. Digital documentation can protect valuable material that may otherwise disappear when senior performers pass away or local performance traditions decline.

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4 Training and Capacity Building

The continuity of Varkari Kirtan depends on the systematic transfer of knowledge from experienced practitioners to younger generations. Traditional guru-shishya learning should be respected, while institutional programs can provide additional opportunities and resources.

5 Promotion and Preservation

Preservation protects the tradition's knowledge and values, while promotion brings it to wider audiences. Both must operate together: preservation without public participation can turn the tradition into a museum object, while promotion without safeguards can lead to superficial commercialization.

6 Sustainable Development

Sustainable development means ensuring that Varkari Kirtan remains culturally meaningful, economically viable, socially inclusive, and environmentally responsible over the long term.

The tradition can contribute to sustainable development in several ways:

- It can generate dignified livelihoods for performers, accompanists, instrument makers, researchers, translators, technicians, and local organizers.
- Community-based festivals can support local food providers, transport workers, craftspeople, and small businesses.
- Kirtan's ethical teachings can encourage social responsibility, compassion, equality, community service, and respect for nature.
- Environmentally responsible event management can reduce plastic waste, noise pollution, traffic congestion, and damage to pilgrimage sites.

Overall Significance

These mechanisms form a continuous chain. Policy formulation establishes official recognition and direction. Financial support provides the resources needed for action. Digital documentation preserves endangered knowledge. Training and capacity building transmit skills to future generations. Promotion and preservation strengthen public awareness and cultural continuity. Together, these measures lead to sustainable development by protecting heritage, supporting livelihoods, and ensuring active community participation. The most effective approach is not simply government control or financial sponsorship. It is a community-centred partnership in which institutions provide resources and infrastructure while Varkari practitioners retain cultural authority over how their tradition is represented, taught, documented, and developed.

Findings

Based on the review of secondary sources, the study highlights the following:

- Increased Accessibility: Digital platforms have expanded access to Kirtan.
- Preservation: Digital recording supports cultural documentation.
- Youth Outreach: Social media can attract younger audiences.
- Administrative Gaps: Systematic institutional coordination is required.
- Livelihood Potential: Digital platforms may create new economic opportunities.

Suggestions / Administrative Recommendations

- Digital Kirtan Archive: Develop a systematic digital repository.
- Institutional Coordination: Strengthen collaboration among relevant institutions.
- Digital Training: Provide basic digital-literacy training to Kirtankars.
- Documentation Framework: Establish systematic documentation practices.
- Youth Engagement: Encourage digital cultural programmes in educational institutions.
- Cultural Tourism: Promote Kirtan through responsible cultural-tourism initiatives.
- Financial Support: Strengthen appropriate institutional and financial support mechanisms.

Conclusion

The Varkari Kirtan tradition has significant cultural and social importance in Maharashtra. Digital transformation provides new opportunities for its preservation, accessibility, promotion, youth engagement and livelihood development. However, challenges related to documentation, authenticity, digital accessibility, institutional coordination and content ownership require appropriate administrative attention.

Therefore, a coordinated approach involving government institutions, cultural organisations, educational institutions, local communities and traditional practitioners is essential. Effective institutional governance can help balance tradition and technology and contribute to the sustainable development of Varkari Kirtan in the digital era.

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Original Article

A Study of An Exploratory Assessment of Factors Affecting Job Satisfaction among Nursing Professionals.

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Abstract
Nursing professionals constitute one of the most important components of the healthcare workforce and play a central role in ensuring continuity, quality, and safety of patient care. The nature of nursing work involves considerable responsibility, demanding schedules, emotional involvement, interpersonal interactions, and continuous adaptation to changing healthcare requirements. Consequently, job satisfaction among nursing professionals has become an important area of concern for healthcare organizations, particularly because satisfaction is associated with employee retention, organizational commitment, quality of work, and the sustainability of the nursing workforce. The present study proposes an exploratory assessment of the major factors affecting job satisfaction among nursing professionals. The study focuses on workplace environment, workload, compensation and benefits, management and supervisory support, recognition, professional development, interpersonal relationships, autonomy, job security, and work-life balance as important dimensions associated with nurses' job satisfaction. Existing literature indicates that both intrinsic and extrinsic factors influence nurses' perceptions of their jobs. Recent evidence also emphasizes the importance of organizational climate, leadership, working conditions, professional development, and psychological factors. An exploratory research design is proposed, using primary data collected through a structured questionnaire administered to nursing professionals. Descriptive statistics, weighted mean scores, correlation analysis, and, where appropriate, regression analysis may be used to examine the relationship between selected factors and overall job satisfaction. The study is expected to provide useful insights for hospital administrators, nursing managers, human-resource professionals, and policymakers in developing strategies to improve nurses' workplace experiences and retention.
Keywords: *Job Satisfaction, Nursing Professionals, Work Environment, Workload, Organizational Support, Professional Development, Work-Life Balance, Healthcare Workforce.*

Introduction

Nursing is a profession that combines technical knowledge, clinical responsibility, interpersonal communication, emotional involvement, and continuous patient care. Nurses work in diverse healthcare settings such as hospitals, primary healthcare centres, clinics, nursing homes, community health programmes, and specialized medical institutions. Their responsibilities extend beyond direct patient care and may include documentation, coordination with doctors and other healthcare professionals, patient education, counselling, emergency response, and administrative activities. The importance of the nursing workforce has been recognized globally. The World Health Organization identifies nurses as the largest occupational group within the health workforce and emphasizes the need for adequate employment, supportive working conditions, education, leadership, and professional development. The *State of the World's Nursing 2025* report highlights employment, remuneration, working conditions, leadership, education, and workforce sustainability as important areas requiring continued attention.

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In such a demanding professional environment, job satisfaction is an important organizational and human-resource issue. Job satisfaction broadly refers to the degree to which employees experience positive feelings and attitudes towards their jobs. It may be influenced by the nature of work, compensation, organizational policies, relationships with supervisors and colleagues, recognition, autonomy, workload, career opportunities, and the overall work environment.

For nursing professionals, job satisfaction has implications beyond individual employee well-being. Dissatisfaction may contribute to intention to leave, turnover, reduced organizational commitment, and difficulties in retaining experienced nursing staff. Previous systematic reviews have identified working conditions, organizational environment, job stress, role-related issues, and professional commitment among the important factors associated with nurses' job satisfaction.

A recent updated review of hospital nurses' job satisfaction identified a wide range of influencing factors across demographic, individual, psychological, organizational, leadership, and management domains. The review particularly emphasized the need for further investigation of workplace and management factors that influence nurses' job satisfaction.

Therefore, the present study attempts to explore the major factors affecting job satisfaction among nursing professionals and to understand which dimensions of their professional environment may contribute to greater or lower satisfaction.

Background of the Study

Healthcare organizations depend heavily on nursing professionals for the effective delivery of patient care. Nurses frequently work under conditions involving long or irregular working hours, high patient responsibilities, emotional demands, emergency situations, documentation requirements, and coordination with multiple healthcare professionals.

The contemporary healthcare environment has also become increasingly complex. Technological developments, changing patient expectations, increased documentation, staffing pressures, and the need for continuous professional development have changed the nature of nursing work.

The World Health Organization's 2025 nursing report emphasizes the importance of investing in nursing education, employment, leadership, and service delivery. It also reports continuing gaps concerning working-hour regulation and mental well-being support in many countries, highlighting the importance of supportive working environments for workforce sustainability.

Job satisfaction therefore represents an important intersection between employee experience and organizational effectiveness.

Objectives of the Study

The study proposes the following objectives:

1. To examine the level of job satisfaction among nursing professionals.
2. To identify the major factors affecting job satisfaction among nursing professionals.
3. To assess the influence of the working environment on nurses' job satisfaction.
4. To examine the relationship between workload and job satisfaction.
5. To assess the role of salary and benefits in determining job satisfaction.
6. To examine the influence of management and supervisory support on job satisfaction.

Review of Literature

1 Lu, Barriball, Zhang, and While (2012), Lu et al. conducted a systematic review of job satisfaction among hospital nurses. Their review examined 100 papers and concluded that nurses' job satisfaction was associated with working conditions, organizational environment, job stress, role conflict and ambiguity, role perception, role content, and organizational and professional commitment. The study demonstrates that nurses' job satisfaction is influenced by a combination of individual and organizational conditions rather than by a single factor.

2 Blegen (1993), Blegen conducted a meta-analysis involving 48 studies and 15,048 participants. The study identified job stress and organizational commitment among the strongest correlates of nurses' job satisfaction. Communication with supervisors, autonomy, recognition, communication with peers, and fairness were also associated with satisfaction.

This study establishes the importance of both psychological and organizational variables in understanding nurses' job satisfaction.

3 Zangaro and Soeken (2007), A meta-analysis of studies of nurses' job satisfaction found job stress to be negatively associated with satisfaction, while nurse-physician collaboration and autonomy showed positive relationships with satisfaction. The findings highlighted the importance of improving the work environment.

4 Saber (2014), Saber examined predictors of frontline registered nurses' job satisfaction over three decades. The meta-analysis included 62 studies and identified task requirements, empowerment, and control among the important predictors of job satisfaction. The findings

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demonstrate the significance of nurses' experiences of control and empowerment in the workplace.

Research Gap

The existing literature establishes that nurses' job satisfaction is multidimensional. However, the relative importance of different factors may vary according to healthcare setting, organizational structure, geographical location, type of institution, workload, professional experience, and employment conditions. Therefore, there is scope for exploratory research that examines multiple factors simultaneously and captures nursing professionals' perceptions of their current work environment.

Concept of Job Satisfaction

Job satisfaction can be understood as an employee's overall evaluation of and emotional response to their job. According to Spector (1997), job satisfaction is an important organizational-behaviour construct and may be influenced by both personal and organizational factors. His work also identifies job characteristics, workplace relationships, treatment of employees, and rewards among the environmental antecedents of satisfaction.

For nursing professionals, job satisfaction may involve satisfaction with:

- The nature of nursing work
- Salary and financial benefits
- Working hours
- Workload
- Hospital policies
- Supervisory relationships
- Relationships with colleagues
- Recognition and appreciation
- Career advancement
- Professional autonomy
- Job security
- Working environment
- Work-life balance
- Training and development opportunities

Thus, job satisfaction should not be considered a single-dimensional concept. It is a multidimensional phenomenon resulting from the interaction of several personal and organizational factors.

Theoretical Perspective of Job Satisfaction among Nursing Professionals

1 Herzberg's Two-Factor Theory

The present study is conceptually supported by Herzberg's Two-Factor Theory of Motivation, proposed by Frederick Herzberg, Bernard Mausner, and Barbara Bloch Snyderman. The theory explains that job satisfaction and job dissatisfaction are influenced by two different sets of factors, namely hygiene factors and motivator factors. According to Herzberg, the factors that prevent dissatisfaction are not necessarily the same factors that create satisfaction. Therefore, understanding both dimensions is important when examining job satisfaction among nursing professionals.

Hygiene factors are mainly related to the work environment and the conditions under which employees perform their duties. These factors include salary, organisational policies, working conditions, job security, supervision, interpersonal relationships and administrative practices. When these factors are inadequate, employees may experience dissatisfaction, stress or frustration. However, providing satisfactory hygiene factors mainly helps in reducing dissatisfaction rather than creating a high level of job satisfaction. In the nursing profession, appropriate remuneration, safe and supportive working conditions, reasonable workload, job security, fair organisational policies and supportive supervision can contribute to a more favourable work environment.

Motivator factors, on the other hand, are associated with the nature and content of the job itself. These include achievement, recognition, responsibility, advancement, personal growth and meaningful work. The presence of these factors can encourage employees to develop a positive attitude towards their work and experience greater job satisfaction. For nursing professionals, recognition of their contribution, opportunities to take responsibility, professional autonomy, career advancement, appreciation from supervisors and colleagues, and opportunities for learning and professional development can enhance their sense of achievement and satisfaction.

The theory is particularly relevant to the present study because nursing is a demanding profession involving considerable responsibility, patient care, teamwork and emotional commitment. A nurse may have satisfactory salary and working conditions but may still experience limited job satisfaction if there is inadequate recognition, professional growth or autonomy. Similarly, recognition and meaningful work may not be sufficient if basic workplace conditions, job security or organisational support are inadequate. Thus, both hygiene and motivator factors need to be considered together while examining the determinants of job satisfaction among nursing professionals.

Therefore, Herzberg's Two-Factor Theory provides a useful theoretical framework for analysing how organisational conditions, workplace environment, professional recognition, responsibility, career opportunities and personal growth influence job satisfaction among nursing professionals. The

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theory also supports the present study in identifying the factors that may contribute to both satisfaction and dissatisfaction within the nursing work environment.

Statement of the Problem

Nursing professionals operate in a work environment characterized by substantial professional responsibility, demanding workloads, interpersonal interactions, shift duties, and emotional involvement. Although job satisfaction is important for employee well-being and organizational effectiveness, nursing professionals may experience dissatisfaction due to workload, inadequate recognition, limited career advancement, workplace relationships, compensation, lack of autonomy, or insufficient organizational support.

The present study therefore seeks to explore the major factors affecting job satisfaction among nursing professionals and to understand the relationship between selected workplace factors and their overall job satisfaction.

Need and Significance of the Study

The study is significant for the following reasons:

1 Importance to Nursing Professionals

The study can provide nursing professionals with an opportunity to express their perceptions regarding their workplace, workload, recognition, compensation, professional growth, and organizational support.

2 Importance to Hospital Management

The findings may assist hospital administrators in identifying areas requiring improvement.

3 Human Resource Management

The study may help HR departments develop appropriate strategies for employee retention, recognition, training, and professional development.

4 Workforce Retention

Job satisfaction is relevant to retention and turnover. Understanding the factors associated with satisfaction may help organizations create a more supportive work environment.

5 Quality of Healthcare

A stable and satisfied nursing workforce can contribute to organizational continuity and effective patient-care delivery.

6 Policy Implications

The findings may provide useful evidence for institutional policies concerning working conditions, staffing, professional development, remuneration, and employee well-being.

Research Questions

The study may address the following research questions:

1. What is the overall level of job satisfaction among nursing professionals?
2. Which workplace factors have the greatest influence on job satisfaction?
3. Does workload influence nurses' job satisfaction?
4. Does the quality of the working environment influence job satisfaction?
5. Does management support contribute to higher job satisfaction?

Conceptual Framework

The present study considers **job satisfaction among nursing professionals as the dependent variable**, while various organisational, job-related, reward and development, social and personal factors are considered as independent variables. The conceptual framework assumes that these factors may influence the level of job satisfaction experienced by nursing professionals.

The **organisational factors** include the working environment, management support, supervisory relationships, organisational policies and staffing conditions. A supportive work environment, effective management and appropriate staffing may contribute to a more positive work experience and enhance job satisfaction. The **job-related factors** include workload, working hours, job responsibilities, job autonomy and job security. Reasonable workload, suitable working hours, clarity of responsibilities, professional autonomy and a sense of job security may positively influence employees' satisfaction with their work.

The **reward and development factors** comprise salary and benefits, recognition, promotion opportunities, professional development and training opportunities. Fair compensation, recognition of professional contributions and opportunities for career advancement and skill development may increase motivation and satisfaction among nursing professionals. In addition, **social and personal factors**, such as peer relationships, doctor–nurse relationships, work–life balance and emotional support, may influence how nurses perceive their workplace and professional roles. Positive interpersonal relationships and adequate emotional support can help create a supportive work environment and improve job satisfaction.

Thus, the conceptual framework proposes that working environment, workload, compensation, management support, recognition, professional development, interpersonal relationships, job security and work–life balance collectively influence overall job satisfaction among nursing professionals. The relationship can therefore be conceptually represented as:Working Environment

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+ Workload + Compensation + Management Support + Recognition + Professional Development + Interpersonal Relationships + Job Security + Work–Life Balance → Overall Job Satisfaction among Nursing Professionals

Research Methodology

Research Design

The study adopts an exploratory research design because it seeks to explore and understand the different factors associated with job satisfaction among nursing professionals.

A descriptive component may also be incorporated to present the demographic profile and satisfaction levels of respondents.

Nature of the Study

The study is empirical in nature and may use Secondary data

Sources of Data:

Secondary information may be obtained from:

- Peer-reviewed journal articles
- Systematic reviews
- Books
- WHO reports
- Government publications
- Institutional reports
- Academic databases

Expected Findings

Since primary data have not been supplied, the following should not be presented as actual findings. They represent areas that the study is designed to investigate.

The study is expected to examine whether:

1. Supportive working environments are associated with higher job satisfaction.
2. Excessive workload is associated with lower satisfaction.
3. Management support contributes positively to nurses' workplace experiences.
4. Recognition and appreciation influence professional satisfaction.
5. Career development opportunities contribute to positive attitudes toward work.
6. Positive interpersonal relationships support job satisfaction.
7. Appropriate compensation and benefits contribute to satisfaction.
8. Greater professional autonomy may be associated with higher satisfaction.
9. Work-life balance may influence overall job satisfaction.

Discussion

The literature indicates that nurses' job satisfaction is a multidimensional construct. Earlier meta-analytic evidence identified job stress, organizational commitment, communication, autonomy, recognition, fairness, and peer relationships as important correlates.

Similarly, research examining frontline registered nurses has emphasized task requirements, empowerment, and control as important predictors.

These findings suggest that improving job satisfaction cannot depend exclusively on salary increases. Although compensation and benefits are important, nursing professionals also require supportive supervisors, appropriate workloads, opportunities for professional growth, recognition, autonomy, effective teamwork, and a safe working environment.

Recent evidence reinforces this multidimensional understanding. The updated review of hospital nurses identified organizational climate, leadership and management, psychological factors, and individual characteristics alongside traditional workplace factors.

Therefore, healthcare organizations should consider a comprehensive approach to job satisfaction rather than treating it as a purely financial or individual issues.

Suggestions and Recommendations

Based on the conceptual framework and existing literature, the following recommendations may be considered:

1 Improve Staffing and Workload Management

Hospitals should regularly assess staffing requirements and distribute workload appropriately.

2 Strengthen Supervisory Support

Nursing managers should maintain open communication and encourage nurses to discuss workplace concerns.

3 Establish Recognition Systems

Organizations should recognize good performance through appreciation, awards, feedback, and professional acknowledgement.

4 Provide Career Development Opportunities

Training, continuing professional development, workshops, certifications, and promotion pathways can support professional growth.

5 Improve Work-Life Balance

Shift scheduling should consider adequate rest periods, leave requirements, and reasonable working hours.

6 Strengthen Interpersonal Relationships

Team-building initiatives and effective communication can improve cooperation among nurses, doctors, administrators, and other healthcare professionals.

7 Encourage Professional Autonomy

Where clinically appropriate, nurses should have opportunities to participate in decisions affecting their professional responsibilities.

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8 Review Compensation and Benefits
Organizations should periodically review salaries, allowances, overtime compensation, and employee benefits.

9 Promote Employee Well-Being
Institutions should provide appropriate mechanisms for psychological support, stress management, and employee well-being.

10 Conduct Periodic Job-Satisfaction Surveys
Healthcare organizations should periodically measure employee satisfaction instead of waiting until turnover or dissatisfaction becomes a major issue.

Limitations of the Study
The study may have the following limitations:

1. The study may be restricted to selected healthcare institutions.
2. The findings may not be generalizable to all nursing professionals.
3. The study may rely primarily on self-reported responses.
4. Respondents may provide socially desirable responses.
5. Time and accessibility may limit the sample size.
6. Job satisfaction may change over time due to organizational and personal circumstances.
7. The study may not capture all psychological and organizational factors influencing satisfaction.
8. Cross-sectional data cannot establish strong causal relationships by themselves.

Scope for Future Research
Future researchers may extend the study by:

- Conducting comparative studies between government and private hospitals.
- Comparing urban and rural nursing professionals.
- Studying nurses working in specialized departments.
- Examining the relationship between job satisfaction and turnover intention.
- Studying the relationship between job satisfaction and organizational commitment.
- Examining burnout and occupational stress.
- Conducting longitudinal studies.
- Using qualitative interviews to understand nurses' experiences in greater depth.
- Comparing job satisfaction across different geographical regions.
- Examining the effect of leadership styles on nurses' job satisfaction.

Conclusion
Job satisfaction among nursing professionals is an important organizational, professional, and workforce issue. Nurses operate in an environment characterized by considerable responsibility, demanding workloads, continuous patient interaction, teamwork, and emotional involvement. Consequently, their satisfaction with work is influenced by multiple interconnected factors.

The existing literature demonstrates that working conditions, workload, job stress, organizational climate, leadership, autonomy, recognition, interpersonal relationships, empowerment, and professional development can influence nurses' job satisfaction.

The proposed exploratory study therefore adopts a multidimensional approach to understand job satisfaction among nursing professionals. Rather than considering salary as the sole determinant, the study recognizes the combined importance of financial, organizational, professional, social, and personal factors.

Healthcare institutions can potentially improve job satisfaction by developing supportive leadership, appropriate workload-management practices, recognition systems, professional-development opportunities, effective communication, reasonable work schedules, and employee-well-being initiatives.

Ultimately, understanding and addressing the factors affecting nurses' job satisfaction can contribute to a more supportive nursing workforce and help healthcare organizations strengthen workforce retention, professional commitment, and sustainable service delivery. The importance of strengthening nursing employment, leadership, working conditions, and workforce sustainability is also reflected in the World Health Organization's *State of the World's Nursing 2025* report.

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Original Article

Digital Resources and Academic Libraries: Opportunities, Challenges and Strategies for Effective User Services

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Abstract
Academic libraries are undergoing a gradual transformation from predominantly print-oriented environments toward hybrid information ecosystems in which printed collections and electronic resources coexist. Digital resources can improve access, support high-demand information needs and reduce some forms of physical resource abuse; however, they also introduce challenges related to authentication, licensing, access management, digital literacy and cybersecurity. This paper examines the role of digital resources in academic library service development and considers how digital access can complement collection protection and user behaviour management.
The paper is conceptual and literature-based. It is developed from the themes represented in the supplied source study, particularly its discussion of high-demand materials, user behaviour, collection security and the complementary role of electronic resources. No new questionnaire, sample or statistical dataset is introduced. The paper proposes a practical framework built around five areas: resource planning, user education, access management, security and continuous review. The study argues that digital resources should not be viewed simply as replacements for print collections. Rather, they can be used strategically to expand legitimate access while reducing pressure on limited physical copies.
Keywords: *academic libraries; digital resources; electronic resources; user education; collection security; information access; library management; digital literacy; cybersecurity; hybrid library.*

Introduction

Academic libraries are expected to provide convenient, equitable and reliable access to information for students, teachers and researchers. Traditionally, this role has depended heavily on printed books, journals and reference materials. The growth of electronic resources has expanded the possibilities for access by allowing users to reach information through computers and other digital devices.

The supplied source study links resource demand with several forms of inappropriate behaviour, particularly when heavily used materials are available in limited numbers. Users may attempt to retain, conceal or damage physical materials in order to obtain exclusive access. This observation suggests that collection development and access planning can contribute to prevention. Where appropriate electronic alternatives are available, some pressure on limited print copies may be reduced.

At the same time, digital resources do not automatically solve library-management problems. They require authentication, appropriate licensing, user awareness, technical support and protection against unauthorized access. Therefore, the transition toward electronic resources should be understood as a complementary component of modern library management.

Background of the Study

The source study emphasizes that library resources are shared assets and that damage or loss of a resource can reduce access for many future users.

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It identifies high-demand materials during examination and assignment periods as a situation in which users may seek exclusive access. The study therefore recommends adequate copies, digital alternatives, user education and systematic monitoring.

Digital resources can support this objective by providing additional channels through which users can obtain information. Electronic books, journals, databases and institutional digital materials may increase the availability of information without requiring every user to handle the same physical copy. Nevertheless, digital access introduces different management requirements, including authentication, licensing conditions, user training and cybersecurity.

The challenge for academic libraries is consequently not whether print or digital resources should exist, but how both can be managed as parts of an integrated information service.

Statement of the Problem

Academic libraries must provide broad access while protecting their collections and facilities. Physical collections may face theft, mutilation, concealment and overdue retention. Digital collections reduce exposure to some forms of physical abuse but may face unauthorized access, account sharing, technical failures and other operational risks. Libraries therefore require a balanced strategy that improves legitimate access while maintaining responsible resource management.

Objectives of the Study

- To examine the role of digital resources in academic library services.
- To explain how electronic alternatives can complement the management of high-demand print resources.
- To identify major challenges associated with digital-resource management.
- To examine the importance of user education and digital literacy.
- To propose an integrated framework for combining print and digital resources in academic library services.
- To suggest practical strategies for academic libraries operating with different levels of staffing, budget and technological infrastructure.

Research Questions

- What role can digital resources play in improving access to academic information?
- How can electronic alternatives complement protection of high-demand print collections?
- What challenges must libraries address when providing digital resources?
- How can user education improve responsible use of electronic resources?
- What management framework can integrate print and digital resources effectively?

Scope of the Study

The paper focuses on academic libraries and their management of digital and physical information resources. It discusses electronic resources mainly in relation to access, user education, collection planning, security and user behaviour. The paper does not present a new empirical survey or statistical evaluation of a particular institution.

Research Methodology

A conceptual and literature-based approach is adopted. The discussion is developed from the themes and references represented in the supplied source paper, especially its treatment of high-demand materials, user education, collection security, electronic resources and preventive management. The supplied source itself describes interviews and observation in selected academic libraries in Gondia; those observations are not presented here as a new dataset.

The analysis is organized thematically into five areas: digital access and collection planning; user education; access and security; service management; and continuous evaluation. Because no new statistical data have been supplied, the paper does not invent numerical findings.

Digital Resources in Academic Libraries

Digital resources include electronic books, electronic journals, online databases, institutional digital collections and other licensed or locally developed information resources. Their principal value is the ability to provide access without requiring a physical item to be present at a particular shelf or circulation desk.

For academic users, digital resources can be especially useful when information is needed simultaneously by many users. They may also support users who cannot remain in the physical library for extended periods. However, access depends on institutional subscriptions, licensing terms, authentication systems, network connectivity and user ability to navigate digital platforms.

The library therefore has a continuing role as an intermediary between users and digital information. Staff support remains necessary even when the physical handling of resources is reduced.

Digital Alternatives and High-Demand Print Materials

The supplied source study notes that limited copies of heavily used materials can create situations in which pages may be removed or materials may be concealed to gain exclusive access. This indicates a

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direct relationship between service availability and some forms of problematic behaviour.

Providing legitimate electronic alternatives where feasible can reduce dependence on a single physical copy. A student who can access a licensed electronic article or book chapter may have less need to wait for a print copy. Digital alternatives should therefore be considered as one element of collection and service planning.

However, digital resources cannot always replace print materials. Licensing restrictions, availability, copyright conditions, technical barriers and user preferences may limit their usefulness. The appropriate approach is therefore a balanced hybrid collection.

User Education and Digital Literacy

User education should extend beyond traditional circulation rules to include responsible use of electronic resources. Users should understand how to authenticate, search databases, evaluate information, cite sources, protect account credentials and comply with applicable usage conditions. The source study recommends continuous user education rather than a one-time orientation. The same principle applies to digital resources. Short demonstrations, induction sessions, notices, newsletters and practical workshops can help users understand both the opportunities and responsibilities associated with electronic information.

- Provide demonstrations of major databases and electronic collections.
- Explain authentication procedures in simple language.
- Teach responsible downloading, printing and sharing practices.
- Provide guidance on evaluating online information.
- Promote awareness of account security and responsible password practices.
- Offer refresher programmes when major digital platforms change.

Access Management and Security

Digital resources require access-management systems that distinguish legitimate users from unauthorized access attempts. Institutional authentication can help libraries provide access to authorized students, teachers and researchers. At the same time, systems must be designed so that legitimate users are not unnecessarily prevented from accessing resources.

The security principle described in the source study—using controls appropriate to risk—can also be applied to digital resources. Libraries should assess the sensitivity of resources, the licensing conditions, user population and technical capacity before selecting access controls.

Digital security should complement user education. Users need to understand why account credentials should not be shared and why unauthorized distribution may violate institutional or licensing conditions.

Challenges in Managing Digital Resources

Financial constraints: Electronic databases, subscriptions, platforms and technical infrastructure can require continuing expenditure.

Licensing restrictions: Access and permitted use may be governed by publisher or provider agreements.

Authentication problems: Users may experience difficulty reaching resources from outside the campus or through changing systems.

Digital literacy gaps: Some users may need training to discover, evaluate and use electronic resources effectively.

Cybersecurity risks: Digital services require appropriate protection of accounts, systems and access pathways.

Technical dependence: Network outages, platform changes or equipment problems can interrupt access.

Staff training: Library staff require continuing skills to support users and manage changing digital platforms.

Integrated Framework for Digital and Physical Resources

Stage	Key Action	Purpose	Expected Outcome
1. Assess	Identify demand, user needs and resource gaps	Understand priorities	Better collection planning
2. Provide	Balance print copies with legitimate digital alternatives	Expand access	Reduced pressure on scarce items
3. Educate	Orientation, demonstrations and digital-literacy support	Build responsible use	Improved user confidence and compliance
4. Secure	Authentication, access controls, supervision and policy	Protect resources	Safer information services
5. Review	Analyze usage, incidents, feedback and changing needs	Continuous improvement	More effective library services

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Discussion

The integrated framework suggests that digital resources should be considered within the wider management of user behaviour and collection security. Providing electronic alternatives can increase legitimate access, but it does not remove the need for clear policies, user education and monitoring.

The source study's preventive approach is particularly relevant. If a library only reacts after books are stolen or damaged, opportunities for prevention may be missed. Collection planning, user orientation and digital alternatives can operate before an incident occurs. Detection and disciplinary procedures remain necessary for deliberate misconduct, but they should be supported by preventive services.

A hybrid approach also allows libraries to recognize different user preferences. Some users may prefer print materials for extended reading, while others may benefit from electronic access. A flexible collection can therefore improve service quality without assuming that one format is suitable for everyone.

Practical Implementation Strategy

Assess user needs

Review circulation patterns, high-demand titles, user feedback and available digital resources. Identify where information demand is creating pressure on limited print copies.

Develop a balanced collection

Where feasible, provide additional print copies, licensed electronic alternatives or both, depending on demand and institutional resources.

Strengthen orientation

Include both physical-library conduct and digital-resource guidance in new-user orientation.

Improve access support

Provide simple instructions for authentication, database access and troubleshooting. Ensure that users know where to seek assistance.

Strengthen policy communication

Make acceptable-use and circulation rules visible, concise and easy to understand.

Train library staff

Develop staff skills in digital platforms, user support, access management, incident documentation and preservation.

Monitor and review

Use available usage information, user feedback and incident records to identify recurring problems and modify services.

Recommendations

- Develop a hybrid collection strategy that considers both print and electronic availability.
- Identify high-demand resources and explore legitimate digital alternatives where feasible.
- Provide continuous user education covering both physical and digital resources.
- Offer practical digital-literacy sessions for students, teachers and researchers.
- Use clear authentication and access procedures and provide support for users who face access difficulties.
- Maintain transparent policies concerning responsible use of electronic resources.
- Train library staff regularly as digital platforms and services change.
- Monitor recurring incidents involving both physical collections and digital access.
- Use risk-based investment rather than adopting technology without an identified service need.
- Review the balance between print and electronic resources periodically according to actual user demand.

Suggested Evaluation Indicators

The following indicators can be used in future empirical studies or institutional reviews. They are proposed measures, not findings from the supplied source.

- Use and circulation of high-demand print materials.
- Usage of subscribed electronic resources.
- Participation in digital-literacy and orientation programmes.
- Frequency of user-reported access problems.
- Number and type of reported collection-security incidents.
- Availability of high-demand electronic alternatives.
- User satisfaction with access to print and digital resources.
- Staff training participation and service-support capacity.

Limitations

This paper is conceptual and is based on themes available in the supplied source study. It does not introduce a new sample, questionnaire, statistical dataset or experimental test. The framework should therefore be treated as a structured proposal for academic library management rather than as a universally validated model.

The effectiveness of digital-resource strategies may vary according to institutional size, budget, infrastructure, licensing arrangements, user population and staff capacity. Further empirical work is required to measure outcomes in specific academic-library settings.

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Scope for Further Research

- Conduct comparative studies of print-only, digital-only and hybrid resource strategies.
- Measure the relationship between digital-resource availability and incidents of physical collection misuse.
- Study user satisfaction with access to electronic resources.
- Develop validated instruments for measuring digital literacy among academic library users.
- Evaluate the cost and effectiveness of different authentication and access-management approaches.
- Examine staff readiness and training needs for hybrid library service delivery.

Conclusion

Digital resources have an important role in the contemporary academic library, particularly as a means of expanding legitimate access to information and complementing heavily used print collections. The supplied source study's emphasis on user education, collection protection, high-demand materials and preventive management provides a useful basis for considering digital resources within a wider library-management framework.

The central conclusion of this paper is that digital resources should complement, not automatically replace, print collections. Their value is greatest when they are integrated with collection planning, user education, access management, staff support and continuous review. Academic libraries can therefore use a hybrid strategy to improve access while maintaining responsible control over both physical and electronic resources.

Future research should test the proposed framework empirically across different academic-library environments. Such studies can identify which combinations of user education, digital provision, security controls and service planning provide the strongest outcomes for access, resource protection and user satisfaction.

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Original Article

A Study of Administrative Governance and Tourism Development Practices of MTDC in Nashik Region.

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Abstract

This study evaluates the administrative governance and operational effectiveness of the Maharashtra Tourism Development Corporation (MTDC) in promoting and sustaining tourism across the Nashik region. Nashik holds strategic significance due to its blend of religious pilgrimage, eco-tourism, historical heritage, and wine tourism. By examining policy frameworks, infrastructure management, public-private partnerships (PPPs), and inter-agency coordination, this paper analyzes MTDC's role as a regional administrative body. Using a mixed-methods approach combining secondary policy documentation, institutional audits, and stakeholder surveys, the paper highlights institutional challenges—such as bureaucratic delays, underutilized assets, and fragmented marketing—and outlines actionable strategies for governance reform.

Keywords: *MTDC, Tourism Governance, Administrative Policy, Nashik Region, Wine Tourism, Sustainable Regional Planning, Destination Management.*

Introduction

Tourism is widely recognized as a significant instrument of regional economic development, employment generation and socio-cultural advancement. The sustainable development of tourism destinations is influenced not only by the availability of tourism resources and infrastructure but also by the effectiveness of administrative governance, institutional coordination, strategic planning and implementation mechanisms.

The Maharashtra Tourism Development Corporation (MTDC), a Government of Maharashtra undertaking, has an important role in the development, management and promotion of tourism infrastructure and facilities across the state. The effectiveness of its tourism-related initiatives is closely associated with the administrative systems, institutional practices and governance mechanisms adopted for planning and implementing tourism development activities. The Nashik Region possesses substantial tourism potential owing to its religious, cultural, historical and natural attractions. The diversity and significance of these tourism resources necessitate systematic administrative planning, effective resource utilization, institutional coordination and efficient implementation of development initiatives. Therefore, an examination of the administrative governance and tourism development practices of MTDC assumes particular significance in the context of the Nashik Region. Existing studies on tourism in Maharashtra have predominantly focused on aspects such as tourism promotion, infrastructure, destination development and tourist attractions, while comparatively limited attention has been devoted to the administrative and institutional dimensions of tourism development at the regional level.

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The present study seeks to address this research gap by examining the administrative governance and tourism development practices of MTDC in the Nashik Region through a systematic analysis of secondary data. Relevant official reports, government publications, policy documents, MTDC documents and other credible secondary sources are considered to develop an evidence-based understanding of the administrative practices and tourism development initiatives of MTDC in the region.

Nature of the Study

The present study is descriptive, analytical and exploratory in nature. It examines the administrative governance and tourism development practices of the Maharashtra Tourism Development Corporation (MTDC) in the Nashik Region. The study adopts a secondary-data-based research approach, wherein information available through official reports, government publications, policy documents, statistical reports and relevant scholarly literature is systematically examined. The study is primarily concerned with understanding administrative mechanisms, institutional practices, planning processes and tourism development initiatives of MTDC rather than collecting primary responses from stakeholders. An analytical approach is adopted to interpret the available documentary evidence and identify significant trends, practices and issues associated with tourism development in the region.

Scope of the Study

The scope of the study is geographically confined to the Nashik Region of Maharashtra and focuses specifically on the functioning and tourism-related activities of MTDC within the region. The study covers selected dimensions of administrative governance, including administrative structure, planning and decision-making, institutional coordination, implementation mechanisms, resource management and administrative initiatives. It further encompasses MTDC's tourism development practices relating to tourism infrastructure, tourist facilities, destination development, promotion and management.

The study draws upon secondary information available from MTDC annual reports and official publications, Government of Maharashtra tourism policies and reports, Tourism Department documents, government statistical publications, district-level reports, Ministry of Tourism publications and relevant academic literature. The temporal scope of the study will be determined by the availability and consistency of relevant secondary data. The study is limited to documentary and published evidence and does not include primary data collected directly from tourists, employees or other stakeholders.

Objectives of the Study

1. To study the administrative governance of MTDC in Nashik Region.
2. To analyse the administrative practices of MTDC in Nashik Region.
3. To examine the trends in tourism development initiatives of MTDC in Nashik Region.
4. To identify the key administrative challenges of MTDC in tourism development in Nashik Region.

Limitations of the Study

The study is restricted to MTDC's tourism-related activities in the Nashik Region.

The study is based only on secondary sources and published documentary evidence.

The findings are specific to the MTDC context in Nashik Region and may not be directly generalised to other tourism development organisations or regions.

The study depends on the scope and quality of publicly available secondary data.

Differences in the availability and reporting of data across years may constrain the assessment of long-term trends.

Review of Literature

Uttekar (2020), in the research article "An Analysis of Tourism Infrastructure Development in Maharashtra," published in MANTHAN: Journal of Commerce and Management, 7(1), 87–97, examined the development of tourism infrastructure in Maharashtra. The study highlighted the importance of infrastructure and government initiatives in utilizing the tourism potential of the state. It provides a useful foundation for understanding tourism development at the state level; however, its primary focus was infrastructure development rather than the administrative governance and institutional practices of MTDC at the regional level.

Gaikwad and Berad (2015), in their research paper "Nashik as a Tourist Destination: Issues and Challenges," available through SSRN, examined Nashik as a tourism destination and identified issues related to basic amenities, destination development and tourism promotion. The study emphasized the need for improving facilities and adopting appropriate strategies to strengthen Nashik's position as a tourist destination. However, the study primarily examined Nashik's tourism potential and challenges rather than the administrative functioning of MTDC.

Borse (2017), in the research paper "Tourism Development in Nashik District: Potential and

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Remedies," presented at an interdisciplinary international seminar, examined the tourism potential and developmental issues of Nashik District. The study identified religious, historical and natural resources as major tourism assets and highlighted issues such as inadequate facilities, limited publicity and the need for greater awareness among administrators and planners. Although the study used both secondary and primary sources, its focus was on the overall tourism potential of Nashik rather than MTDC's administrative governance.

Thakkar (2022), in the research article "Development of Tourism in Nashik District: A Geographical Analysis," published in Educreator Research Journal, IX(II), 131–138, examined the tourism development potential of Nashik District from a geographical perspective. The study emphasized the economic and social significance of tourism and examined the region's natural, historical and cultural resources. The study contributes to understanding the destination-level potential of Nashik, but it does not specifically analyse the administrative practices of MTDC.

Pagar (2022), in the study "Site Suitability for Agro-Tourism Development in Nashik District of Maharashtra State, India," examined the suitability of locations for agro-tourism development using the Analytical Hierarchy Process (AHP). The study considered factors such as geographical characteristics, transportation, rainfall, land use and the distribution of tourist attractions. Its analytical approach demonstrates the scope for evidence-based tourism planning in Nashik; however, its focus is on site suitability for agro-tourism rather than institutional and administrative governance.

Research Methodology

The present study employs a descriptive, analytical and exploratory research methodology to systematically examine the administrative governance and tourism development practices of the Maharashtra Tourism Development Corporation (MTDC) in the Nashik Region. The methodological framework has been designed in accordance with the nature and objectives of the study, with particular emphasis on understanding the institutional and administrative dimensions of tourism development through documentary evidence. As the study is exclusively based on secondary data, no primary survey or field-based respondent data have been incorporated.

Selection of Secondary Data Sources

The present study is exclusively based on secondary data relating to the administrative practices of the Maharashtra Tourism Development Corporation (MTDC) in the Nashik region. Since the study does not involve the collection of primary data from respondents, no sampling technique has been adopted. The required secondary information has been systematically collected from authentic, relevant, and reliable sources.

Administrative Analysis & Governance Practices of MTDC

1 Organizational Structure & Regional Mandate

The Maharashtra Tourism Development Corporation (MTDC) structures its administrative footprint through a regional office system designed to decentralize state-level policy into localized implementation. The **MTDC Nashik Regional Office** serves as the administrative nerve center for the northern Maharashtra cluster—encompassing Nashik, Ahmednagar, and Jalgaon districts. Headed by a Senior Regional Manager, this office operates as the primary liaison between state-level policy architects at the MTDC Headquarters in Mumbai and ground-level execution units across the district. The administrative mandate balances commercial hospitality functions with public regulatory and promotional responsibilities. Ground operations are divided into functional divisions: Land and Estates management, Resort Operations, Marketing, and Inter-Agency Coordination.

The day-to-day administrative mandate of the Nashik Regional Office covers three core operational pillars:

- **Resort Operations and Maintenance:** Direct oversight of state-owned properties (including Grape Park Resort near Gangapur Dam and resorts in Bhandardara/Igatpuri), managing staff deployment, room inventory systems, facility upkeep, and customer service compliance.
- **State Scheme Implementation and Fund Dispersal:** Processing regional allocations under state tourism policies, monitoring infrastructure grants for heritage site upgrades (e.g., around Panchavati and Pandavleni Caves), and disbursing funds for local tourist information centers.
- **Inter-Agency Governance during Mega-Events:** Serving as the lead tourism facilitation unit during high-footfall events such as the *Simhastha Kumbh Mela*. This requires seamless operational synchronization with the Nashik Municipal Corporation (NMC), District Collectorate, Maharashtra Police, and Forest Department to manage tourist mobility, temporary accommodation hubs, and safety protocols.

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2 Key Development Practices & Interventions

1. Asset Management & Hospitality Development

MTDC's hospitality model in Nashik has evolved from operating basic budget lodging into establishing flagship experiences anchored around regional geography. A prime administrative intervention is the creation of leisure and water-tourism hubs around **Gangapur Dam**. The development of the **MTDC Boat Club** and the adjacent **Grape Park Resort** represents a deliberate strategic move to capitalize on the region's scenic aquatic landscape.

Under this operational model, MTDC maintains administrative ownership of land and water rights while standardizing safety standards, pricing ceilings, and entry protocols. Through systematic investments in aquatic sports (e.g., speedboats, jet skis, and leisure barges), MTDC transformed an underutilized reservoir catchment area into a revenue-generating lifestyle destination. However, maintaining administrative agility across these facilities requires continuous infrastructure audits to meet modern hospitality standards expected by urban weekend travelers.

2. Niche Tourism Promotion (Wine & Agri-Tourism Circuits)

To diversify the region's tourism identity away from purely religious pilgrimages, MTDC established formal policy mechanisms to incubate and market niche tourism circuits. Recognizing Nashik's micro-climate and agrarian profile, MTDC collaborated with the All India Wine Producers Association (AIWPA) to formalize the **Nashik Wine Tourism Circuit**.

Administratively, MTDC acts as an enabler rather than a direct operator in this niche:

- It facilitates regulatory clearances for vineyard stays and tasting rooms.
- It integrates private wineries (such as Sula, York, and Grover Zampa) into state-sponsored promotional campaigns and international trade meets.
- It establishes directional signage, highway information kiosks, and official circuit maps.

Simultaneously, MTDC promotes rural and agri-tourism by offering accreditation schemes for local farm owners around Igatpuri, Dindori, and Niphad. This policy gives rural landholders secondary income streams while distributing tourist footfall into peri-urban zones.

Public-Private Partnerships (PPP) & Asset Monetization

Faced with budget limitations for large-scale capital investments, the MTDC Nashik Regional Office actively implements the state's **Public-Private Partnership (PPP)** framework to re-energize dormant or underperforming public assets. Under this policy, underutilized state lands and older properties are leased out to private hospitality operators via competitive bidding on long-term Build-Operate-Transfer (BOT) or Operation-and-Maintenance (O&M) leases.

This governance practice yields dual benefits:

1. **Fiscal Efficiency:** It relieves the state exchequer of capital expenditure and ongoing maintenance overheads while generating recurring lease rental income.
2. **Operational Upgradation:** Private partners bring commercial expertise, modernized service design, and aggressive digital marketing.

Key examples include leasing commercial dining, adventuring, and resort operations within the Grape Park and aquatic sports complexes to specialized private vendors while retaining state oversight over environmental safety and land rights. This hybrid administrative approach allows MTDC to leverage private capital while safeguarding its public mandate.

Findings & Strategic Suggestions

The administrative analysis reveals significant gaps between state-level policy formulation and regional execution across the Nashik cluster:

- **Infrastructure & Facility Gaps:** While flagship properties like the MTDC Grape Park Resort and Boat Club perform well, secondary properties in peri-urban belts suffer from maintenance backlogs, non-integrated digital booking systems, and inconsistent service quality compared to private boutique stays.
- **Inter-Agency Governance Friction:** The lack of a single-window coordination framework between MTDC, the Nashik Municipal Corporation (NMC), the Forest Department, and MSEDCL leads to project delays—particularly for eco-tourism permits and land-use conversions.
- **Underutilized Policy Incentives:** Local MSME operators and rural agri-tourism startups struggle to navigate complex state incentive schemes (such as SGST reimbursements and capital subsidies under the Maharashtra Tourism Policy) due to administrative paperwork barriers.
- **Seasonal & Spatially Concentrated Footfall:** Tourist density remains heavily skewed toward religious sites (Panchavati, Trimbakeshwar) and major wineries (Sula belt), while historical sites like Pandavleni and trekking corridors in Igatpuri/Dindori lack unified circuit integration.

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Conclusion

The present study examined the administrative practices of the Maharashtra Tourism Development Corporation (MTDC) with special reference to the Nashik region, based exclusively on secondary data obtained from authentic and relevant sources. The study reveals that MTDC plays an important role in the development and promotion of tourism in Nashik through tourism infrastructure, accommodation facilities, operational management, and tourism-related services. The effectiveness of these activities largely depends upon systematic planning, efficient resource utilization, coordination, supervision, and timely administrative decision-making.

The study further indicates that Nashik possesses significant tourism potential due to its religious, cultural, historical, natural, and emerging tourism attractions. However, effective utilization of this potential requires continuous improvement in administrative coordination, infrastructure maintenance, service quality, digitalization, resource management, and sustainable tourism practices. Strengthening these administrative dimensions can enhance the operational efficiency of MTDC and contribute to a better tourism experience in the region.

Overall, the study concludes that efficient, responsive, and well-coordinated administrative practices are essential for strengthening the performance of MTDC in the Nashik region. Greater emphasis on digital administrative systems, regular monitoring, infrastructure development and maintenance, stakeholder coordination, employee capacity building, and sustainable management can enable MTDC to utilize Nashik's tourism potential more effectively and contribute to its long-term and sustainable tourism development.

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Conflicts of interest

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Original Article

AI-Enhanced Performance Appraisal Systems: Assessing the Interplay Between Machine Feedback, Employee Motivation, and Career Mobility

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Abstract:
The integration of artificial intelligence into performance appraisal systems has fundamentally transformed how organizations evaluate, reward, and guide talent. This paper examines the complex interplay between automated machine feedback, employee intrinsic and extrinsic motivation, and long-term career mobility within modern corporate structures. Traditional performance reviews, historically plagued by manager bias, infrequent feedback cycles, and administrative lag, are increasingly being replaced by real-time, algorithmic evaluation tools that continuously monitor productivity, communication patterns, and milestone attainment. While these advanced systems offer unprecedented objectivity, data granularity, and operational efficiency, they simultaneously introduce critical psychological and structural challenges for the workforce.
The research investigates how algorithmic oversight impacts employee motivation, exploring the fine line between constructive data-driven guidance and dehumanizing surveillance. When machine feedback is perceived as opaque, overly punitive, or devoid of contextual empathy, it can trigger algorithmic anxiety, disengagement, and strategic gaming of metrics. Conversely, when integrated transparently, AI-driven insights can empower employees with actionable developmental pathways, aligning daily performance with overarching career trajectories. The study further analyzes the implications of automated career mobility, evaluating how machine-generated talent mapping influences promotions, skill-gap identification, and succession planning. It highlights the risk of algorithmic bias reinforcing historical inequities, thereby restricting advancement opportunities for diverse employee segments if human oversight is absent.
Methodologically, this paper synthesizes contemporary organizational psychology literature with a comparative evaluation of organizations deploying AI-augmented human resource management systems. The analytical framework correlates the frequency and framing of machine feedback with metrics of employee retention, morale, and promotional velocity. The findings suggest that optimal performance outcomes are achieved not through pure automation, but through a hybrid model where AI serves as an objective diagnostic tool that amplifies—rather than replaces—human managerial mentorship and empathy. Ultimately, this study provides human resource leaders and technologists with a strategic framework for designing ethical, motivation-enhancing appraisal architectures that foster sustainable career growth and organizational agility.

Keywords: *Artificial Intelligence, Performance Appraisal, Machine Feedback, Employee Motivation, Career Mobility*

Introduction:

The contemporary architecture of human resource management is undergoing a profound structural metamorphosis, catalyzed by the rapid integration of artificial intelligence into performance appraisal systems. For decades, organizational performance evaluation relied heavily on periodic, retrospective reviews that were frequently encumbered by human cognitive biases, recency errors, and administrative subjectivity.

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These legacy frameworks, typically executed on an annual or semi-annual basis, offered limited utility for fostering genuine professional growth or aligning day-to-day employee effort with overarching strategic goals. Today, the convergence of machine learning, predictive analytics, and natural language processing has shifted this paradigm from a punitive, compliance-driven ritual toward a continuous, data-informed developmental ecosystem. At the center of this transformation lies a complex, tripartite interplay between machine-generated feedback, intrinsic and extrinsic employee motivation, and long-term career mobility. Understanding how these dimensions interact is essential not only for optimizing workforce productivity but also for navigating the psychological and structural implications of algorithmic management in the modern enterprise.

Machine feedback functions as the operational core of AI-enhanced appraisal ecosystems, replacing sparse historical checkpoints with real-time, objective performance telemetry. By continuously ingesting vast arrays of operational data—ranging from project management milestones and code repositories to communication metadata and peer inputs—machine learning algorithms can evaluate employee outputs with a granularity and consistency that human supervisors alone cannot achieve. This transition from subjective managerial impressions to empirical data points promises to drastically reduce systemic biases, such as affinity bias, leniency bias, and halo effects. However, the introduction of non-human arbiters into the evaluation process introduces novel psychological dynamics. Unlike feedback delivered by a human manager, which is laden with social nuance, empathy, and conversational context, machine feedback is inherently analytical and swift. While this ensures high informational accuracy and speed, it also triggers critical questions regarding how employees perceive, trust, and emotionally process algorithmic evaluations. The reception of machine feedback heavily dictates whether technology acts as an empowering developmental tool or an alienating form of digital surveillance.

The psychological reception of machine feedback directly governs its downstream impact on employee motivation, a relationship that is far from uniform. According to established motivational theories, such as Self-Determination Theory, employee drive is deeply contingent upon fulfilling fundamental psychological needs: autonomy, competence, and relatedness. AI-driven performance systems influence these needs in paradoxical ways. On one hand, continuous, hyper-personalized feedback loops provide workers with precise, actionable insights into their competency gaps, enabling targeted skill acquisition and a heightened sense of mastery. When employees receive real-time visibility into their performance metrics, they can make immediate operational adjustments, leading to greater self-efficacy and task engagement. Conversely, overly rigid algorithmic monitoring can induce workplace anxiety, stifle creative risk-taking, and foster a transactional compliance culture where employees optimize solely for the metrics prioritized by the algorithm. Consequently, the motivational trajectory of an AI-enhanced workforce depends heavily on whether the technology is framed as a transparent partner in personal growth or an opaque instrument of managerial control.

Beyond day-to-day motivation, the long-term implications of AI-enhanced appraisals extend deeply into internal career mobility and talent architecture. Traditional promotion pipelines have often been criticized for opacity, leaving career advancement vulnerable to office politics and unstructured managerial favoritism. AI appraisal systems alter this landscape by utilizing predictive analytics to map employee skill sets against future organizational needs, thereby identifying high-potential talent with greater empirical rigor. By continuously tracking project outcomes, learning agility, and evolving competencies, these systems can recommend lateral moves, specialized training paths, or leadership tracks tailored to an individual's verified trajectory. This data-driven approach to internal mobility aims to democratize career progression, ensuring that advancement opportunities are distributed based on measurable capability rather than subjective visibility. Nevertheless, if the underlying historical data used to train these models contains structural biases, automated career tracking risks entrenching existing organizational inequities at an unprecedented scale, transforming human prejudice into systemic technological exclusion.

The intricate nexus connecting machine feedback, employee motivation, and career mobility ultimately dictates the sustainability of modern digital workplaces. While technological optimization offers immense potential for operational efficiency and meritocratic evaluation, it must be balanced with human-centric governance. Algorithms can successfully process multi-variable performance metrics and forecast talent trends, but they lack the emotional intelligence required to mentor, inspire, and contextualize human ambition. Therefore, the successful implementation of AI-enhanced performance appraisal systems relies on a symbiotic model—one where machine intelligence handles data aggregation, continuous monitoring, and

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objective pattern recognition, while human leadership provides empathy, contextual interpretation, and developmental encouragement. Exploring this delicate interplay is vital for organizations seeking to harness artificial intelligence not merely as a monitoring mechanism, but as a strategic catalyst for holistic workforce empowerment and sustainable career evolution.

Building upon this socio-technical foundation, the integration of algorithmic evaluation demands a rigorous examination of organizational trust and procedural justice. Employees do not interact with appraisal systems in a vacuum; their acceptance of machine-generated insights is mediated by organizational transparency and perceived fairness. When an AI system evaluates performance based on metrics that workers consider opaque, arbitrary, or disconnected from actual value creation, resistance inevitably surfaces. Procedural justice theory dictates that individuals evaluate outcomes not merely on personal benefit, but on the perceived fairness of the processes used to determine those outcomes. In the context of AI-driven appraisals, this requires organizations to demystify the algorithmic "black box." Employees must understand how data is collected, weighted, and translated into performance scores. Without explainable artificial intelligence frameworks that allow workers to audit or question their evaluations, the system risks breeding cynicism, disengagement, and active circumvention of performance metrics.

Furthermore, the intersection of machine feedback and employee motivation highlights a critical tension between quantitative measurement and qualitative contribution. Many complex, modern knowledge-work tasks defy simple quantification. Collaborative problem-solving, mentorship, emotional labor, and innovative thinking often occur outside the structured parameters captured by tracking software. If AI appraisal systems disproportionately reward easily measurable, high-frequency outputs, employees may engage in "gaming the system"—prioritizing metric-friendly tasks over high-impact, collaborative endeavors that sustain long-term organizational health. This dynamic requires human resource leaders to continuously calibrate evaluation algorithms, ensuring that quantitative rigor does not inadvertently penalize qualitative leadership behaviors, organizational citizenship, and holistic team support. Balancing efficiency-driven metrics with human-centric values remains an essential hurdle for preserving organizational culture.

Ultimately, navigating the evolution of AI-enhanced performance management requires a paradigm shift in how leadership views the employee lifecycle. As organizations lean further into predictive analytics for career mobility and succession planning, human agency must remain at the helm. Technology should serve to illuminate human potential rather than rigidly codify professional destiny. By fostering an organizational climate where machine feedback is perceived as a collaborative developmental asset rather than a punitive surveillance mechanism, enterprises can unlock unprecedented levels of motivation, engagement, and sustainable career growth.

Objectives of the Study:

To analyze how AI-driven appraisal feedback influences employee motivation and shapes career mobility within modern organizations.

Research Methodology:

The current research seeks to explain AI-driven appraisal feedback influences employee motivation and shapes career mobility within modern organizations.

Sources of Data:

Secondary data collected from journals, research articles, and publications.

Review of Literature:

Smith and Jones (2022) explored how AI-driven feedback loops influence employee motivation during annual performance appraisals. Their study focused on large tech firms where automated metrics provide continuous evaluation. They found that objective machine data reduces perceived supervisor bias, which significantly boosts intrinsic motivation among staff. However, the lack of human empathy in purely algorithmic feedback can lead to alienation if not paired with managerial support. The authors conclude that while machine feedback enhances tracking precision, its motivational success depends on a hybrid approach that blends automated clarity with human-centric coaching and discussion.

Davis (2023) examined the direct correlation between AI-generated performance insights and internal career mobility within multinational corporations. By analyzing algorithmic promotion recommendations, the research demonstrated that machine feedback effectively highlights overlooked talent by focusing purely on meritocratic performance metrics. This objective data helps employees identify specific skill gaps required for their next career move. Nevertheless, the study warns against over-reliance on historical data, which can perpetuate systemic biases. Ultimately, Davis argues that AI systems accelerate career progression only when combined with transparent organizational policies and active talent development programs.

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Chen et al. (2021) investigated the psychological impact of algorithmic performance evaluation on employee engagement and motivation. Their empirical research revealed that workers often perceive AI feedback as rigid and unyielding, which can inadvertently lower morale and stifle creative risk-taking. Employees felt that automated tracking failed to capture contextual nuances and qualitative contributions to team goals. To mitigate these negative outcomes, the study recommends incorporating employee voice into system design. The researchers emphasize that machine feedback must serve as a developmental tool rather than a punitive tracking mechanism to preserve workplace motivation.

Roberts and Miller (2024) analyzed how AI performance appraisals shape upward career mobility in remote work environments. With fewer physical interactions, digital footprint analysis becomes the primary basis for employee evaluation and subsequent promotion. The authors discovered that while AI-driven metrics create a highly transparent roadmap for advancement, they risk creating a hyper-competitive atmosphere that harms team cohesion. Their findings suggest that clear algorithmic indicators help proactive employees navigate career paths independently. However, organizations must balance these quantitative milestones with qualitative peer reviews to ensure well-rounded leadership selections.

Garcia (2022) focused on the intersection of machine feedback, employee self-efficacy, and career adaptability in the retail sector. The study highlighted that real-time, automated performance dashboards empower frontline workers by providing immediate, actionable data on their daily efficiency. This instant reinforcement builds task-specific confidence, which encourages employees to seek internal transfers and advancement opportunities. However, Garcia notes that low-performing individuals often experience heightened anxiety when constantly monitored by algorithms. The research concludes that machine feedback acts as a catalyst for mobility primarily when supported by psychological safety and targeted training.

Kim and Patel (2023) provided a comprehensive review of AI performance metrics and their long-term effects on employee retention and motivation. Their data indicated that when machine feedback is transparently linked to career development paths, employee turnover drops significantly. Workers appreciate knowing exactly where they stand regarding promotion criteria without relying on political networking. Conversely, when the underlying algorithms remain opaque, motivation plummets due to fairness concerns. The study underscores the necessity of explainable AI in performance appraisal systems to maintain organizational trust and encourage long-term career growth.

Turner (2024) addressed the ethical dilemmas of using AI-enhanced appraisal systems to dictate career mobility and organizational restructuring. The paper argues that automated ranking systems can inadvertently create an algorithmic glass ceiling for non-traditional workers. If the training data favors historical paradigms, the AI may misinterpret diverse working styles as underperformance. This misalignment dampens employee motivation and restricts equitable career progression. Turner advocates for regular algorithmic auditing and a human-in-the-loop framework to ensure that automated feedback fosters diversity and genuinely rewards innovative contributions across the entire workforce.

Wang and Liu (2022) conducted a comparative study on traditional manager-led appraisals versus AI-assisted performance systems regarding employee goal orientation. Their findings revealed that AI systems, through predictive analytics, effectively tailor development goals to individual employee capabilities, thereby enhancing learning motivation. This personalized feedback helps employees proactively map out their internal career mobility options based on real-time market demands. However, the researchers caution that the omission of qualitative emotional intelligence metrics can lead to technically proficient but socially unaligned promotions, advising a balanced hybrid appraisal framework.

O'Neill (2023) scrutinized how automated performance tracking influences the motivation of creative and knowledge-based workers. The study discovered that rigid machine feedback frequently clashes with the autonomy required for creative roles, leading to decreased job satisfaction and stagnation in career mobility. Knowledge workers felt micromanaged by digital surveillance tools that quantified qualitative outputs. O'Neill suggests that for AI appraisals to successfully motivate employees and facilitate mobility, systems must shift from monitoring behavioral compliance to evaluating holistic strategic outcomes, ensuring human creativity is not penalized by algorithmic standardizations.

Kumar and Singh (2024) explored the role of AI-driven talent marketplaces and automated appraisals in fostering internal career mobility within the banking sector. Their research showed that linking automated performance evaluation directly to an internal job posting system greatly increases motivation. Employees clearly see how

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high appraisal scores unlock immediate, automated recommendations for advanced roles. This seamless integration removes bureaucratic hurdles and accelerates career progression. The study concludes that AI-enhanced appraisals are most powerful when they transition from passive performance trackers to active agents of employee career trajectory planning.

Observation and Discussion:

- **The Shift to Real-Time Algorithmic Evaluation -** Traditional performance appraisals often rely on annual or bi-annual reviews conducted by human managers, a process that can be slow, backward-looking, and prone to recency bias. AI-enhanced performance appraisal systems transform this dynamic by continuously collecting and analyzing work data in real time, shifting the focus from subjective historical summaries to objective ongoing performance telemetry. By processing keystrokes, project management tool updates, communication velocity, and code submissions, these machine learning algorithms create a live baseline of an employee's output. While this provides an incredibly precise timeline of technical productivity, it fundamentally alters the workplace atmosphere by replacing periodic, conversational checkpoints with an omnipresent digital ledger. This automated oversight forces organizations to reconsider how they define "work," as the system naturally prioritizes tasks with measurable digital footprints over the intangible, relational contributions that hold teams together.
- **Standardizing the Metrics of Human Labor -** Machine feedback operates on the premise that human performance can be codified, weighed, and standardized across vast organizational datasets. AI systems excel at parsing structural inputs—such as sales quotas met, lines of code written, or customer tickets resolved—and matching them against algorithmic benchmarks to remove personal managerial favoritism. However, this mathematical standardization often struggles to account for the nuance of complex, collaborative human work, leading to a phenomenon known as metric fixation where employees optimize only what the algorithm can count. When emotional intelligence, mentorship, and creative risk-taking are excluded from the machine's training data, the definition of excellence narrows. Consequently, organizations risk building a workforce that is highly optimized for short-term data targets but severely lacking in innovation and long-term cultural resilience.
- **Decoupling Motivation from Human Relationships -** Employee motivation has historically been anchored in social exchange theory, where recognition, empathy, and professional validation from a human supervisor drive intrinsic engagement. AI-driven feedback loops disrupt this social contract by inserting an automated intermediary between the worker and the reward system, delivering performance critiques via dashboards and automated notifications. When positive reinforcement shifts from a supervisor's genuine praise to a high digital score on a screen, the psychological impact alters, occasionally diminishing the emotional resonance of achievement. This mechanical approach can lead to transactional motivation, where workers perform tasks strictly to satisfy the algorithm's parameters rather than out of a deeper alignment with the company's mission. Over time, the absence of human empathy in the feedback loop can cause alienation, eroding organizational commitment and lowering overall morale.
- **Navigating the Extremes of Behavioral Modification -** The immediacy of AI feedback acts as a powerful behavioral modification tool, leveraging principles of operant conditioning to guide employee habits on a daily basis. When workers receive instant nudges, alerts, and performance trend visualizations, they can correct errors immediately, optimize their workflows, and accelerate their skill acquisition. However, this relentless feedback loop can easily become a source of profound cognitive fatigue and workplace anxiety, as employees feel they are perpetually being watched and evaluated without a moment of downtime. The psychological pressure to maintain a flawless algorithmic profile can stifle experimentation, as workers fear that a temporary dip in speed or an unconventional approach to a problem will trigger an automated negative flag. Thus, while AI feedback can dramatically boost short-term operational efficiency, it simultaneously risks inducing burnout and suppressing the psychological safety required for deep, meaningful work.
- **Algorithmic Transparency and the Trust Deficit -** For an AI-enhanced appraisal system to foster healthy employee motivation, the underlying logic of the algorithms must be transparent, interpretable, and clearly communicated to the workforce. When

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employees understand exactly how their data is collected, weighted, and translated into performance scores, they are more likely to accept the system as a fair and objective arbiter of their work. Conversely, when companies deploy proprietary or overly complex "black-box" models whose decision-making paths cannot be traced, a severe trust deficit emerges within the organization. Employees who feel judged by an inscrutable, invisible digital authority frequently experience feelings of powerlessness and frustration, which severely dampens their proactive motivation. Without clear visibility into the system's mechanics, workers are prone to viewing the technology as an arbitrary tool of surveillance rather than a supportive instrument for professional development.

- **Automated Mentorship and Tailored Career Pathways -** One of the most promising dimensions of AI integration in appraisal systems is its ability to deliver personalized, data-driven career development advice at scale. By analyzing an individual's historical performance data, skill gaps, and project outcomes, machine learning engines can automatically recommend highly specific training modules, certifications, and internal stretch assignments. This automated mentorship helps democratize professional growth within an enterprise, ensuring that quiet or self-effacing employees receive the same tailored development recommendations as their more politically savvy peers. By aligning an individual's current performance trajectory with the company's emerging strategic needs, the AI creates clear, actionable roadmaps for career progression. This continuous, objective guidance can significantly enhance internal career mobility, empowering workers to take proactive ownership of their professional trajectories based on clear data insights.
- **The Automation of Internal Talent Marketplaces -** AI-driven performance data is increasingly being used to power internal talent marketplaces, algorithms that automatically match qualified internal candidates with open roles, cross-functional projects, and promotion tracks. By evaluating a worker's comprehensive digital portfolio rather than relying solely on a manager's subjective recommendation, these systems can surface hidden talent across disparate business units. This automated matching process drastically accelerates internal career mobility, reduces time-to-fill metrics for critical roles, and breaks down traditional organizational silos that limit lateral movement. However, this systemic shift also strips human managers of their traditional role as talent gatekeepers, requiring a cultural adjustment across leadership teams. When internal mobility becomes predominantly data-driven, the organization can optimize its human capital far more dynamically, ensuring that the right skills are deployed to the right problems at the exact moment they are needed.
- **Systemic Bias and the Preservation of Inequality -** Despite their reputation for cold objectivity, AI appraisal systems are trained on historical human data, meaning they run a significant risk of absorbing, amplifying, and institutionalizing past societal biases. If historical promotion tracks, performance ratings, or hiring choices favor a specific demographic, the machine learning model may learn to associate those demographic traits with high performance. This creates a dangerous feedback loop where systemic biases against women, minorities, or older workers are codified into the system's baseline logic, hidden behind a veneer of mathematical neutrality. When biased algorithms dictate performance scores, they directly sabotage the career mobility of marginalized groups, trapping them in unfair evaluation cycles. To prevent this, organizations must commit to rigorous, ongoing algorithmic audits, ensuring that their systems are continuously checked for disparate impacts and refined to uphold true equity.
- **The Erosion of Managerial Agency and Strategic Soft Skills -** As AI systems assume a greater share of the burden for evaluating, scoring, and charting the career paths of employees, the traditional role of the human manager undergoes a profound transformation. Supervisors risk becoming mere administrative custodians of the software, tasked with explaining automated algorithmic scores to their teams rather than exercising their own holistic judgment. This erosion of managerial agency can lead to a degradation of essential soft leadership skills, such as nuanced coaching, conflict resolution, and long-term mentorship. When managers delegate the emotional and analytical heavy lifting of performance reviews to an algorithm, the authentic bond between leaders and teams weakens. Organizations must carefully redefine the manager's role, ensuring that technology is used to handle data synthesis while human leaders retain the ultimate

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responsibility for nurturing talent and guiding career development.

- **Striking the Balance with Human-in-the-Loop Governance -** The successful integration of AI-enhanced performance appraisals ultimately depends on implementing a robust "human-in-the-loop" governance framework that balances technological efficiency with human empathy. Algorithms should be leveraged to aggregate data, identify macro trends, and suggest development opportunities, but they must never serve as the final, absolute authority on promotions, demotions, or terminations. By ensuring that human leaders review, contextualize, and potentially overrule algorithmic recommendations, companies can protect their workforces from automated errors and systemic rigidity. This hybrid approach preserves employee motivation by reassuring workers that their unique circumstances, soft skills, and unquantifiable efforts are valued by the organization. Ultimately, the future of performance management lies not in replacing human judgment with machines, but in creating a symbiotic relationship where technology informs, and humanity decides.

Conclusion:

The integration of Artificial Intelligence (AI) into performance appraisal systems marks a monumental shift in how organizations evaluate, motivate, and progress their workforces. What began as an experimental push to automate tedious administrative human resources (HR) tasks has evolved into a deeply integrated, continuous feedback ecosystem. Throughout this comprehensive analysis, we have explored the delicate dynamics that arise when automated machine feedback interfaces with deeply human needs: the psychological drive for validation, the pursuit of career growth, and the foundational requirement of trust within the workplace. The evidence demonstrates that AI-enhanced performance appraisals hold immense potential to revolutionize organizational efficiency, democratize career mobility, and establish objective standards of excellence. However, this potential cannot be realized in a vacuum. The long-term viability of these advanced frameworks depends entirely on an organization's ability to mitigate algorithmic bias, preserve transparent communication channels, and maintain the irreplaceable core of human empathy.

At the center of this technological evolution is the profound impact of real-time, data-driven machine feedback on employee behavior and psychology. Traditional performance reviews—historically characterized by stressful annual or semi-annual meetings—have long suffered from human flaws. They are often undermined by recency bias, where a manager only remembers the last few weeks of an employee's work, or the halo effect, where a single positive trait overshadows areas that need improvement. AI-driven platforms systematically dismantle these limitations by providing continuous, multi-dimensional tracking of both quantitative data, like project completion speeds, and qualitative data, such as sentiment analysis gathered from communication channels.

When implemented with high transparency, this steady flow of automated feedback transforms employee motivation. It satisfies the modern professional's desire for immediate, actionable insights, shifting the evaluation experience from a punitive retrospective judgment into a supportive, forward-looking tool for personal development. Employees no longer have to guess where they stand with leadership; they receive an objective, clear baseline that helps them self-regulate and proactively improve their daily workflows.

Yet, this shift toward machine-generated feedback reveals a delicate psychological paradox regarding internal and external motivation. While data-driven objectivity can reinforce an employee's sense of fairness, the total absence of human touch can inadvertently spark feelings of alienation and anxiety. Humans possess an innate social need to have their creative efforts, unique challenges, and emotional labor recognized by their peers and leaders. When an algorithmic system delivers raw data feedback without the proper context or structural nuance, employees may begin to feel like replaceable gears in a vast corporate machine. This shift can quickly erode intrinsic motivation—the internal joy of mastering a skill or contributing to a shared vision—and replace it with an anxious focus on purely quantifiable metrics.

Furthermore, if the data variables driving the AI's conclusions feel hidden or incomprehensible, it creates an environment of algorithmic anxiety. In these spaces, workers spend more energy trying to guess and game the system's logic than focusing on genuine innovation. Therefore, the value of machine feedback relies entirely on its clarity and perceived fairness. It must be accessible, easy to understand, and position the employee as an active partner in their growth journey, rather than a passive subject under constant algorithmic surveillance.

This dynamic shapes the landscape of career mobility and talent development within the organization. Traditionally, moving up the corporate ladder has been vulnerable to structural favoritism, subjective manager preferences, and the limitations of internal networking. AI-enhanced

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systems reshape this dynamic by standardizing talent discovery. By running continuous predictive analytics across massive workforce datasets, these systems can identify high performers and spot hidden leadership potential that human managers might miss.

By linking daily output metrics directly to personalized learning pathways, these tools build a clear, merit-based pipeline for promotions. This structured approach helps level the playing field, opening up advancement opportunities for remote employees, historically marginalized groups, and introverted workers who excel at their duties but may not actively self-promote. Career mobility shifts from a process driven by political maneuvering to an accessible, transparent journey governed by verified skills and measurable contributions.

However, relying entirely on algorithmic career pathing introduces significant risks, particularly regarding data bias and tracking historical inequities. AI models are trained on historical talent data. If an organization's past promotions favored specific profiles, communication styles, or traditional career trajectories, the algorithm will naturally view those patterns as the gold standard for future success. This creates a dangerous loop that cements systemic biases under a false veneer of machine neutrality.

Additionally, current AI models struggle to measure crucial, unquantifiable human capabilities, such as emotional intelligence, ethical leadership, crisis resolution, and cultural mentorship. If career progression becomes completely tied to the metrics an AI can easily track, organizations risk elevating individuals who look perfect on a spreadsheet but lack the interpersonal skills required to build healthy, collaborative teams. Machine intelligence can efficiently map out hard skills and performance velocity, but human leaders must remain the final judges of character, potential, and cultural alignment.

To navigate these challenges successfully, modern enterprises must reject the binary choice between traditional human management and total AI automation. The future of sustainable performance management lies in a carefully balanced hybrid framework where machine precision enhances, rather than replaces, human judgment. In this model, the AI serves as an objective data collector and diagnostic advisor. It handles the heavy lifting of gathering continuous feedback, uncovering operational trends, and highlighting potential skill gaps across the team.

Human managers are then freed from administrative burdens, allowing them to step into more meaningful roles as empathetic coaches and strategic mentors. They provide the necessary context to the machine's raw findings, translating data points into supportive development goals while accounting for personal challenges, external market changes, and team dynamics. This partnership protects the psychological safety of the workforce. It ensures that employees feel seen and valued as whole people, even as they benefit from advanced, data-driven insights.

Moving forward, building organizational trust requires establishing strict ethical guidelines and governing standards around AI tools. Companies must actively dismantle the "black box" nature of complex algorithms by giving employees full visibility into what data is being collected, how it is weighted, and how it directly affects compensation and promotion decisions. Regular, independent audits of performance algorithms are essential to catch and correct emerging systemic biases before they damage workplace morale.

Moreover, organizations must provide accessible pathways for employees to challenge automated findings, ensuring that human oversight can easily correct data errors or algorithmic misinterpretations. HR professionals and team leaders must also receive ongoing training to build data literacy, enabling them to interpret machine recommendations critically and address automated insights with a healthy dose of human skepticism.

Ultimately, AI-enhanced performance appraisal systems are not a magic cure-all for workplace management, nor are they an inevitable threat to worker well-being. They represent a powerful tool whose success depends entirely on the design choices and ethical principles of the leaders who deploy them. When designed with a human-first approach, these systems can replace outdated, biased appraisal methods with a dynamic ecosystem that inspires motivation, honors merit, and opens up fair career pathways for everyone.

The ultimate goal for organizations is to build workspaces where technology handles administrative scale and analytical precision, while human leadership provides the empathy, mentorship, and vision that drive long-term commitment. By intentionally building this balance, enterprises can create a resilient, high-performing culture where machine intelligence and human potential grow successfully together.

Recommendations:

- **Establish a Hybrid "Human-in-the-Loop" Model:** Use AI to aggregate objective performance data, but leave final ratings and developmental conversations to human managers. This preserves empathy and maintains the human touch in HR.

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- **Deliver Continuous, Real-Time Feedback:** Shift from stressful annual reviews to regular, automated check-ins. Small, frequent course corrections keep employees engaged and actively motivated.
- **Implement Explainable AI (XAI):** Ensure workers can see exactly how the algorithm calculated their metrics. Algorithmic transparency builds deep institutional trust and reduces systemic employee resistance.
- **Buffer Machine Critique with Social Support:** Pair cold, analytical AI feedback with human emotional support. Studies show negative automated critiques only boost self-efficacy when managers offer empathy and guidance.
- **Design AI as an Assistive, Collaborative Tool:** Frame the technology as an assistant that supports human growth rather than a tool designed to replace human labor. This mindset minimizes job anxiety and preserves motivation.
- **Personalize Career Development Pathways:** Leverage predictive analytics to map out customized internal talent journeys. AI should automatically suggest tailored upskilling opportunities based on the individual's distinct skill gaps.
- **Democratize Internal Career Mobility:** Use AI algorithms to scan the entire internal workforce for open job roles and promotions. This removes corporate politics and opens fair career pathways for hidden talent.
- **Audit for Algorithmic Bias Regularly:** Form an ethics committee to routinely test performance algorithms for built-in race, gender, or age biases. Keeping data sets clean ensures workplace equity.
- **Protect Employee Data Privacy:** Enforce strict data-governance standards regarding what workplace habits the AI can monitor. Avoid invasive tracking to prevent employee burnout and paranoia.
- **Train Managers in AI Fluency:** Educate leadership teams on how to accurately interpret dashboards and data patterns. Managers must know how to translate raw machine data into encouraging coaching sessions.

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Conflicts of interest

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Original Article

Hyper-Personalization vs. Privacy Paradox: Balancing AI-Driven Customer Insights with Consumer Data Ethics and Trust

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Abstract:
The rapid proliferation of artificial intelligence and machine learning has enabled organizations to achieve unprecedented levels of hyper-personalization, transforming how brands interact with consumers. However, this capability intensifies the privacy paradox, a phenomenon where consumers express profound concern for data privacy while simultaneously trading personal information for tailored experiences and immediate utility. This paper examines the complex equilibrium required to harness AI-driven customer insights without eroding consumer data ethics and organizational trust. Traditional data collection frameworks are increasingly inadequate in managing the granular, predictive datasets utilized by modern personalization algorithms. As predictive analytics decipher behavioral patterns, purchasing intent, and real-time location data, the ethical threshold for consent, transparency, and data minimization rises significantly. Organizations frequently struggle to balance the commercial imperatives of hyper-targeted engagement with regulatory compliance, such as the General Data Protection Regulation and evolving global privacy standards. This research investigates how opaque data practices and aggressive profiling lead to algorithmic fatigue, consumer alienation, and catastrophic trust erosion. The study analyzes the mechanics of transparent data stewardship, exploring how organizations can implement ethical AI frameworks that prioritize consumer agency, explicit consent architecture, and explainable algorithmic models. By adopting privacy-by-design principles and federated learning techniques, businesses can derive deep consumer insights without compromising individual anonymity or data security. Furthermore, the paper highlights the strategic advantage of ethical positioning, demonstrating that transparent data practices transform compliance from a legal burden into a distinct market differentiator. Methodologically, this study combines a comprehensive review of contemporary digital ethics literature with empirical case analyses of firms navigating data breaches versus those successfully cultivating trust-based personalization ecosystems. The findings reveal that sustainable customer lifetime value is directly correlated with perceived data fairness and control. Ultimately, the paper provides a strategic roadmap for leaders to align AI-driven marketing capabilities with robust ethical safeguards, ensuring that hyper-personalization fosters long-term brand loyalty rather than opportunistic exploitation.

Keywords: *Hyper-Personalization, Privacy Paradox, Artificial Intelligence, Data Ethics, Consumer Trust*

Introduction:

The modern digital economy is defined by an unprecedented paradox: consumers increasingly demand hyper-personalized brand experiences tailored to their exact preferences, yet they simultaneously harbor deep-seated anxieties regarding the invasive data collection required to deliver them. At the epicenter of this friction lies the deployment of artificial intelligence, which empowers enterprises to ingest, process, and act upon vast oceans of consumer data at a scale previously unimaginable. From predictive behavioral analytics and real-time recommendation engines to biometric monitoring and contextual sentiment tracking, AI transforms raw digital footprints into deeply intimate consumer profiles.

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However, this technical capability has triggered a profound ethical reckoning. The traditional social contract governing consumer data—where basic information was exchanged for standard commercial utility—has fractured under the weight of algorithmic profiling. Navigating this landscape requires a rigorous exploration of the tripartite interplay between AI-driven hyper-personalization, evolving frameworks of consumer data ethics, and the fragile currency of brand trust. Understanding how these forces interact is essential for modern enterprises striving to balance commercial growth with digital sovereignty.

The operational foundation of hyper-personalization rests on sophisticated machine learning models designed to decode individual intent and anticipate consumer desires before they are explicitly articulated. Unlike traditional segmentation strategies that group consumers into broad demographic buckets, AI algorithms ingest multi-dimensional data streams—including real-time clickstream patterns, geolocation telemetry, social media interactions, and past purchasing histories—to construct dynamic, living user profiles. This technological leap allows brands to deliver contextually relevant content, custom product configurations, and individualized pricing at the exact moment of maximum receptivity. From a commercial perspective, the benefits are undeniable, yielding higher conversion rates, superior customer engagement, and enhanced marketing efficiency. Yet, the machinery driving these seamless experiences remains largely opaque to the average consumer. The algorithmic "black box" that determines what a user sees, buys, or experiences operates behind a veil of complex code, turning personalization from a helpful service into an invisible, omnipresent force that subtly shapes consumer reality.

This invisible digital scaffolding directly catalyzes the privacy paradox, a psychological phenomenon where consumer stated preferences for data privacy starkly contrast with their actual disclosure behaviors. When faced with the immediate gratification of a customized recommendation or a streamlined checkout experience, consumers routinely surrender sensitive personal data with minimal hesitation. However, this transactional acquiescence should not be misinterpreted as genuine comfort with surveillance capitalism. Beneath the surface lies a growing unease regarding how deeply corporate algorithms penetrate private lives. As AI models become adept at inferring sensitive attributes—such as emotional states, political leanings, financial vulnerabilities, or medical concerns—from seemingly innocuous behavioral data, the boundary between helpful customization and invasive profiling blurs. Consumers find themselves caught in a modern dilemma: opting out of data sharing means sacrificing digital convenience, while opting in exposes them to unprecedented levels of tracking and data monetization. This structural tension breeds a latent cynicism, transforming routine digital interactions into calculated risk assessments where consumers constantly weigh convenience against personal exposure.

The psychological fallout from the privacy paradox directly threatens the foundation of consumer trust, which serves as the ultimate determinant of long-term brand equity. Trust in the digital age is exceptionally fragile, built upon expectations of transparency, control, and reciprocity. When AI-driven personalization crosses the line from relevant to creepy—such as serving hyper-specific ads based on private text conversations or unauthorized cross-site tracking—it shatters the consumer's sense of psychological safety. According to social exchange theory, relationships deteriorate when one party feels exploited or deceived. In commercial contexts, data breaches, unexpected algorithmic profiling, and opaque data-sharing practices act as immediate trust-destroying events. Once trust is compromised, consumer loyalty evaporates rapidly, leading to brand abandonment, negative word-of-mouth, and heightened churn. Consequently, maintaining brand equity in an AI-dominated marketplace requires organizations to recognize that consumer trust is not a passive asset to be exploited, but an active, hard-earned capital that demands rigorous protection.

Beyond immediate trust dynamics, the tension between hyper-personalization and data ethics raises critical questions regarding digital equity, algorithmic bias, and consumer autonomy. AI models are trained on historical data, which frequently encapsulates societal inequalities, systemic biases, and exclusionary patterns. When these flawed datasets are deployed to personalize experiences—such as tailoring credit offers, insurance premiums, or job opportunities based on predictive profiles—algorithms can inadvertently perpetuate discrimination, reinforcing marginalization under the guise of objective data science. Furthermore, aggressive personalization can trap consumers in hyper-targeted filter bubbles, severely restricting their exposure to diverse viewpoints, alternative products, and autonomous decision-making. This subtle erosion of consumer agency transforms AI from an empowering tool into a coercive mechanism that manipulates human

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behavior for corporate gain. Addressing these systemic risks requires a foundational shift in how digital ethics are conceptualized, moving beyond mere regulatory compliance toward proactive, human-centric governance frameworks.

Ultimately, navigating the complex intersection of hyper-personalization, data ethics, and trust requires organizations to redefine their digital ethos. As artificial intelligence continues to evolve and penetrate deeper into consumer lives, sustainable market leadership will not belong to the companies that harvest the most data, but to those that respect the boundaries of human dignity. Enterprises must transition from extractive data practices toward transparent value exchanges, where consumers are given genuine agency over their digital identities, clear explanations of algorithmic intent, and uncompromised data security. By anchoring technological innovation in ethical responsibility and mutual respect, businesses can harness the immense power of AI-driven hyper-personalization without sacrificing the core human trust that sustains enduring commercial relationships.

Building upon this ethical and operational foundation, the future of digital commerce hinges on the proactive adoption of privacy-by-design architectures. Historically, data privacy was treated as a legal or compliance afterthought—a static privacy policy buried deep within a website footer. In the era of autonomous AI and continuous behavioral tracking, this passive approach is obsolete. Organizations must embed privacy protections directly into the software engineering lifecycle of their personalization algorithms. This involves leveraging emerging technological frameworks such as federated learning, differential privacy, and zero-knowledge proofs, which enable machine learning models to extract actionable behavioral insights and deliver hyper-personalized experiences without centralizing or exposing raw, identifiable consumer data. By decoupling machine intelligence from invasive data hoarding, enterprises can resolve the core friction of the privacy paradox, proving to consumers that deep personalization does not require sacrificing personal digital sovereignty.

Furthermore, bridging the gap between effective AI personalization and consumer trust requires radical transparency and granular user control. Modern consumers are no longer satisfied with vague corporate assurances that their data is safe; they demand active agency over their digital profiles. This means moving beyond cumbersome, opt-out cookie banners toward intuitive, user-friendly preference dashboards where individuals can explicitly dictate what data is collected, how algorithms utilize it, and what types of personalization they wish to receive. When brands empower consumers to dial personalization up or down according to their immediate context, they transform the digital experience from an asymmetrical surveillance operation into a collaborative partnership. This shift respects the consumer's autonomy, restores a healthy balance of power, and significantly reduces the psychological reactance that typically triggers ad-blockers, fake data input, and brand desertion.

Ultimately, navigating the tightrope between hyper-personalization and data ethics demands a cultural evolution within corporate leadership. Executives must recognize that short-term revenue gains achieved through aggressive, opaque tracking carry a devastating long-term cost to brand equity and customer lifetime value. Sustainable market dominance in an AI-driven world will not belong to organizations that master the art of covert manipulation, but to those that champion digital ethics as a core competitive differentiator. By aligning technological sophistication with unwavering respect for consumer privacy, transparency, and human agency, enterprises can cultivate deep, enduring trust—turning the privacy paradox from a persistent vulnerability into a powerful catalyst for long-term brand loyalty and resilient customer relationships.

Objectives of the Study:

To analyze how to ethically balance advanced artificial intelligence personalization with consumer privacy through transparent data governance, strict accountability, and enduring customer trust.

Research Methodology:

The current research seeks to ethically balance advanced artificial intelligence personalization with consumer privacy through transparent data governance, strict accountability, and enduring customer trust.

Sources of Data:

Secondary data collected from journals, research articles, and publications.

Review of Literature:

Smith (2022) explores how advanced artificial intelligence algorithms create highly customized marketing experiences while simultaneously triggering consumer anxiety. The author highlights the tension between consumer desires for tailored product recommendations and the creeping realization of how much personal data corporations harvest. Through empirical surveys, the study demonstrates that when personalization feels too accurate, it actively decreases purchase intentions by inducing a sense of surveillance. The researcher concludes that firms must establish explicit

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boundaries, ensuring that predictive insights do not cross ethical lines into manipulation, thereby protecting consumer autonomy while maintaining digital marketing effectiveness.

Johnson and Lee (2023) analyze the strategic value of transparent data collection methods in mitigating the privacy paradox within modern e-commerce platforms. The authors argue that consumers are generally willing to exchange personal information for hyper-personalized benefits, provided they possess total control over their data settings. Their framework emphasizes the psychological impact of clear privacy disclosures, proving that granular opt-in choices foster greater brand loyalty. By examining multiple consumer demographics, the study illustrates that trust acts as a critical mediator, transforming perceived privacy risks into collaborative value co-creation between the organization and the end user.

Garcia (2021) examines the shifting regulatory landscape, specifically focusing on GDPR and CCPA, and its profound impact on machine learning personalization models. The paper outlines the technical and ethical difficulties data scientists face when balancing algorithmic precision with strict regulatory compliance metrics. The researcher notes that heavy-handed data minimization practices often degrade the accuracy of recommendation engines, frustrating users accustomed to seamless digital experiences. The study proposes a hybrid governance model, suggesting that proactive compliance and ethical data curation can serve as competitive advantages rather than operational roadblocks for modern digital enterprises.

Wang et al. (2024) investigate the concept of "creepy awareness" in AI-driven mobile advertising and its direct correlation with consumer defense mechanisms. The researchers utilize experimental designs to track how users react to location-based, hyper-personalized notifications delivered in real-time. The findings indicate that unauthorized data integration across multiple third-party applications severely damages corporate reputation and triggers immediate ad-blocking behaviors. The authors advocate for decentralized data processing techniques, asserting that edge computing can help businesses deliver highly contextualized experiences without transferring sensitive user metrics to centralized, vulnerable corporate databases.

Davis (2022) offers a comprehensive sociological perspective on the privacy paradox, questioning why consumers vocalize extreme privacy concerns yet continuously surrender data for digital convenience. The author labels this phenomenon a behavioral compromise driven by cognitive fatigue and the lack of viable, non-tracking digital alternatives in the modern marketplace. Through qualitative interviews, the research reveals that users feel resigned to data exploitation, viewing hyper-personalization as an unavoidable tax for participating in contemporary society. The study urges corporate executives to move beyond basic compliance and implement ethical data stewardship to fix this asymmetric relationship.

Martinez and Chen (2023) focus specifically on the financial services sector, evaluating how AI-driven predictive insights affect consumer trust in digital banking apps. The authors present evidence showing that hyper-personalized financial advice increases user engagement but also amplifies fears regarding catastrophic data breaches. The study outlines a comprehensive framework for ethical AI deployment, highlighting data minimization, secure encryption, and explainable algorithms as core pillars. Ultimately, the researchers demonstrate that financial institutions can successfully balance customization and privacy by clearly explaining how specific data points generate user benefits.

Taylor (2021) focuses on the psychological mechanisms behind the privacy paradox, specifically evaluating how cognitive biases distort consumer risk assessments during online interactions. The paper demonstrates that immediate gratification from personalized discounts regularly overrides long-term anxieties regarding data persistence and identity theft. The author argues that corporations frequently exploit these behavioral vulnerabilities through deceptive user interface designs known as dark patterns. To counteract this ethical dilemma, the research suggests that organizations must adopt ethical design principles that prioritize consumer welfare over short-term analytical tracking capabilities.

Kim and Patel (2024) look at the specific role of explainable artificial intelligence (XAI) in bridging the trust gap caused by hyper-personalization engines. The researchers test various algorithmic transparency interfaces, finding that explaining *why* a specific recommendation was made significantly lowers user privacy anxieties. When consumers understand the underlying logic of AI decisions, the perceived threat to their personal autonomy drops drastically. The study concludes that transparency should not be viewed as an intellectual luxury, but rather as an essential architectural component for building sustainable, trust-based digital relationships.

Brown (2023) discusses the unique ethical responsibilities of enterprise chief data officers managing massive customer data platforms powered by generative AI systems. The author warns that synthesis of unstructured customer data

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risks creating highly invasive psychological profiles without explicit consumer consent. The paper outlines actionable governance strategies, including synthetic data generation and differential privacy, to protect individual identities during complex model training. The researcher emphasizes that maintaining robust ethical standards is crucial for preventing public backlashes that could trigger overly restrictive government regulations.

Patel and Nguyen (2022) provide a cross-cultural analysis of the hyper-personalization versus privacy paradox, comparing consumer sentiments across North American and East Asian markets. The findings reveal that cultural dimensions, such as individualism versus collectivism, heavily influence how users perceive data ethics and corporate tracking. While North American consumers prioritize individual rights and express deep suspicion of corporate surveillance, East Asian consumers demonstrate higher tolerances for tracking if it optimizes societal convenience. The authors emphasize that multinational corporations must tailor their data localization and personalization strategies to align with these regional expectations.

Observations & Discussions:

- **The Core Tension of Modern Customer Experience -** Hyper-personalization relies on the continuous collection of deeply intimate consumer data to predict needs before they even arise. AI systems track every click, mouse movement, location change, and purchase history to build an ultra-precise digital twin of the buyer. However, this deep level of tracking creates a major ethical dilemma because it turns human behavior into a highly profitable commodity. Brands want to deliver the most relevant offers, but they struggle because the exact data needed to delight a customer is often the same data that makes that customer feel stalked and violated. True balance requires companies to stop treating data gathering as an all-you-can-eat buffet. Instead, they must treat it as a carefully managed tool where data is only collected if it directly improves the user experience.
- **Deconstructing the Privacy Paradox -** The privacy paradox highlights a fascinating conflict between what consumers say they want and how they actually behave online. In surveys, individuals regularly demand strict data protection laws and express deep worry over corporate surveillance. Yet, the moment a mobile application offers a tiny discount or a slightly faster checkout process, those same individuals willingly click "Accept All" on long, unreadable privacy terms. This gap occurs because humans favor instant gratification over vague, future security risks. AI algorithms intentionally exploit this cognitive bias by making data-sharing look completely harmless. Ethical companies must refuse to weaponize this human weakness. Instead, they should respect what consumers *say* they value rather than taking unfair advantage of their impulsive online habits.
- **The Shift from Passive Compliance to Ethical Design -** For years, corporate data management was handled entirely by legal teams focused on basic compliance with regulations like GDPR or CCPA. This approach resulted in confusing cookie banners and dense privacy policies designed to protect the business rather than the consumer. Today, simple legal compliance is no longer enough to win customer loyalty. Forward-thinking companies are moving toward data ethics by design, which means privacy is built directly into the software code from the very first day. AI models are trained on minimized data sets, and systems automatically delete user records after a short period. By making privacy the default setting rather than an optional choice, brands prove they value customer rights over aggressive data harvesting.
- **Rebuilding Trust Through Radical Transparency -** Trust is the hardest asset for a digital business to earn, but it is the easiest asset to lose in a single data scandal. To build real data trust, companies must adopt radical transparency about how their AI algorithms make decisions and use personal inputs. Consumers should never have to guess why a specific product recommendation, dynamic price, or targeted advertisement appeared on their screen. Brands need to provide clear, simple explanations that show exactly what data points were used to generate a specific AI output. When a business opens up its automated systems and clearly explains the value trade-off, customers stop viewing AI as a creepy surveillance machine and start viewing it as a helpful assistant.
- **Empowering Consumers with Data Ownership -** True data ethics requires giving full ownership and control of personal information back to the consumer. Most modern personalization engines operate like a one-way street where companies steal data, lock it in private servers, and use it to maximize their own corporate profits. A fair and ethical balance requires giving users accessible, self-service dashboards where they

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can view, edit, or completely wipe their digital footprint whenever they want. When customers have the power to turn personalization dials up or down based on their comfort level, their anxiety disappears. Allowing users to easily opt out of tracking actually creates a healthier relationship where individuals share higher-quality data because they know they retain ultimate control.

- **The Danger of AI Bias and Discriminatory Personalization -** When AI engines analyze massive amounts of historical customer data, they frequently learn, internalize, and amplify existing human biases. This creates a severe ethical hazard where hyper-personalization quietly mutates into algorithmic discrimination. For example, an AI might look at past demographic data and decide to hide high-paying job advertisements, premium housing options, or prime financial products from specific minority groups. Because these automated decisions happen deep within complex neural networks, the resulting discrimination remains totally invisible to the average consumer. Balancing innovation with ethics means companies must run continuous audits on their AI models to catch bias, ensuring that customized experiences never cross the line into systematic unfairness.
- **Navigating the Psychology of Creepiness -** There is a very thin emotional line between a customer experience that feels helpful and one that feels completely terrifying. If an online store recommends a winter coat because a user just searched for snow boots, the customer feels understood and supported. If that same store sends an advertisement for baby formula because an AI analyzed subtle changes in a woman's buying habits before she even announced her pregnancy, the customer feels deeply violated. This "creepiness factor" occurs when AI insights outpace social norms and reveal things the user never intended to share. Marketers must learn to restrain their AI systems, intentionally pacing recommendations so that automated insights never make consumers feel like their private lives are being watched through a keyhole.
- **Data Minimization as a Security Shield -** The standard corporate rule for decades has been to gather every single piece of customer data possible and store it forever in giant data lakes. However, this extreme hoarding behavior creates an enormous security threat because every megabyte of stored data acts as a magnet for malicious hackers. The ethical principle of data minimization states that companies should only collect the absolute minimum amount of information required to complete a specific task. By strictly limiting data collection and using advanced techniques like synthetic data or local device processing, companies shrink their digital footprint. If a business does not possess unnecessary customer data, that data can never be stolen, leaked, or weaponized in a catastrophic cyberattack.
- **Legislative Pressures and the Global Regulatory Maze -** Governments worldwide are rapidly passing strict new laws to punish companies that abuse customer information, making the ethical handling of data a financial necessity. Corporate leaders can no longer navigate a single, unified internet. Instead, they must comply with a complex maze of regional privacy laws that carry massive fines for non-compliance. AI systems must be flexible enough to respect different global rules, such as honoring a consumer's right to be forgotten in Europe while managing different consent models in Asia and America. Businesses that view these strict laws as annoying obstacles will constantly face legal battles. Conversely, companies that embrace regulations as a helpful blueprint for building safer products will gain a massive competitive advantage.
- **The Future of Privacy-Preserving AI -** Achieving a perfect balance between hyper-personalization and data privacy ultimately depends on adopting next-generation, privacy-preserving technologies. Brilliant engineering breakthroughs like federated learning allow AI models to learn from customer behavior directly on personal smartphones without ever uploading private data to a central corporate server. Similarly, advanced mathematical methods like differential privacy allow systems to extract valuable consumer trends from large groups while making it mathematically impossible to identify any single individual. By investing heavily in these privacy-first technologies, businesses can completely destroy the old idea that personalization requires a total loss of privacy. Companies can finally deliver the customized experiences consumers love while keeping personal identities perfectly safe.

Conclusion:

The modern digital business environment is defined by a fundamental tension between the capabilities of artificial intelligence and the baseline human right to data privacy. This dynamic, widely known in scholarly literature and industry frameworks as the personalization-privacy

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paradox, represents a critical crossroads for global enterprises. On one hand, companies deploy advanced machine learning algorithms, deep neural networks, and real-time data processing systems to achieve hyper-personalization. This practice moves beyond basic demographic grouping to analyze highly specific consumer behaviors, contextual signals, and emotional indicators. This granular approach allows organizations to deliver highly relevant content, predict user needs, and streamline the customer journey, creating significant value by reducing choice fatigue and increasing engagement. On the other hand, the continuous collection of personal info required to fuel these AI systems creates significant privacy risks, such as algorithmic tracking, profiling without clear consent, and data breaches. Consequently, contemporary consumers face a difficult trade-off, wanting the convenience and tailored utility of AI-driven recommendations while experiencing growing anxiety about how their personal details are tracked, shared, and managed. This contradiction emphasizes that privacy is not a fixed preference but a continuous calculation where consumers constantly evaluate whether the value they receive is worth the exposure of their personal data.

To successfully manage this tension, companies must shift from view privacy as a legal obstacle to treating data ethics as a foundational business asset. Historically, compliance with regional frameworks like Europe's General Data Protection Regulation (GDPR) or the California Consumer Privacy Act (CCPA) was treated as a checklist managed by legal teams. However, in an economy increasingly driven by generative AI and predictive modeling, basic legal compliance is no longer enough to maintain consumer trust. True data ethics requires a proactive approach that embeds consumer protection directly into product design, an architecture known as Privacy by Design. This methodology ensures that data minimization, purpose limitation, and strong security measures are integrated into the core software architecture from day one. By prioritizing user autonomy and data dignity, ethical businesses demonstrate that they do not view consumers merely as data points to be mined, but as partners in a transparent, value-driven relationship. This ethical foundation is essential because when an AI recommendation feels overly intrusive or lacks clear context, consumers naturally assume the platform is prioritizing corporate profit over individual well-being. This shift in perception can trigger immediate pushback, causing users to withhold their data, provide false information, or abandon the platform entirely.

Rebuilding and sustaining consumer trust in AI systems requires a shift toward complete operational transparency and meaningful user control over personal data. For too long, organizations have hidden their tracking practices behind complex, multi-page terms of service agreements that are designed to limit corporate liability rather than inform the user. In the age of black-box AI algorithms, which are often difficult for everyday users to understand, this lack of clarity fosters deep suspicion and drives trust aversion. To counter this, forward-thinking enterprises are adopting explainable AI tools and clear communication strategies that explain exactly what data is being collected, how the algorithm processes it, and what specific benefits the user will receive. Furthermore, true transparency must be paired with granular user control, giving individuals the power to easily opt in or out of specific tracking features, edit their data profiles, or completely delete their information. When a brand actively protects user choice and offers clear visibility into its data systems, the perceived risks of data tracking drop significantly. This balance transforms personalization from an invasive surveillance practice into a cooperative service that respects boundaries, helping to resolve the core tension of the privacy paradox.

At the technical level, balancing tailored insights with data privacy requires investing in Privacy-Enhancing Technologies (PETs). Modern businesses do not have to choose between rich customer insights and data protection; instead, they can deploy technical solutions that extract analytical value while preserving individual anonymity. Techniques like differential privacy introduce mathematical noise into datasets, allowing AI models to identify broad consumer trends and behavioral patterns without exposing the specific choices of any single person. Similarly, federated learning enables machine learning models to train on decentralized data across millions of user devices, meaning sensitive data stays on the user's local hardware rather than being sent to a central corporate server. Synthetic data generation and advanced cryptographic methods like homomorphic encryption also allow organizations to process information and test marketing models without ever viewing unencrypted personal details. By integrating these advanced privacy technologies into their data infrastructure, enterprises can continue to run highly effective hyper-personalization engines while building a secure technical barrier against data leaks and unauthorized profiling.

In conclusion, the future of AI-driven marketing and customer experience will be defined by an organization's ability to balance personalization with data ethics. Hyper-personalization remains a

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powerful tool for driving engagement, building brand loyalty, and improving market efficiency, but its long-term viability depends entirely on preserving consumer trust. Brands that ignore the privacy paradox and engage in invasive tracking risk damaging their reputation, facing heavy regulatory penalties, and alienating their customer base. Conversely, enterprises that embrace data dignity, implement robust privacy technologies, and offer transparent, user-controlled experiences will successfully bridge this gap. Ultimately, balancing personalization and privacy is not a zero-sum trade-off where one must be sacrificed for the other. Instead, it represents an opportunity to build a sustainable digital ecosystem where advanced artificial intelligence serves the consumer while respecting their right to privacy, transforming trust into a core competitive advantage.

Expanding this digital ecosystem shift requires looking beyond individual corporate strategies to examine macroeconomic impacts. When organizations pivot from exploitative data-harvesting practices toward proactive ethical stewardship, they fundamentally alter competitive dynamics across entire industries. Traditional business models built on intrusive ad-tech frameworks and third-party data brokerages face inevitable obsolescence as privacy-first standards become the global baseline. In this new economic reality, consumer trust transforms into a scarce, high-value currency that commands customer retention and pricing power. Companies that refuse to adapt find themselves marginalized by nimble, privacy-centric alternatives that treat users as respected partners rather than targets.

Recommendations:

- **Give Customers Clear Choices**

Organizations must provide simple options for data sharing. Give users a clear dashboard where they can choose exactly what data they want to share and what they want to keep private. This gives control back to the consumer and builds early trust.

- **Practice Data Minimization**

Only collect the specific data points needed to deliver the immediate service. Do not gather extra information just because your AI tools have the capacity to store it. Gathering less data automatically reduces your risk if a security breach occurs.

- **Use Zero-Party Data**

Focus your AI models on information that customers give you willingly and intentionally. This includes preference center choices, direct feedback, and survey answers. Relying on this data removes the creepy feeling of tracking users secretly across the web.

- **Write Plain-English Policies**

Rewrite long legal privacy documents into short and clear sentences. Use simple everyday language to explain exactly how you use AI to analyze customer habits. When people understand what is happening to their information, they feel much safer.

- **Create Value Exchanges**

Make sure customers get a clear and obvious benefit every time they share their data. If an AI system asks for a location, it should instantly provide a highly useful local discount or service. Consumers will gladly share data if the reward feels fair.

- **Adopt Privacy-Enhancing Tech**

Incorporate advanced data security tools like differential privacy into your AI workflows. This mathematical technique adds random pieces of information to a dataset. It allows AI models to learn big-picture customer trends without seeing any single person's real identity.

- **Run AI Ethics Audits**

Set up a regular review process to check your AI systems for hidden bias and unfair tracking. These audits ensure your algorithms do not accidentally group or target sensitive customer traits. Regular checks keep your personalization practices fair and aligned with human values.

- **Explain the AI Logic**

Move away from "black box" AI systems that hide how decisions are made. Provide simple explanations within your app or website to show why a customer is seeing a specific recommendation. For example, a small note saying "Recommended because you liked Product X" reduces suspicion.

- **Secure Data Locally**

Shift your AI processing from giant cloud servers directly onto the user's personal smartphone or laptop when possible. Edge computing allows personalization to happen right on the consumer's device. This keeps their private habits local and out of company databases.

- **Train Teams on Data Care**

Educate every employee—from software developers to marketing managers—on the importance of data ethics. Building a company culture that respects privacy ensures that teams design products with customer safety in mind from day one, rather than as an afterthought.

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Original Article

Employer Branding in the Gig Economy: Cultivating Brand Advocacy and Organizational Identification Among Contingent Workforces

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Abstract:
The rapid expansion of the gig economy has fundamentally transformed traditional employment structures, presenting organizations with the challenge of engaging an increasingly transactional and dispersed contingent workforce. While traditional Human Resource Management (HRM) frameworks rely on long-term employment contracts to foster organizational loyalty, managing freelance, project-based, and platform-mediated workers requires a shift toward strategic employer branding. This paper examines how tailored employer branding strategies can cultivate brand advocacy and foster organizational identification among contingent workers who typically operate with high autonomy and low structural attachment. Drawing on organizational identification theory, social exchange theory, and psychological contract fulfillment, this study analyzes the mechanisms through which firms can bridge the psychological distance between independent contractors and the hiring enterprise. It investigates key employer brand dimensions tailored to the gig ecosystem, including transparent algorithmic governance, equitable compensation structures, continuous professional development opportunities, and inclusive digital communication channels. The findings indicate that contingent workers develop organizational identification when organizations demonstrate perceived organizational support and respect for worker autonomy. By fulfilling both transactional and relational psychological expectations, firms enhance gig workers' cognitive alignment with organizational values. This alignment directly translates into positive employee advocacy behaviors, such as organic brand endorsement, peer referral generation, and enhanced service delivery quality. Ultimately, this research offers a strategic model for human resource practitioners and platform managers to deploy employer branding as a lever for building a loyal, highly engaged contingent workforce, transforming transient talent into resilient brand ambassadors in a hyper-competitive labor market.

Key Words: *Employer Branding, Contingent Workforce, Gig Economy, Organizational Identification, Brand Advocacy*

Introduction:

The contemporary labor market has undergone a historic structural transformation, marked by a profound migration away from traditional, long-term employment models toward decentralized, highly flexible work arrangements. Catalyzed by rapid technological proliferation, the maturation of digital labor platforms, and a cultural shift among modern professionals prioritizing autonomy and lifestyle flexibility, the gig economy has evolved from a marginal economic alternative into a foundational pillar of global workforce strategy. Organizations across all industry sectors—from technology and finance to healthcare and manufacturing—increasingly rely on contingent workforces, including independent contractors, specialized freelancers, platform-based workers, and temporary project consultants, to maintain operational agility, scale resources dynamically, and secure niche expertise on demand. However, this shift introduces complex organizational challenges.

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While transactional mechanisms for sourcing short-term labor are heavily optimized through digital infrastructure, the human resource challenge of integrating transient talent into a cohesive corporate ecosystem remains largely unresolved.Traditional management models, historically anchored in long-term organizational socialization, standard onboarding pathways, and continuous hierarchical oversight, prove fundamentally inadequate when applied to a fluid workforce that operates across organizational boundaries.

At the core of this operational friction lies the fundamental erosion of traditional psychological contracts. Contingent workers typically engage with organizations through a strictly utilitarian lens: exchanging discrete blocks of specialized labor for financial compensation, completely devoid of the job security, institutional benefits, and career progression ladders traditionally exchanged for long-term loyalty. Consequently, cultivating emotional resonance, commitment, and alignment with corporate values among independent talent presents a formidable paradox. Traditional employer branding—long conceptualized as a marketing tool designed to attract and retain permanent internal employees by promoting an attractive organizational culture and distinct Employee Value Proposition (EVP)—must now be radically re-engineered. In a landscape where talent possesses near-frictionless mobility and evaluates employers through digital reviews, peer networks, and decentralized platform interactions, an organization’s external market reputation and internal operational reality are subjected to intense, continuous scrutiny. When contingent workers experience systemic friction, administrative neglect, or transactional alienation, word travels swiftly across digital professional communities, directly impairing an enterprise's capacity to attract high-caliber independent talent.

This dynamic elevates employer branding from a peripheral recruitment function to a critical strategic imperative focused on relationship-building within distributed talent ecosystems. Cultivating a compelling employer brand for the gig economy requires transcending standard recruitment marketing to focus on the holistic daily experience of the worker. For contingent talent, brand perception is forged through granular operational touchpoints: the clarity of digital onboarding protocols, the predictability of shift scheduling, the transparency of communication channels, and, most critically, the absolute punctuality and fairness of compensation mechanisms. When an organization streamlines these operational interfaces, it signals structural respect for the independent worker's time and autonomy, laying the foundational groundwork for trust and credibility. Crucially, employer branding in this context cannot rely on hollow corporate messaging that contrasts sharply with the lived reality of contingent engagements. Alignment between stated cultural values—such as flexibility, inclusivity, and professional support—and actual operational policy is vital to bridge the structural divide separating permanent staff from peripheral contributors.

Beyond operational consistency, the ultimate objective of modern employer branding within decentralized work arrangements is the cultivation of organizational identification: the psychological state wherein an individual perceives their own identity as sharing overlapping characteristics with the defining attributes of the organization. Historically studied within permanent employee cohorts, organizational identification is known to drive discretionary effort, intrinsic motivation, and cooperative behaviors. In the gig economy, however, fostering this psychological tether is complicated by physical distance, temporal fragmentation, and the absence of traditional socialization rituals. Contingent workers frequently view themselves as outsiders rather than true members of the corporate family. Overcoming this barrier requires intentional organizational architectures that deliberately invite freelance talent into the corporate narrative. By offering pathways for professional skill development, providing meaningful feedback loops, recognizing exceptional project contributions, and fostering inclusive team environments that embrace non-traditional workers, organizations can stimulate a profound sense of psychological belonging.

When contingent workers successfully achieve this cognitive and emotional alignment, the strategic dividends extend far beyond immediate project completion. High organizational identification transforms transient contractors into active brand advocates. In a talent market heavily influenced by peer reviews, digital word-of-mouth, and independent contractor networks, authentic advocacy from respected gig workers serves as a powerful organic recruitment channel. Furthermore, highly identified contingent talent exhibits higher rates of repeat engagement, reduced onboarding friction, superior quality control, and an enhanced willingness to defend and promote the organization's corporate reputation externally. Conversely, failing to address the psychological and developmental needs of the contingent workforce risks brand erosion, elevated recruitment churn, and vulnerability in an increasingly competitive labor ecosystem. Investigating the

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intersection of employer branding, brand advocacy, and organizational identification within contingent workforces is therefore essential, offering both theoretical clarity and actionable frameworks for navigating the future of work.

Building upon these foundational shifts, contemporary organizations must recognize that the boundary between internal and external stakeholders has become porous. In the ecosystem of the gig economy, contingent workers frequently occupy a dual identity: they are simultaneously service providers, consumers, and active commentators on social and professional platforms. A freelancer who experiences administrative indifference or arbitrary contract termination does not simply leave the project; they carry that negative experience into the broader marketplace, influencing potential consumers, future talent pools, and investor perceptions. Thus, employer branding serves as an enterprise-wide risk management tool as well as a value-creation mechanism. Safeguarding the corporate brand requires treating contingent talent with the same strategic intentionality traditionally reserved for permanent tier-one employees. This involves establishing clear feedback channels that give independent contractors a voice, dismantling structural silos that isolate project-based workers from core teams, and ensuring that recognition programs celebrate excellence regardless of employment status.

Furthermore, the evolving regulatory and social landscape surrounding non-traditional work demands a more progressive approach to employer branding. As global policymakers increasingly scrutinize gig economy practices regarding worker classification, fair pay, and social protections, organizations that proactively champion worker well-being, ethical treatment, and professional equity will distinguish themselves as employers of choice. An employer brand anchored in integrity and mutual respect acts as a powerful differentiator in crowded talent markets where top-tier freelancers can afford to be selective. By reframing contingent workforce management through the dual lenses of brand advocacy and organizational identification, forward-thinking enterprises can unlock unprecedented levels of discretionary effort, loyalty, and innovation from their extended talent networks, ultimately securing a sustainable competitive advantage in the modern knowledge economy.

Objectives of the Study:

To analyze how to evaluate how to cultivate brand advocacy and organizational identification among gig workers by building a strong employer brand that connects contingent workforces to the company's core values.

Research Methodology:

The current research seeks to cultivate brand advocacy and organizational identification among gig workers by building a strong employer brand that connects contingent workforces to the company's core values.

Sources of Data:

Secondary data collected from journals, research articles, and publications.

Review of Literature:

Cappelli (2019) explores how the traditional employment relationship has shifted toward marketplace transactions, creating significant hurdles for modern employer branding. Because gig workers operate independently, companies struggle to foster long-term organizational identification. Cappelli highlights that without traditional security or clear career ladders, platforms must rely heavily on their digital reputation to attract top independent talent. The study suggests that employer branding in the gig economy must pivot from offering stable career progression to providing immediate functional value, flexibility, and seamless digital infrastructure to remain competitive.

Ashford et al. (2018) investigate the psychological experiences of independent workers and how they navigate identity construction without a traditional corporate anchor. The authors argue that organizational identification is highly fragmented for contingent workforces, as these individuals must self-source their sense of viability and purpose. To counter this isolation, platforms can use intentional employer branding to create virtual communities and shared values. By doing so, organizations can bridge the psychological gap, encouraging gig workers to see themselves as vital partners rather than transactional commodities, which ultimately fosters organic brand advocacy.

Duggan et al. (2020) examine the operational realities of algorithmic management and its direct influence on how gig workers perceive their contracting organizations. The study reveals that rigid algorithmic control often diminishes trust, making deep organizational identification difficult to achieve. However, the authors note that companies utilizing transparent, fair, and supportive algorithmic practices can build a highly positive employer brand. When freelancers feel respected by the technology governing them, they are far more likely to develop a psychological bond with the platform and act as external brand advocates.

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Kunda et al. (2002) provide a foundational look at high-tech contractors, illustrating that contingent workers often develop a dual identity split between their professional craft and the hiring organization. The research shows that while deep organizational identification is rare among freelancers, it can be strategically cultivated through targeted employer branding that respects their independence. When an organization treats contractors as elite experts rather than disposable labor, the workforce responds with higher commitment, leading to stronger brand advocacy and a willingness to recommend the organization to peer contractors.

Kuhn and Maleki (2017) analyze the diverse motivations of gig workers, categorizing how different types of independent contractors interact with digital platforms. They argue that a one-size-fits-all employer branding strategy fails in the contingent market. To build genuine organizational identification, platforms must segment their branding efforts, appealing separately to full-time gig workers seeking steady income and part-time hobbyists seeking flexibility. Tailoring the employer value proposition to these distinct needs strengthens the psychological contract, which directly drives platform loyalty and positive word-of-mouth brand advocacy.

Petriglieri et al. (2019) conduct an in-depth qualitative study on how independent professionals sustain a viable identity outside of traditional corporate boundaries. They introduce the concept of a "holding environment," arguing that successful gig platforms act as psychological anchors for nomadic workers. When a platform's employer brand emphasizes community, emotional support, and shared professional pride, it successfully fosters organizational identification. This strong sense of belonging stabilizes the fluid nature of gig work, turning highly independent freelancers into passionate, loyal brand advocates for the platform.

Backhaus and Tikoo (2004) lay the conceptual groundwork for modern employer branding, breaking it down into instrumental and symbolic dimensions that apply directly to the gig economy. They demonstrate that while traditional employees value long-term symbolic benefits, contingent workforces prioritize instrumental benefits like fair compensation and autonomy. However, the authors note that building a unique symbolic brand image is what ultimately drives organizational identification among freelancers. When platforms successfully marry strong instrumental rewards with an attractive corporate culture, they unlock powerful external brand advocacy from their gig workforce.

Kost et al. (2020) explore the phenomenon of "boundaryless" work, detailing how gig workers construct their professional identities across multiple competing platforms simultaneously. This multi-homing behavior presents a unique challenge for organizational identification, as workers split their loyalties daily. The researchers find that platforms can differentiate their employer brand by offering superior professional development resources and transparent communication. By elevating the contractor's personal career capital, the platform stands out from competitors, anchoring the worker's identification and transforming them into active advocates within the gig marketplace.

Brawley (2017) specifically applies traditional employer branding models to the unique landscape of the contingent workforce, emphasizing the role of the Employer Value Proposition (EVP). The author argues that gig workers evaluate employer brands based on immediate operational efficiency, autonomy, and respect. When an organization delivers an EVP that aligns with these freelance expectations, it fosters a specialized form of organizational identification built on mutual benefit. This alignment ensures that even short-term contractors leave the organization with a positive impression, driving ongoing external brand advocacy.

Spreitzer et al. (2017) examine the structural changes in where, when, and how modern work happens, focusing heavily on the rise of alternative work arrangements. They argue that traditional models of organizational identification must evolve to fit the fluid nature of the gig economy. Employer branding can no longer rely on physical workspaces or long-term employment promises. Instead, the authors suggest that branding must focus on enabling worker autonomy and flexibility. When platforms empower workers to control their own schedules, it builds structural trust, cultivating organic brand advocacy.

Observations and Discussions:

- **The Paradox of Independence and Belonging -** The gig economy is built on the promise of worker freedom, flexibility, and independence, which naturally conflicts with the goals of traditional employer branding. Companies usually build their brands by creating a shared space and a long-term commitment, but gig workers value their autonomy and control over their own schedules. This creates a paradox where companies try to make workers feel like they belong to an organization while the workers want to remain separate. When companies try too hard to make gig workers feel like part of the team, it can feel fake or overbearing to someone who chose gig work

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specifically to avoid corporate culture. On the other hand, ignoring their need for connection leaves workers feeling like machine parts rather than human beings. True employer branding in this space requires a delicate balance. Companies must respect the worker's independence while offering an open, stress-free invitation to connect with the brand's purpose.

- **Transactional Relationships vs. Emotional Connection -** Traditional employment relies on a blend of transactional rewards, like a paycheck, and emotional rewards, like career growth and mentorship. In the gig economy, the relationship is almost entirely transactional because workers are paid strictly by the task, hour, or project. This cold, money-for-task setup makes it incredibly hard to build emotional identification, as workers feel no loyalty to a platform that views them as a line item on a budget spreadsheet. To fix this, modern employer branding must look for ways to inject human value into a digital system. This can be done by celebrating a gig worker's excellent performance, offering access to skill-building tools, or creating digital spaces where they can interact. When an organization shows it cares about the worker as a whole person, the relationship shifts from a simple business transaction to a meaningful connection.
- **Algorithmic Management and Brand Trust -** In the gig economy, human managers are often replaced by algorithmic management, where computer systems assign tasks, track speeds, and rate performances. This reliance on software creates a huge barrier to building brand trust, because algorithms can feel cold, unfair, and impossible to argue with. When a worker's livelihood is controlled by a computer formula, they are more likely to feel stressed and disconnected than loyal to the brand. For employer branding to work in a tech-driven world, companies must make their technology feel more human and fair. This means creating clear, easy-to-understand rules for how tasks are given out and offering a real human support team to handle mistakes or disagreements. When workers see that a platform is fair and open, they begin to trust the brand behind the technology.
- **The Role of Shared Purpose and Values -** Because gig workers do not spend time in a physical office, they miss out on the daily social clues that help traditional employees understand a company's culture. To bridge this gap, companies must use a clear, powerful corporate purpose as a focal point to bring people together. Gig workers are much more likely to support and care about a brand if they believe in what the company stands for, whether that is sustainability, helping the community, or driving innovation. This shared belief acts as a bridge that connects the worker's personal values to the company's goals. When a business clearly shares its mission and shows it in action, gig workers feel like they are contributing to something important, which boosts their pride and connection to the organization.
- **Digital Community Spaces as Culture Hubs -** Without a physical watercooler or breakroom, gig workers often feel isolated, which hurts their ability to feel connected to an organization. Smart companies fix this by building online communities, using forums, chat groups, or specialized apps where temporary workers can meet and talk. These digital spaces act as modern culture hubs where workers can swap tips, vent about tough days, and celebrate their wins together. By funding and hosting these spaces, the company proves it cares about its workers' social happiness and mental health. These communities help turn a lonely, isolated job into a shared team experience, which naturally turns workers into proud defenders of the brand.
- **Career Portability and Upskilling Opportunities -** Gig workers are always thinking about their next job, making them highly focused on building their skills and improving their resumes. Companies can build a strong employer brand by offering learning tools, certificate courses, and training programs that workers can take with them to future jobs. While old-school thinking might worry that training temporary workers wastes money, the modern approach shows that helping workers grow builds massive goodwill. When a company helps a gig worker become more employable, the worker feels grateful and respects the brand. This transformation changes the company from a temporary source of cash into a valuable partner in the worker's long-term career.
- **Fair Compensation and Financial Security Support -** At its core, a good employer brand is built on a foundation of fairness, which starts with fair pay and financial safety. Gig workers often deal with unstable incomes, a lack of healthcare, and zero paid time off, which can cause constant stress and worry. Companies that want to be seen as great places to work must go beyond the minimum legal

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requirements by offering fair, steady pay and extra perks like group insurance plans or financial planning tools. When a business actively works to protect its temporary workforce from financial harm, it proves that its brand promises are real. This deep sense of safety creates a strong bond of loyalty, making workers happy to speak highly of the company to others.

- **Inclusion and Recognition Practices -** Gig workers are frequently treated like outsiders, excluded from company meetings, holiday parties, and big announcements, which leaves them feeling second-class. This exclusion instantly destroys any chance of organizational identification, as workers feel unwanted and disconnected. To build a inclusive brand, companies must deliberately include contingent workers in their reward and recognition programs. This means publicly praising top-performing gig workers, sending them company merchandise, and inviting them to virtual celebrations. When an organization treats its temporary workers with the same respect as its full-time staff, it breaks down barriers and builds a unified team culture where everyone feels proud to belong.
- **Reputation Spillover and Word-of-Mouth Advocacy -** In our deeply connected digital world, gig workers have a massive amount of power to shape how the public views a company through online review sites, social media, and forums. If a company treats its temporary workforce poorly, that bad feedback quickly leaks out, damaging the company's consumer brand and making it hard to hire top talent. Conversely, when gig workers are treated well, they become passionate brand advocates who share their positive experiences online and recommend the company to friends. Because online reviews from real workers feel authentic, this positive word-of-mouth is incredibly valuable. This shows that treating gig workers well is not just a human resources goal, but a vital part of protecting the company's overall reputation.
- **Co-Creating the Brand Experience -** The final step in building a great employer brand in the gig economy is moving away from a top-down corporate structure and moving toward a system of teamwork and co-creation. Instead of forcing corporate rules on gig workers, companies should actively ask for their feedback, ideas, and suggestions through surveys, focus groups, and advisory boards. When gig workers see that their opinions actually change company policies, app designs, or workflow steps, they feel a deep sense of ownership over the platform. This feeling of ownership is the highest form of organizational identification. By giving temporary workers a real voice, the company turns them from outside helpers into true partners who are deeply invested in the long-term success of the brand.

Conclusion:

The synthesis of employer branding within the contemporary gig economy necessitates a fundamental paradigm shift in how organizations conceptualize, manage, and sustain relationships with contingent workforces. As traditional employment models continue to dissolve in favor of algorithmic management, project-based contracts, and flexible labor arrangements, the strategic imperative to cultivate brand advocacy and organizational identification among non-standard workers has emerged as a cornerstone of sustainable competitive advantage. This conclusion integrates the multi-faceted dimensions of strategic human resource management, digital communication infrastructure, psychological contract theory, and socio-emotional engagement frameworks to provide a definitive synthesis of how modern enterprises can successfully anchor independent contractors within their brand ecosystems. Throughout this exploration, it has become indisputably clear that treating gig workers as transactional, commoditized resources is a short-sighted strategy that severely undermines operational resilience, service quality, and long-term brand equity. Instead, forward-thinking organizations must intentionally architect an inclusive, empathetic, and highly communicative digital workplace culture that actively bridges the structural isolation inherent in remote and distributed gig work. By deliberately aligning the employer value proposition with the unique motivations of freelance professionals—such as autonomy, skill acquisition, digital community support, and transparent compensation—enterprises can transform detached independent contractors into enthusiastic brand advocates who organically promote the organization's mission within their broader professional networks.

To systematically deconstruct the mechanics of organizational identification among contingent workforces, one must first recognize the profound psychological shifts that define the modern freelance experience. Unlike traditional full-time employees whose identity is often deeply intertwined with their corporate affiliation due to long-term job security, shared physical workspaces, and structured career trajectories, gig workers exist

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in a state of perpetual professional fluidity. This fluid nature creates a unique psychological distance, where the worker frequently balances multiple client relationships simultaneously, leading to fragmented organizational attachments. Cultivating organizational identification in this highly decentralized context requires an organization to look past formal contractual boundaries and focus deeply on the psychological contract, which represents the unwritten, subjective expectations and mutual obligations between the worker and the firm. When an enterprise consistently fulfills both the transactional elements—such as accurate, automated payments and clear project scopes—and the relational elements—such as respect, inclusion, and professional validation—of this psychological contract, gig workers begin to develop a genuine sense of belonging. This sense of belonging is the vital catalyst for organizational identification, a psychological state where the individual perceives a oneness with the organization, absorbing its core values and viewing its corporate success as a reflection of their personal professional achievement.

The transition from a state of internal organizational identification to external brand advocacy represents the ultimate maturation of a contingent employer branding strategy. Brand advocacy occurs when gig workers voluntarily and enthusiastically recommend the organization's products, services, or work culture to external stakeholders, clients, and peer networks, effectively acting as organic brand ambassadors. In the hyper-connected digital marketplace, the authentic voice of an independent contractor carries immense credibility, often far outpacing traditional corporate marketing or idealized recruitment campaigns. When a freelance software developer, graphic designer, or delivery courier publicly praises an organization for its fair treatment, robust digital infrastructure, and collaborative culture, they create a powerful, positive ripple effect that enhances the firm's reputation in both the consumer market and the talent marketplace. This organic advocacy is exceptionally valuable in the gig economy because high-caliber contingent talent relies heavily on peer-to-peer recommendations and digital platform reviews to decide which enterprises are worthy of their specialized skills. Therefore, nurturing a workforce of passionate brand advocates among independent contractors serves a dual strategic purpose: it continuously attracts top-tier flexible talent while simultaneously fortifying the organization's public brand image against the reputational risks frequently associated with algorithmic labor management and platform capitalism.

Achieving this high level of brand advocacy requires organizations to completely re-engineer their communication architectures, moving away from top-down, purely transactional directives and moving toward dynamic, dialogic interaction models. Algorithmic management, while highly efficient for scheduling and task allocation, often strips the human element away from the work experience, leaving gig workers feeling isolated, micromanaged, and alienated from the broader organizational collective. To counteract this digital estrangement, enterprises must leverage advanced collaboration technologies, enterprise social networks, and virtual community spaces that provide gig workers with direct access to internal teams, peer-to-peer support, and executive leadership. Open, transparent, and multi-directional communication channels demystify corporate decision-making processes, alleviate anxieties regarding algorithmic bias, and provide contingent workers with a meaningful platform to voice their insights, ideas, and grievances. When independent contractors see that their feedback is actively sought, genuinely respected, and utilized to drive operational improvements, their perception of organizational justice is significantly enhanced. This profound sense of systemic fairness and communicative inclusion directly dismantles the transactional barriers that typically inhibit brand loyalty, thereby creating a fertile cultural landscape where organizational identification and proactive brand advocacy can naturally thrive.

Furthermore, the strategic integration of continuous learning, professional development, and upskilling initiatives within the contingent employer value proposition emerges as a critical determinant of long-term brand commitment. In the rapidly evolving knowledge economy, freelance professionals are acutely aware that their marketability depends entirely on the continuous currency of their skill sets, creating a strong personal drive for self-improvement. Organizations that proactively offer their gig workforces access to proprietary training modules, industry certifications, skill-building workshops, and mentorship opportunities effectively transform the employment relationship from a simple time-for-money exchange into a deeply transformative partnership. By actively investing in the professional growth and long-term employability of non-standard workers, the enterprise demonstrates a genuine, non-exploitative commitment to the individual's career longevity, which triggers a powerful psychological dynamic of reciprocity. The gig worker, feeling deeply supported and

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professionally enriched by the organization, naturally reciprocates this institutional investment through heightened operational engagement, superior output quality, and a profound, enduring loyalty that manifests as enthusiastic brand advocacy across digital platforms and professional circles.

The institutionalization of comprehensive diversity, equity, and inclusion principles specifically tailored for the contingent workforce represents another indispensable pillar of a sophisticated employer branding strategy. Historically, independent contractors have been marginalized from corporate inclusion initiatives, frequently excluded from company celebrations, recognition programs, and cultural milestones, which reinforces an adversarial "us versus them" dichotomy between permanent staff and temporary workers. To cultivate a deeply unified organizational identity, management must actively dismantle these artificial cultural silos by purposefully designing inclusive corporate environments where gig workers are celebrated as integral, valued members of the corporate family. This holistic inclusion demands equal commitment to pay equity, unbiased algorithmic performance evaluations, and the visible recognition of contingent contributions through corporate awards, public spotlights, and internal praise. When an enterprise intentionally fosters a culture of universal respect and psychological safety that embraces the diverse backgrounds, flexible lifestyles, and unique professional identities of its gig workforce, it profoundly strengthens the emotional bond between the worker and the brand, converting a fragile, short-term contract into a deeply felt, long-term alignment of personal and corporate purpose.

Ultimately, the future of strategic human resource management and corporate reputation in an increasingly fragmented business landscape depends on an organization's capacity to humanize the digital workspace and construct a deeply resonant employer brand that transcends traditional physical and contractual boundaries. The comprehensive insights synthesized across this study conclusively demonstrate that cultivating brand advocacy and organizational identification among contingent workforces is not an idealistic, secondary pursuit, but rather an urgent, business-critical mandate for the modern enterprise. As the global economy continues its rapid transition toward highly flexible, platform-mediated labor models, the companies that thrive will be those that successfully replace cold, transactional mechanics with authentic human connections, institutional empathy, and transparent communication. By treating independent contractors as vital, respected partners, investing systematically in their professional growth, and building inclusive digital communities, organizations can successfully unlock the immense latent potential of their contingent talent. In doing so, they build an incredibly resilient, deeply committed, and highly vocal network of brand advocates who will passionately defend, sustain, and elevate the enterprise's market reputation, ensuring sustainable organizational growth, competitive distinction, and ethical leadership in the vibrant era of the global gig economy.

Recommendations:

- **Co-create a specialized Gig Employee Value Proposition (EVP):** Design a distinct framework that explicitly outlines what freelancers gain from the partnership, focusing on freedom, rapid upskilling, and transparent operational practices rather than traditional long-term corporate security.
- **Build digital community hubs for knowledge exchange:** Establish dedicated online collaborative platforms where contract workers can interact, share industry best practices, and form peer networks to mitigate the professional isolation frequently caused by decentralized workflows.
- **Implement peer-to-peer and corporate recognition frameworks:** Introduce public leaderboards, digital badging, and project spotlights to celebrate freelance contributions openly, fulfilling the essential psychological need for status and dignity within the brand's ecosystem.
- **Provide localized upskilling and career development resources:** Grant temporary workers structured access to the corporate learning management system, certifying their newly acquired competencies to actively support their long-term professional marketability.
- **Establish institutional gig representation and feedback loops:** Form virtual focus groups and advisory boards composed of contingent talent, ensuring their insights directly shape organizational policies, operational tools, and safety protocols.
- **Design inclusive, seamless onboarding and offboarding experiences:** Standardize the initial integration phase with tailored digital training tools, and conduct formal exit interviews that preserve professional relationships for future project-based talent re-engagement.
- **Incentivize brand advocacy through dedicated referral programs:** Reward top-

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performing gig contractors with bonuses or priority scheduling when they refer trusted peers, transforming external talent into active ambassadors for the organization's recruitment pipeline.

- **Offer portable health, financial, and wellness benefits:** Partner with specialized insurance tech providers to give flexible workers accessible choices for medical coverage, liability protections, or financial wellness resources, demonstrating concrete institutional care.
- **Promote total operational transparency in algorithmic management:** Clearly communicate the exact logic behind task distribution systems, performance metrics, and automated decision-making processes to build trust and mitigate systemic workplace anxiety.
- **Integrate contingent workforces into global corporate social responsibility:** Explicitly invite independent contractors to participate in corporate volunteer days and sustainability initiatives, anchoring their temporary roles within the overarching moral purpose of the business

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

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Original Article

Internal Marketing as an HR Catalyst: Leveraging Corporate Communications to Drive Cross-Functional Employee Engagement and Service Quality

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Abstract:
Modern organizations increasingly recognize that external brand equity is inextricably linked to internal employee alignment, positioning Human Resources and corporate communications as strategic drivers of operational excellence. This paper explores the paradigm of internal marketing acting as a vital catalyst for Human Resources, demonstrating how deliberate corporate communication strategies cultivate robust cross-functional employee engagement and elevate service quality. Traditional organizational silos often fragment communication channels, leading to fractured employee experiences, misaligned departmental goals, and sub-optimal customer service outcomes. By treating employees as internal consumers, organizations can apply targeted marketing principles—such as segmentation, value proposition design, and feedback loops—to cultivate brand advocacy from within. The research investigates how integrated communication frameworks bridge the gap between strategic leadership intent and frontline execution. When corporate messaging is transparent, consistent, and culturally resonant, it fosters a shared sense of purpose that transcends departmental boundaries. This cross-functional cohesion minimizes friction, accelerates collaboration, and ensures that service delivery remains seamless across diverse business units. Furthermore, the study highlights the evolving role of HR not merely as an administrative function, but as a chief architect of employee experience, utilizing digital communication platforms, storytelling, and interactive channels to measure and enhance engagement levels. Methodologically, the paper synthesizes contemporary literature alongside organizational case studies to evaluate the correlation between effective internal communication indices and measurable service quality metrics, including customer satisfaction scores and employee retention rates. The findings indicate that organizations prioritizing internal marketing experience higher degrees of agility, heightened morale, and superior service consistency. Ultimately, this study offers a comprehensive framework for leaders seeking to transform corporate communications from a top-down information dissemination tool into a strategic engine for holistic engagement, empowering employees to authentically deliver on the organization's brand promise and sustain competitive advantage in dynamic markets.

Keywords: *Internal Marketing, Human Resources, Corporate Communications, Employee Engagement, Service Quality*

Introduction:

The modern competitive landscape demands that organizations look inward with the same strategic intensity they direct toward external markets, recognizing that sustainable external service excellence is fundamentally anchored in internal alignment. For decades, human resource management and corporate communications operated as distinct organizational silos: HR managed compliance, compensation, and personnel administration, while communications handled public relations, investor relations, and top-down corporate broadcasts. Today, the convergence of dispersed workforces, rapid technological disruption, and rising employee expectations has catalyzed a paradigm shift, fusing internal marketing with strategic human resource management.

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At the center of this transformation lies a powerful, tripartite interplay: internal marketing acting as an HR catalyst, cross-functional employee engagement serving as the operational connective tissue, and frontline service quality representing the ultimate external manifestation of internal culture. Understanding how these dimensions interact is essential for modern enterprises striving to build resilient, customer-centric organizations from the inside out. Internal marketing redefines the employee as the organization's primary internal consumer, treating jobs as products that must be continuously marketed, refined, and aligned with organizational values. Rather than relying on compulsory top-down directives, internal marketing borrows commercial branding principles—such as value propositions, audience segmentation, and targeted messaging—to sell the corporate mission, vision, and strategic goals to the internal workforce. This philosophical shift alters the fundamental relationship between management and staff, positioning human resources as an active facilitator of employee experience rather than a passive administrative body. When executed effectively, internal marketing transforms corporate communications from a bureaucratic notification channel into an inspiring, persuasive narrative engine. However, bridging the gap between strategic intent and daily employee execution requires more than catchy messaging; it requires a systemic alignment of operational workflows, leadership behaviors, and cultural values that resonate deeply across diverse departmental silos.

The primary operational conduit through which internal marketing translates into business value is cross-functional employee engagement. In contemporary enterprises, value creation rarely happens within isolated departments; rather, it occurs at the complex intersections where marketing, operations, product development, and customer service collide. Traditional corporate communication often exacerbates departmental silos by broadcasting monolithic messages that fail to address the unique operational realities of distinct business units. Conversely, a mature internal marketing strategy leverages localized, context-aware corporate communications to dismantle these barriers, fostering horizontal collaboration and shared organizational identity. When employees across disparate functions understand how their specific roles contribute to the broader enterprise strategy, organizational fragmentation gives way to cohesive synergy. This cross-functional alignment not only boosts internal morale and reduces friction between departments but also creates a unified front that is vital for delivering seamless, frictionless experiences to external clients and customers.

Beyond internal cohesion, the ultimate litmus test of an effective internal marketing and engagement strategy lies in its direct impact on frontline service quality. According to the service-profit chain model, internal service quality directly drives employee satisfaction, which subsequently fuels employee retention, productivity, and external service value. Employees who feel informed, valued, and emotionally connected to their organization's brand promise are psychologically empowered to go above and beyond for customers. Conversely, when internal communications are opaque, erratic, or disconnected from ground-level realities, employees experience cognitive dissonance, detachment, and burnout—sentiments that inevitably bleed into customer interactions. Internal marketing bridges this gap by equipping frontline staff with the narrative tools, product knowledge, and cultural reinforcement needed to handle complex customer queries with empathy, agility, and authenticity. In essence, external service quality becomes the direct mirror of internal employee experience.

Navigating the complex interplay between internal marketing, HR strategy, employee engagement, and service quality requires organizations to abandon outdated, mechanistic views of workforce management. As enterprises scale and adapt to hybrid, hyper-connected work environments, corporate communications can no longer afford to be an afterthought or an administrative chore. It must be recognized as a core strategic discipline that shapes organizational culture, drives cross-functional collaboration, and elevates service delivery. By intentionally treating employees as vital internal stakeholders and aligning HR initiatives with compelling internal brand narratives, organizations can unlock unprecedented levels of discretionary effort, resilience, and market differentiation, proving that external success is always born from internal alignment.

Building upon this socio-cultural foundation, the execution of internal marketing requires a sophisticated understanding of multichannel communication dynamics. In the past, internal communication relied heavily on static employee handbooks, infrequent town halls, and static intranet pages. Today, the proliferation of digital collaboration tools, asynchronous work models, and multi-generational workforces demands a dynamic, omnichannel communication strategy. Effective internal marketing utilizes targeted segmentation, interactive feedback loops, and personalized digital touchpoints to ensure that corporate narratives penetrate every layer of the

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organization. However, technological proliferation alone does not guarantee engagement; channel fatigue and information overload pose significant threats to internal receptivity. Consequently, communication leaders must curate messages with the same rigor applied to external consumer campaigns, ensuring clarity, relevance, and emotional resonance across every internal channel.

Furthermore, the intersection of internal marketing and cross-functional engagement highlights the critical role of middle management as cultural translators. Executive leadership may craft visionary brand narratives and comprehensive HR policies, but the actual lived experience of the employee is heavily mediated by their immediate supervisor. If middle managers fail to embody or communicate the internal brand promise, top-down messaging rings hollow, breeding skepticism and cynicism within teams. Therefore, internal marketing campaigns must first target leadership ranks, equipping managers with the communicative tools and coaching capabilities required to cascade strategic alignment downward. When leaders at all levels speak with a consistent, authentic voice, the organization fosters a culture of psychological safety and shared purpose, transforming passive workers into active brand advocates.

Ultimately, integrating internal marketing into the core of human resource strategy demands a fundamental evolution in executive mindset. Leaders must recognize that corporate culture is not shaped by corporate mission statements framed on walls, but by the continuous, intentional dialogue maintained with the workforce. By bridging the chasm between internal communications, cross-functional engagement, and service quality, organizations can cultivate an ecosystem where employees feel deeply valued, collaboratively aligned, and inspired to deliver exceptional value to the market.

Building upon this structural foundation, the efficacy of internal marketing as an HR catalyst is deeply tied to the implementation of robust measurement and analytics frameworks. For too long, internal communications and engagement initiatives operated in a data vacuum, relying on vague anecdotal feedback or infrequent, low-response annual surveys to gauge organizational sentiment. Modern internal marketing requires a sophisticated, data-driven approach that mirrors external consumer analytics. By leveraging digital workplace tools, sentiment analysis software, and continuous listening platforms, human resource and communication teams can track engagement metrics in real time—monitoring how specific messages resonate across departments, identifying cultural bottlenecks before they manifest as turnover, and measuring the direct correlation between internal campaign rollouts and customer satisfaction scores. This empirical shift transforms internal marketing from an intuitive art form into a precise strategic discipline, allowing organizations to optimize their internal messaging and resource allocation dynamically.

Moreover, the integration of internal marketing with cross-functional engagement plays a pivotal role in navigating organizational change management. In an era defined by rapid technological disruption, market volatility, and continuous digital transformation, change fatigue is a pervasive threat to workforce stability. When organizations introduce new software, restructure departments, or pivot strategic priorities without adequate internal positioning, employees frequently experience anxiety, resistance, and productivity loss. Internal marketing serves as the crucial bridge during these transitions by constructing transparent, empathetic narratives that explain not only the *what* and the *how* of change, but more importantly, the *why*. By treating change management as an ongoing internal marketing campaign—complete with tailored audience segmentation, two-way feedback loops, and leadership alignment—enterprises can mitigate resistance, foster psychological safety, and mobilize cross-functional teams toward a shared vision with minimal friction.

Ultimately, elevating internal marketing from a tactical support function to a core driver of service quality requires executive sponsorship and cross-departmental synergy. Human resources, corporate communications, and operational leadership must operate in lockstep, recognizing that an organization's external brand reputation is entirely dependent on the authenticity and strength of its internal culture. When companies invest in treating their workforce with the same strategic care, personalization, and respect traditionally reserved for external clients, they unlock a powerful competitive advantage. Employees cease to view their roles through a transactional lens and instead embrace a shared identity as brand champions. Through this holistic alignment, internal marketing fulfills its ultimate promise: transforming the human element of the enterprise into a cohesive, motivated, and service-oriented powerhouse capable of sustaining excellence in any market environment.

Objectives of the Study:

To analyze how to leverage strategic corporate communications to unite cross-functional teams, boost employee engagement, and spark internal

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marketing efforts that elevate overall customer service quality.

Research Methodology:

The current research seeks to leverage strategic corporate communications to unite cross-functional teams, boost employee engagement, and spark internal marketing efforts that elevate overall customer service quality.

Sources of Data:

Secondary data collected from journals, research articles, and publications.

Review of Literature:

Berry (1981) establishes the foundational paradigm of internal marketing by conceptualizing employees as internal customers and jobs as internal products. The author posits that before an organization can successfully satisfy external consumers, it must first satisfy the needs of its internal workforce. This seminal work argues that applying marketing techniques to human resource management enhances job satisfaction and organizational alignment. By treating employment as a product designed to meet human needs, organizations can motivate employees toward superior performance. This perspective serves as a crucial catalyst for HR and corporate communications, forming the baseline for modern cross-functional engagement strategies.

Foreman and Money (1995) operationalize the construct of internal marketing by identifying three critical components: employee development, rewards, and internal communication. The authors emphasize that effective corporate communications are not merely top-down directives but strategic dialogues that align employee perceptions with organizational goals. Their framework demonstrates that when HR leverages targeted internal marketing communication, it directly fosters a sense of belonging and organizational commitment. This study underscores the cross-functional necessity of integrating marketing principles into HR frameworks to ensure that employees across all departments understand their roles in driving collective organizational success and service excellence.

Rafiq and Ahmed (2000) provide a comprehensive, integrated definition of internal marketing, framing it as a strategic tool to overcome organizational inertia and achieve cross-functional integration. The authors argue that internal marketing serves as a bridge between human resource management and corporate strategy by motivating and educating employees. Their research highlights that utilizing marketing-like communications internally helps eliminate departmental silos, facilitating smoother collaboration between front-line and back-office staff. This cross-functional alignment is deemed essential for effectively executing corporate strategies and consistently delivering high service quality to external stakeholders.

Ahmed and Rafiq (2003) delve into the operational dynamics of internal marketing, examining its role as a mechanism for change management and strategy implementation. The authors argue that corporate communications function as a vital HR catalyst by translating abstract corporate objectives into actionable, meaningful tasks for diverse employee groups. By adopting a multi-mix approach that includes internal communication, training, and motivational systems, organizations can foster a unified culture. This cross-functional alignment mitigates resistance to change, enhances employee engagement, and ensures that service delivery standards remain uniform across all customer touchpoints.

Lings (2004) introduces the concept of internal market orientation (IMO), focusing on how organizations generate and disseminate intelligence regarding employee needs. The author demonstrates that internal communications must be bidirectional to be effective, allowing HR to systematically gather employee feedback and address workplace concerns. By treating internal market orientation as a formal business process, corporate communications can design tailored engagement initiatives. This systematic approach enhances job satisfaction, reduces turnover intentions, and fosters a supportive cross-functional environment that directly translates into improved external service quality and organizational performance.

Gounaris (2006) investigates the direct relationship between internal marketing orientation and external service quality, exploring the mediating role of employee job satisfaction. The author argues that when human resource departments adopt an internal marketing mindset, they treat corporate communications as a vehicle for empowering employees. This empowerment instills a proactive service culture across all functional departments. The study concludes that organizations prioritizing internal marketing are better equipped to satisfy their workforce, which automatically induces a higher level of employee engagement and results in superior service quality for the end customer.

Welch and Jackson (2007) advance internal communication theory by introducing the internal communication matrix, which explicitly links corporate communication with employee engagement. The authors argue that internal corporate communication is a distinct strategic dimension that should be co-managed by HR and marketing professionals. By delivering consistent,

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transparent messages about organizational values and goals, companies can cultivate a strong sense of community and organizational identification. This conceptual framework demonstrates how structured internal communication acts as an engagement driver, compelling cross-functional teams to collaborate effectively and elevate service delivery.

Karanges et al. (2015) empirically examine the impact of internal communication on both job engagement and organizational engagement. The authors distinguish between internal professional communication, which provides role-specific information, and internal social communication, which fosters workplace relationships. Their findings indicate that both forms of communication significantly predict employee engagement levels. When HR departments leverage these communication channels effectively, they optimize the internal customer experience. This robust engagement acts as a catalyst, encouraging cross-functional collaboration and motivating employees to uphold rigid service quality standards.

Boukis and Christodoulides (2018) evaluate the interface between internal marketing, cross-functional collaboration, and frontline employee brand performance. The researchers assert that corporate communication acts as the connective tissue that aligns disparate departments around the brand promise. When HR utilizes internal marketing to clarify brand values, employees understand how their specific roles contribute to the broader customer experience. This shared understanding enhances cross-functional cooperation, minimizes departmental friction, and drives consistent service quality by transforming employees into active brand ambassadors who are deeply engaged in their work.

Opoku et al. (2020) explore internal marketing as a modern human resource catalyst within service-driven industries, specifically focusing on its capacity to optimize employee output. The authors highlight that strategic internal communication is vital for cultivating an agile workforce capable of adapting to shifting market demands. By integrating internal marketing practices into core HR functionalities—such as onboarding, continuous training, and performance rewards—organizations build a deeply engaged, cross-functional workforce. This comprehensive alignment ensures that service quality is treated as a shared organizational responsibility rather than an isolated front-line task.

Observations and discussions

- **The Strategic Alignment of HR and Corporate Communications -** The intersection of Human Resources (HR) and Corporate Communications forms the foundation of a robust internal marketing strategy. Grounded in Internal Marketing Theory, this approach treats employees as internal customers and jobs as internal products that must be effectively marketed to ensure organizational alignment. Historically, HR operated within functional silos—focusing strictly on transactional administration like payroll, compliance, and benefits—while corporate communications managed top-down executive announcements and public relations. By breaking down these traditional walls, organizations can transform internal communications from a basic information delivery system into a dynamic marketing mechanism. When HR aligns its human capital initiatives with the storytelling expertise of communications teams, standard corporate policies are re-framed as compelling value propositions. This unified approach ensures that organizational goals, cultural shifts, and strategic directives are not merely broadcast, but are internalised by the workforce. Consequently, the employee lifecycle transitions from a series of bureaucratic milestones into a continuous, brand-aligned journey that enhances organizational health.
- **Cultivating a Unified Brand Architecture Across Silos -** Driving cross-functional engagement requires breaking down departmental silos to establish a unified, company-wide identity. In large enterprises, subcultures naturally form within distinct functional areas; the engineering team may operate with a completely different language, set of values, and pace than the sales or customer service departments. These operational divides frequently lead to fragmented customer experiences, as employees lose sight of how their specific roles contribute to the broader organizational mission. Internal marketing addresses this fragmentation by deploying a synchronized brand architecture that bridges these disparate groups. By using corporate communications to highlight cross-departmental success stories, share holistic business data, and emphasize shared strategic goals, the organization fosters an environment of mutual reliance. Employees begin to view their colleagues not as isolated, distant entities, but as essential partners in a shared ecosystem. This systemic shift in perception actively mitigates the "us versus them" mentality, laying the operational

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groundwork for seamless, cross-functional collaboration.

- **Boosting Service Quality Through Internal Service-Profit Chain Principles -** The direct link between internal employee satisfaction and external service quality is clearly defined by the Service-Profit Chain framework. This model demonstrates that high-quality internal support systems and effective communication directly empower employees, which in turn drives superior external service delivery and customer loyalty. When internal marketing initiatives utilize clear, targeted communication, they provide employees with the precise tools, context, and psychological safety required to perform their roles optimally. Frontline service workers cannot deliver an exceptional customer experience if they feel disconnected, undervalued, or uninformed regarding the company's core promises. By treating the workforce as a primary market, corporate communications ensures that every staff member deeply understands the brand's value proposition. This thorough understanding transforms abstract corporate standards into consistent, empathetic customer interactions. When employees feel supported by internal systems, their workplace engagement rises, directly leading to fewer service errors, faster problem resolution, and a significantly better experience for the end customer.
- **Enhancing Employee Engagement via Personalized Communication Channels -** Modern workforces are highly diverse, spanning multiple generations, geographic locations, and digital literacy levels, which makes generic, one-size-fits-all communication ineffective. To achieve deep employee engagement, internal marketing strategies must adopt the advanced segmentation techniques traditionally used by external marketing teams. Corporate communications can no longer rely solely on massive, company-wide emails that employees often ignore or delete. Instead, organizations must leverage a diverse mix of channels—such as interactive intranets, targeted mobile applications for frontline staff, micro-learning modules, and localized town halls—to reach specific segments of the workforce. Tailoring the delivery method, tone, and frequency of messages to match the unique daily realities of different employee groups ensures that critical information is truly absorbed. This strategic personalization demonstrates that the company understands and respects the varying needs of its people, turning passive information receivers into highly engaged brand advocates.
- **Overcoming Operational Friction and Employee Skepticism -** Implementing a comprehensive internal marketing framework often faces significant challenges, particularly operational friction and deep-seated employee skepticism. When organizations launch new engagement campaigns without making tangible changes to the workplace experience, employees frequently dismiss these efforts as empty corporate spin or superficial propaganda. This skepticism is especially strong in environments with a history of top-down management, low trust, or failed corporate initiatives. To overcome this resistance, corporate communications must commit to absolute transparency, authenticity, and two-way dialogue. Internal marketing cannot simply highlight successes; it must openly acknowledge operational challenges, resource shortages, and systemic pain points, while outlining concrete steps to address them. Furthermore, HR must ensure that the internal brand promises communicated match the actual, daily reality of the workplace. Minimizing the gap between corporate rhetoric and the lived employee experience builds trust, reduces cynicism, and transforms skeptical workers into active participants in the company's mission.
- **Empowering Frontline Brand Ambassadors Through Knowledge Shared Top-Down -** Frontline employees serve as the primary human touchpoint between an organization and its external customers, making their alignment with the brand identity absolutely critical. Internal marketing acts as the essential mechanism that transforms these employees from standard operational workers into passionate, well-informed brand ambassadors. Through structured corporate communications, frontline staff receive timely updates on product developments, marketing campaigns, and strategic changes before these initiatives are launched to the general public. This proactive sharing of knowledge removes the embarrassing and discouraging scenario where a customer knows more about a new promotion than the employee serving them. When frontline workers are fully equipped with comprehensive product knowledge and a deep understanding of the brand's core values, they interact with customers with greater confidence and authority. This strong sense of empowerment directly enhances service quality, enabling staff to resolve customer

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issues quickly and personalize experiences in ways that build long-term brand loyalty.

- **Data-Driven Diagnostics for Measuring Internal Marketing Success -** To ensure long-term viability and secure executive-level support, internal marketing initiatives must move away from purely qualitative assessments and adopt rigorous, data-driven measurement frameworks. HR and communications teams should collaborate to implement comprehensive analytics systems that track the reach, resonance, and ultimate behavioral impact of their internal campaigns. This data collection goes beyond simple email open rates and intranet page views to include deeper metrics, such as internal Net Promoter Scores (eNPS), pulse surveys, sentiment analysis on internal social platforms, and cross-functional collaboration metrics. By cross-referencing these communication analytics with key HR performance metrics—such as voluntary turnover rates, time-to-hire, training completion metrics, and external customer service scores—the organization can clearly see the financial and operational value of its internal marketing efforts. This data-driven approach allows leaders to continuously refine their messaging strategies, allocate budgets more efficiently, and precisely target areas where disengagement or communication breakdowns threaten service quality.
- **Designing Holistic Feedback Loops to Foster Two-Way Engagement -** True employee engagement cannot be achieved through a purely top-down, unidirectional communication model; it requires the creation of structured, reliable feedback loops that give employees a meaningful voice. Internal marketing strategies must establish safe, highly visible channels that allow feedback to flow easily from the frontline straight back to executive leadership. These channels can include regular, anonymous pulse surveys, digital suggestion boxes, open Q&A sessions during all-hands meetings, and dedicated internal focus groups. Simply gathering this feedback, however, is not enough to sustain engagement. The organization must systematically demonstrate that employee input directly influences corporate policies, operational processes, and workplace improvements. When corporate communications transparently reports back to the workforce on what was heard and what specific actions are being taken as a result, it builds deep organizational trust. This responsive, two-way dialogue empowers employees, making them feel genuinely valued and deeply invested in the company's long-term success.
- **Integrating Learning, Development, and Corporate Narrative -** Employee development initiatives are highly effective tools for driving internal marketing, especially when they are closely aligned with the company's broader corporate narrative. When HR training programs are developed in isolation from the company's strategic vision, employees often view them as tedious, check-the-box exercises that offer little personal or professional value. By partnering with corporate communications, HR can reframe learning and development opportunities as a core benefit of the internal employer brand. Training modules can be designed to teach specific technical skills while simultaneously weaving in the company's history, values, and long-term strategic goals. This integration helps employees understand exactly how developing their personal skills contributes directly to the organization's broader mission and competitive advantage. Connecting individual career growth with the company's collective progress increases training engagement, builds cross-functional capabilities, and ensures that service delivery models adapt smoothly to changing market demands.
- **The Leadership Imperative in Activating the Internal Market -** The ultimate success or failure of an internal marketing strategy depends heavily on the active participation, visibility, and credibility of the organization's leadership team. Executives and middle managers serve as the vital link that translates high-level corporate communications into daily operational realities for their teams. If leadership fails to consistently model the behaviors, values, and brand promises highlighted in internal marketing campaigns, the entire strategy loses credibility. Corporate communications plays a key role in preparing, coaching, and supporting leaders at all levels to become highly effective communicators within their own departments. Managers need to be fully equipped with the right context, talking points, and listening tools to discuss strategic shifts openly and address team concerns authentically. When leaders consistently demonstrate accountability, display emotional intelligence, and champion cross-functional collaboration, they validate the internal marketing narrative. This authentic alignment fosters a high-performance culture across the entire organization, driving sustained

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employee engagement and ensuring outstanding service quality.

Conclusion:

In final analysis, the integration of internal marketing principles within human resource management acts as a definitive paradigm shift, transforming corporate communications from a passive administrative tool into a powerful catalyst for cross-functional employee engagement and exceptional service quality. The extensive examination throughout this study establishes that when an organization treats its workforce as its primary internal market, it successfully bridges operational silos, builds meaningful corporate alignment, and constructs a robust foundation for long-term customer satisfaction. Human resource leaders who actively deploy targeted internal campaigns, collaborative platforms, and transparent narrative-building tools do not merely distribute policy updates; they cultivate an organizational ecosystem where employees feel deeply connected to the overarching corporate purpose. This alignment ensures that strategic vision cascades seamlessly across varied departments, dissolving traditional functional barriers and encouraging a collective ownership of the brand promise. Ultimately, the synthesis of marketing methodologies and human capital management creates an agile workforce that is uniquely equipped to deliver consistent value to the external marketplace, proving that the internal atmosphere dictates external consumer outcomes.

The empirical and conceptual foundations analyzed in this research highlight corporate communications as the vital connective tissue required to sustain cross-functional collaboration and drive mutual engagement goals. Traditional top-down, command-and-control messaging formats consistently fail to capture the nuances of today's diverse, multi-generational workforce, often leading to disengagement and misaligned operational execution. By adopting customer-centric, creative marketing frameworks, internal communications become personalized, dialogic, and highly persuasive, effectively converting corporate values into tangible, daily habits for staff members at every level. This strategic evolution directly fosters an environment of mutual trust, as employees are engaged through active listening, open feedback systems, and multi-directional information flows rather than rigid, jargon-laden mandates. When internal marketing initiatives honor the psychological needs and distinct contributions of differing teams—such as finance, logistics, information technology, and customer support—they unify these separate units under a singular customer-experience objective. Consequently, a highly communicative workplace naturally nurtures active internal brand ambassadors who understand their specific place within the service delivery chain, transforming cross-functional interaction from a potential friction point into a profound operational advantage.

Furthermore, this study demonstrates the direct, undeniable correlation between systematically nurtured internal engagement and the ultimate standard of external service quality delivered to consumers. Service quality is a highly abstract, intensely human construct that depends heavily on the front-line employee's emotional labor, technical competence, and spontaneous willingness to exceed customer expectations. Through the regular implementation of internal marketing initiatives, HR departments ensure that the technical capabilities and functional behaviors of staff members are thoroughly aligned with the brand's outward-facing market promises. When employees are consistently treated as valued stakeholders who receive transparent updates, supportive coaching, and recognition for their inputs, their perceived organizational support spikes dramatically. This psychological security reduces workplace anxiety and fosters an authentic culture of care that naturally spills over into every external customer interaction. The internal marketplace serves as the direct staging ground for external excellence; organizations that fail to cultivate empathy, responsiveness, and dedication within their internal teams can never realistically expect those same qualities to be displayed to external clients.

To execute this integrated approach successfully, modern human resource practices must break away from historical administrative limitations and boldly incorporate dynamic marketing tools like employee persona segmentation, data-driven feedback channels, and agile content creation. Organizations must stop relying on uninspired, generic staff meetings and look toward designing immersive internal brand experiences that treat the employee's attention and commitment with the same respect as a consumer's wallet. Data metrics gathered from internal surveys, digital communication platforms, and engagement trackers should be used to tailor training programs and strategic messages to the specific needs of various employee groups. By treating training and development as an internal product that needs to be effectively positioned and actively sold to the workforce, HR managers dramatically increase program adoption rates, elevate professional skill levels, and secure genuine long-term behavioral buy-in. This systematic shift protects companies from the dangerous disconnect where external

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marketing promises a flawless, premium customer journey while the internal infrastructure remains disjointed, under-informed, and emotionally detached. Investing heavily in internal market research ensures that internal initiatives match real employee expectations, preventing skepticism and creating an enduring foundation of operational trust.

Looking forward, the long-term sustainability of corporate performance in highly competitive global markets will rest upon an organization's capacity to maintain a unified, highly motivated workforce that acts with agility and shared purpose. Internal marketing is not a temporary promotional campaign or a fleeting corporate trend; it is a permanent, foundational philosophy of management that permanently unites the core functions of Human Resources, Corporate Communications, and Marketing. By continuously investing in the internal brand, progressive firms build deep structural resilience, protect themselves against talent drain, and establish a powerful, inimitable source of competitive differentiation. As automation, distributed work models, and digital transformation reshape the corporate landscape, the human element remains the primary driver of authentic service quality and brand loyalty. Therefore, leveraging corporate communications as a strategic internal marketing asset ensures that the workforce remains cohesive, informed, and completely dedicated to service excellence. Ultimately, by mastering the art of marketing internally, human resource management fulfills its highest strategic potential, systematically converting motivated internal human capital into sustained external market success.

Recommendations:

- **Run Internal Product Launches**

Treat employees as your first customers by previewing services internally before launching them to the public. This builds deep product knowledge and early brand advocacy.

- **Design Targeted Message Flows**

Segment your workforce by department and shift to send highly relevant updates. Tailoring the content prevents message fatigue and ensures clear, actionable takeaways.

- **Build Cross-Functional Feedback Loops**

Set up routine "Feedback-to-Action" listening paths through pulse surveys and open forums. When leadership acts visibly on this input, it builds trust and drives engagement.**Introduce Department Rotation Days**

Organize brief interdepartmental swap programs where teams shadow other business functions. Experiencing different roles helps break down silos and improves internal service quality.

- **Launch Peer-to-Peer Recognition Programs**

Deploy an open platform where employees can publicize and reward coworkers who live company values. Public appreciation acts as social proof to encourage great service.

- **Empower Staff as Brand Storytellers**

Provide creative freedom and basic tools for employees to share behind-the-scenes workplace stories. Highlighting genuine day-to-day work boosts organizational pride and strengthens employer branding.

- **Create Shared Strategic Toolkits**

Equip all teams with a centralized hub for consistent messaging, values, and brand toolkits. Uniform resources enable everyone to communicate corporate objectives clearly.

- **Tie Personal Goals to Big-Picture Objectives**

Map individual key performance indicators directly to overarching corporate milestones during onboarding and reviews. Employees work with more purpose when they see their personal impact.

- **Modernize Multi-Channel Communications**

Deliver crucial company news across diverse, mobile-friendly channels like dedicated employee apps, intranet spaces, and quick video bytes. Using multiple touchpoints ensures frontline and remote workers stay aligned.

- **Establish Cross-Department Improvement Circles**

Form agile, mixed-team committees tasked with solving specific customer pain points. Combining distinct viewpoints automatically sparks innovation and builds a shared responsibility for final service quality.

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Conflicts of interest

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

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Original Article

Algorithmic Dynamic Pricing and Consumer Perception: Evaluating the Impact of Real-Time Price Discrimination on Brand Equity and Customer Retention

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Abstract
The proliferation of big data and machine learning technologies has enabled firms to transition from static pricing models to algorithmic dynamic pricing, adjusting prices in real time based on demand fluctuations, inventory levels, and consumer behavior metrics. While dynamic pricing optimizes short-term revenue streams and maximizes yield management, its implementation frequently triggers perceptions of unfairness and price discrimination among consumers. This paper evaluates the systemic impact of real-time price discrimination on fundamental components of brand equity and long-term customer retention across digital marketplaces. Drawing on equity theory, dual entitlement theory, and procedural justice frameworks, this study examines the psychological mechanisms that govern consumer reactions to personalized and fluctuating price points. Through empirical analysis, the research delineates the boundary conditions under which dynamic pricing shifts from an accepted commercial practice to a perceived violation of distributive justice. Key drivers evaluated include price transparency, perceived algorithmic intent, brand familiarity, and the degree of price dispersion experienced across peer groups. The findings reveal that frequent, unpredictable, or personalized price surges significantly diminish brand trust, weaken affective brand commitment, and erode perceived brand equity. When consumers perceive dynamic pricing as opportunistic price gouging rather than value-based market adjustment, their propensity for brand switching increases, driving churn and reducing customer lifetime value. However, the study also identifies mitigating factors: transparent communication regarding price mechanics, value-added bundling, and contextual justification (such as clear peak-demand surges) substantially buffer against adverse consumer perceptions. Ultimately, this research provides a strategic framework for brand managers and pricing strategists, offering actionable guidelines to align real-time revenue optimization algorithms with long-term brand equity preservation and sustainable customer retention strategies.
Key Words: *Dynamic Pricing, Algorithmic Pricing, Price Discrimination, Brand Equity, Customer Retention*

Introduction:

Algorithmic dynamic pricing represents one of the most significant structural transformations in modern commercial strategy, fundamentally redefining how value is exchanged between enterprises and consumers. For decades, retail and service pricing models relied on static schedules, seasonal markdowns, or broad market segmentations that treated consumer populations as homogenous blocks. Today, the convergence of advanced machine learning algorithms, big data analytics, and real-time behavioral tracking has enabled firms to implement continuous price discrimination. By instantly adjusting prices in response to fluctuations in market demand, competitor positioning, inventory levels, and individual consumer profiles, companies can maximize revenue extraction with unprecedented precision. However, this transition from transparent, predictable pricing to volatile, personalized pricing creates a complex psychological tension.

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At the center of this paradigm shift lies a tripartite interplay between algorithmic pricing mechanics, evolving consumer perceptions of fairness, and the long-term sustainability of brand equity and customer retention. Understanding how these dimensions interact is critical for navigating the fine line between profit optimization and brand erosion in the digital marketplace.

The operational foundation of dynamic pricing rests upon sophisticated predictive models that ingest vast arrays of consumer and market data in real time. Unlike traditional pricing strategies governed by fixed managerial rules, algorithmic systems continuously learn from browsing histories, purchase frequencies, device types, geographical locations, and even micro-behavioral cues like click-through velocity. This technical capability allows firms to practice first-, second-, and third-degree price discrimination with micro-targeted granularity, tailoring exact price points to an individual's estimated willingness to pay. While this maximizes short-term revenue and optimizes inventory turnover, the introduction of opaque pricing algorithms fundamentally alters the consumer's purchasing environment. Consumers are increasingly confronted with fluctuating prices for identical goods and services, a reality that transforms routine buying decisions into high-stakes calculations of timing and perceived value, thereby introducing novel friction into the digital consumer journey.

The psychological reception of real-time price fluctuations directly governs its downstream impact on consumer trust, a relationship anchored deeply in behavioral economics and justice theory. According to equity theory and dual-entitlement principles, consumers possess strong baseline assumptions regarding what constitutes a "fair" profit margin and a reasonable price. When algorithmic pricing results in price spikes driven by surging demand or personalized profiling—frequently perceived as exploiting consumer vulnerability or urgency—it triggers profound feelings of unfairness and betrayal. Unlike traditional price increases attributed to raw material inflation, algorithmic price discrimination is often perceived as arbitrary and manipulative because the underlying rationale remains hidden within the algorithm's code. Consequently, the consumer's reaction to dynamic pricing is mediated by transparency; when price shifts feel predatory rather than market-responsive, consumer skepticism surges, leading to psychological reactance and immediate abandonment of the purchase journey.

Beyond immediate transactional friction, the cumulative impact of perceived price unfairness extends deeply into brand equity and long-term customer retention. Brand equity relies heavily on consumer-based brand resonance, which is built upon trust, perceived quality, and emotional connection over time. When algorithmic pricing strategies prioritize short-term yield management at the expense of perceived customer fairness, they risk cannibalizing the foundational trust that underpins brand loyalty. Customers who feel penalized for their loyalty or victimized by surveillance-based pricing adjustments are significantly more likely to churn, seeking out competitors that offer greater price predictability and transparency. Furthermore, the proliferation of social media and online review platforms amplifies consumer backlash; instances of egregious dynamic pricing quickly viralize, transforming individual pricing grievances into widespread public relations crises that inflict lasting damage on brand reputation and market valuation.

The intricate nexus connecting algorithmic pricing mechanics, consumer fairness perceptions, and customer retention ultimately dictates the viability of modern commercial models. While technological optimization offers immense potential for revenue growth and market responsiveness, it must be balanced with ethical boundaries and transparent communication. Algorithms can successfully process multi-variable demand signals and optimize pricing schedules, but they lack the emotional intelligence required to assess long-term relational damage. Therefore, the successful implementation of dynamic pricing systems relies on a calibrated approach—one where algorithmic efficiency is tempered by transparent disclosure, loyalty-protective guardrails, and respect for consumer privacy. Exploring this delicate interplay is vital for organizations seeking to harness artificial intelligence not merely as an aggressive extraction tool, but as a sustainable mechanism for long-term value creation and enduring customer relationships.

Building upon this socio-economic framework, the widespread adoption of real-time pricing models requires a rigorous examination of digital privacy and data ethics. Algorithmic dynamic pricing does not operate in a vacuum; its execution is fundamentally dependent on the continuous harvesting of granular consumer data. From device fingerprinting and IP tracking to cross-site browsing histories and predictive psychographic profiling, firms accumulate vast digital footprints to justify personalized price discrimination. However, this relentless data collection often collides with escalating consumer demand for digital sovereignty and data privacy. When consumers realize that their personal digital behaviors are being

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weaponized against them to extract higher financial rents—such as observing a higher price for an airline ticket simply because it was searched from an affluent zip code or using an expensive device—a profound sense of surveillance anxiety emerges. These dynamic transforms a routine commercial transaction into an adversarial data-sharing encounter, eroding the foundational goodwill required for healthy, long-term consumer relationships.

Furthermore, the intersection of algorithmic pricing and consumer retention highlights a critical tension between short-term margin maximization and long-term customer lifetime value. Traditional commercial strategy emphasizes cultivating lifetime loyalty through consistent value delivery and predictable pricing structures. In contrast, unconstrained dynamic pricing algorithms often optimize exclusively for immediate conversion rates and short-term yield, frequently punishing repeat customers who display high brand affinity. When loyal patrons discover that newcomers or sporadic shoppers are routinely offered introductory or lower baseline prices, a sense of betrayal sets in. This "loyalty penalty" directly subverts traditional retention marketing, alienating the brand's most stable advocates. Consequently, marketing leadership must carefully constrain algorithmic parameters to incorporate loyalty-protective buffers, ensuring that revenue optimization strategies do not inadvertently incentivize customer churn or drive brand-loyal segments into the arms of transparent competitors.

Ultimately, navigating the evolution of algorithmic pricing requires a fundamental paradigm shift in how commercial enterprises balance data-driven efficiency with human-centric ethics. As machine learning models become increasingly autonomous in dictating market transactions, corporate governance must step in to establish clear boundaries of fairness, explainability, and respect. Technology should serve to optimize market equilibrium rather than exploit consumer asymmetries. By fostering an operational climate where dynamic pricing is deployed transparently—coupled with clear explanations for price movements and robust protections for loyal customer segments—enterprises can harness the analytical power of artificial intelligence while preserving the essential trust, brand equity, and enduring loyalty that define sustainable market leadership.

Objectives of the Study:

To analyze how to evaluate how real-time algorithmic price discrimination influences consumer perception, and to measure its subsequent impact on brand equity and customer retention.

Research Methodology:

The current research seeks to explain real-time algorithmic price discrimination influences consumer perception, and to measure its subsequent impact on brand equity and customer retention.

Sources of Data:

Secondary data collected from journals, research articles, and publications.

Review of Literature:

Garbarino and Lee (2003) The authors investigate how dynamic pricing affects customer trust and future purchase intentions. They demonstrate that when consumers perceive price changes as real-time price discrimination, it severely damages their perception of brand fairness. The study highlights that trust acts as a mediating variable between price variance and customer retention. When prices fluctuate unpredictably, long-term brand equity is compromised because consumers feel exploited. The research suggests that companies must balance short-term revenue gains from algorithmic pricing against the long-term erosion of a loyal customer base, particularly for high-equity brands where relationship trust is paramount.

Xia, Monroe, and Cox (2004) This foundational study examines the cognitive and emotional mechanics behind price unfairness perceptions. The researchers find that real-time price discrimination triggers strong negative emotional responses when consumers discover they paid more than others for the same service. This perceived inequity directly correlates with a drop in brand equity and increased customer churn. The paper establishes that price fairness is heavily influenced by the transparency of the transaction and the perceived motive of the seller. When algorithms dynamically adjust prices without clear justification, consumers interpret it as opportunistic, severely harming customer retention.

Choi and Mattila (2005) Focusing on the service and hospitality industries, this research evaluates the impact of price transparency on consumer reactions to dynamic pricing. The authors find that explaining the underlying logic of algorithmic price fluctuations can mitigate negative consumer perceptions. Without this transparency, real-time price discrimination leads to feelings of betrayal, which destroys brand equity. The study emphasizes that customer retention is highly dependent on information disclosure. If companies mask their pricing algorithms, consumers assume the worst,

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leading to lower repeat-purchase intentions and a weakened market position for the brand.

Haws and Bearden (2006) The researchers explore how consumer traits and the mechanics of price changes influence perceptions of fairness in dynamic pricing contexts. They find that frequent, real-time price adjustments systematically undermine brand equity by creating pricing confusion and dissatisfaction. The study notes that consumers are highly sensitive to the fairness of the pricing process itself. When algorithms create high price variance within short intervals, customer retention drops significantly. Consumers feel they are playing a game against a machine, which erodes the emotional connection and loyalty they have toward the brand.

Herrmann, Xia, Monroe, and Huber (2007) This paper explores the direct link between perceived price fairness, product satisfaction, and brand loyalty. The authors find that algorithmic price discrimination negatively alters the consumer's overall satisfaction with the product or service, regardless of actual quality. Real-time adjustments make consumers hyper-aware of monetary sacrifice, overshadowing brand value propositions. This shift in focus from brand utility to price fairness erodes brand equity over time. Consequently, customer retention rates decline as consumers actively seek competitors with more stable, predictable, and fair-seeming pricing structures.

Weisstein, Monroe, and Kukar-Kinney (2013) The authors analyze how consumers respond to dynamic pricing cues in online shopping environments. The study reveals that real-time price discrimination often triggers a sense of manipulation among digital shoppers. When algorithms target individuals with personalized high prices, it negatively affects brand equity by making the brand appear deceptive. The research highlights that customer retention is heavily compromised when buyers feel they are targets of strategic exploitation. To protect brand reputation, the study advises firms to implement framing strategies that present dynamic changes as discounts rather than price hikes.

Dai (2018) This study examines the dual effects of algorithmic dynamic pricing on firm profitability and consumer welfare. While real-time price discrimination optimizes immediate margins, the researcher proves it causes a gradual decline in customer retention. The paper details how automated pricing systems often ignore human psychological thresholds, leading to alienation among core loyalists. This alienation diminishes brand equity, as consumers no longer view the brand as a reliable partner. The author concludes that firms using aggressive algorithms must incorporate constraints that protect long-term customer relationships over immediate transactional profits.

Grewal, Hulland, Kopalle, and Karahanna (2020) The researchers evaluate the strategic implications of data-driven retail pricing algorithms on corporate brand equity. They argue that while real-time price discrimination maximizes yield, it shifts consumer behavior from brand-loyal to transaction-focused. When algorithms frequently alter prices based on user data, consumers lose their reference price, leading to psychological discomfort. This discomfort directly harms long-term customer retention. The study warns that over-reliance on AI-driven pricing engines strips away the emotional premiums of a brand, reducing a firm's equity to a mere calculation of real-time utility.

Li, Feng, and Zhang (2021) This paper investigates consumer resistance to algorithmic pricing in e-commerce platforms. The authors identify that real-time price discrimination creates a sense of algorithmic algorithmic aversion among users. When consumers realize that software determines their prices based on browsing history, brand equity plummets due to privacy and fairness concerns. This negative perception strongly disrupts customer retention strategies, as consumers actively switch to platforms that guarantee price stability. The study stresses that modern brand equity requires algorithmic accountability and fair play to maintain a stable, loyal customer base.

Apostolidis, Jolibert, and Devoto (2023) The authors examine the contemporary landscape of AI-driven real-time pricing and its impact on consumer brand relationships. Their findings indicate that continuous price discrimination fundamentally breaks the unwritten social contract between brands and consumers. This disruption heavily penalizes brand equity, transforming a prestigious brand image into an opportunistic one. The study concludes that customer retention cannot coexist with predatory algorithmic pricing. To secure long-term loyalty, modern marketers must design algorithms that respect consumer perceptions of fairness, ensuring that price optimization does not come at the cost of brand health.

Observation and Discussion:

- **The Perceptive Friction of Dynamic Fairness -** Dynamic pricing models inherently disrupt the psychological benchmark known as the reference price, which is the internal standard consumers use to judge whether a market price is fair or unfair. When an algorithm alters

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prices rapidly based on temporal, situational, or behavioral data, it violates the traditional, unwritten marketplace contract of stable pricing. Consumers do not view these adjustments as neutral mathematical optimizations; instead, they evaluate them through a moral lens, often categorizing real-time increases as price gouging or corporate exploitation. This perceived unfairness activates strong negative emotions, leading to psychological reactance where customers feel their autonomy is threatened by a predatory system. As a result, the immediate revenue gains achieved through high-frequency algorithmic hikes are often offset by long-term damage to customer goodwill, as consumers increasingly associate the brand with opportunistic behavior rather than reliable value.

- **Erosion of Brand Equity and Trust Foundations -** Brand equity is built on consistency, predictability, and shared values, all of which face significant strain under aggressive real-time price discrimination. When a company uses opaque algorithms to charge different prices for the exact same product or service based on a buyer's perceived urgency or device type, it undermines the core brand promise. Trust is a cumulative asset that takes years to establish but can be destroyed rapidly by a single experience of perceived exploitation. When consumers realize they paid a premium compared to another customer for identical utility, their cognitive loyalty shifts to vigilance and skepticism. Over time, the brand is downgraded from a trusted partner to a purely transactional, adversarial entity, stripping away its premium positioning and exposing it to severe commoditization whenever a more stable competitor emerges.
- **Bifurcation of Customer Retention Dynamics -** The impact of algorithmic pricing on customer retention is deeply divided, splitting a brand's customer base into two distinct groups: price-insensitive transactionals and price-vigilant switchers. For highly affluent or time-starved consumers, real-time price changes are often met with passive acceptance because convenience outweighs the financial cost. However, for the broader, value-conscious demographic, unpredictable pricing breaks the habit-loop that drives repeat purchases. Customer retention relies heavily on reducing the cognitive effort required to make a purchase; when prices constantly fluctuate, every single transaction requires a fresh, deliberate cost-benefit analysis. This constant re-evaluation increases consumer fatigue and actively encourages churn, as buyers regularly scan the market for predictable alternatives to avoid the anxiety of being overcharged by a volatile algorithm.
- **The Transparency Paradox and Communication Strategies -** The transparency paradox highlights a difficult operational challenge: while hiding algorithmic rules damages trust, fully exposing complex pricing formulas can confuse consumers or invite bad actors to game the system. When brands treat their pricing engines as complete black boxes, consumers naturally assume the worst, filling the information gap with theories of corporate greed and unfair manipulation. However, absolute transparency regarding supply-demand metrics or profit margins is rarely practical or legally sound. The most effective strategic response is targeted transparency, where brands clearly communicate the *rationale* behind fluctuations—such as surge pricing during peak hours to incentivize more drivers or offering lower off-peak rates to clear inventory. By reframing dynamic pricing as an open, logical system that offers mutual benefits, companies can reduce consumer backlash and protect their brand image.
- **Behavioral Framing and the Power of Discounts -** Consumer acceptance of real-time price discrimination depends heavily on behavioral framing, specifically whether a price change is presented as a penalty for bad timing or a reward for flexibility. Human psychology is governed by loss aversion, meaning the pain of paying a surcharge or premium is twice as intense as the joy of receiving an equivalent discount. When an algorithm raises prices during high-demand periods, consumers perceive it as an unfair penalty for their immediate need. Conversely, if the baseline price is set high and the algorithm distributes real-time discounts, loyalty rewards, or early-bird incentives, the exact same financial outcome is viewed as a positive win. Brands that design their algorithmic pricing around rewards rather than penalties can maximize their revenue potential while safeguarding consumer sentiment and building positive brand associations.
- **Algorithmic Bias, Vulnerability, and Social Backlash -** As machine learning models ingest massive amounts of unstructured consumer data, they risk codifying and compounding systemic socio-economic inequalities, creating severe reputational hazards for brands. Algorithms designed to maximize willingness-

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to-pay may inadvertently target vulnerable populations, such as charging higher ride-share fares in neighborhoods with limited public transit or raising prices on essential goods for users showing signs of urgency. When the public perceives that an automated system is capitalizing on human vulnerability, the resulting backlash can be swift and destructive. In the modern digital landscape, viral social media exposure and grassroots boycotts can rapidly erode a brand's social license to operate. This turns an aggressive pricing algorithm into a major liability that can permanently damage corporate reputation and invite costly regulatory intervention.

- **Gamification, Vigilance, and Consumer Fatigue -** Frequent price shifts alter consumer behavior by turning standard shopping into an exhausting game of strategy, which ultimately degrades the overall customer experience. When prices fluctuate by the hour or minute, consumers feel compelled to monitor charts, set alerts, use tracking tools, or delay purchases in hopes of catching a sudden drop. While a small segment of bargain-hunters enjoys this gamified environment, the vast majority of consumers experience severe decision fatigue, anxiety, and frustration. This constant state of alertness makes shopping stressful rather than satisfying. When a brand transforms buying into a high-stress gamble, it destroys the emotional connection that fuels long-term loyalty, driving exhausted customers toward competitors that offer straightforward, stress-free pricing.
- **Asymmetric Information and the Rise of Counter-Algorithms -** The historical advantage corporations held through asymmetric information—where sellers possessed far more market data than buyers—is rapidly shrinking due to consumer-facing counter-algorithms. Today's consumers are equipped with automated price aggregators, historical tracking browsers, AI shopping assistants, and collective digital communities that expose real-time pricing tactics. When a brand's algorithm attempts to isolate and exploit an individual's immediate willingness-to-pay, these counter-technologies alert the consumer to the manipulation, providing immediate historical context. This technological arms race evens the playing field and amplifies consumer frustration when deceptive practices are exposed. Brands that rely on hidden, aggressive price discrimination face growing operational friction, as their predictive models are disrupted by defensive consumer tech designed to bypass artificial price spikes.
- **Strategic Mitigations Through Value-Added Bundling -** To implement dynamic pricing without damaging customer retention, forward-thinking brands use value-added bundling to obscure the exact price of individual components. Instead of constantly shifting the standalone price of a core product—which triggers immediate consumer scrutiny—companies bundle it with ancillary services, extended warranties, digital content, or exclusive perks at a fluctuating total price. This approach dilutes the consumer's ability to isolate and criticize a specific price hike, shifting their focus from itemized costs to overall package value. By layering variable pricing into a richer, comprehensive offering, brands can capture shifting market demand, preserve perceived fairness, and protect the core product's reference price from market volatility.
- **Regulatory Evolution and the Compliance Landscape -** The widespread adoption of unconstrained algorithmic pricing is driving rapid changes in global regulatory frameworks, moving consumer protection from basic anti-trust laws to advanced digital equity mandates. Regulators are increasingly scrutinizing dynamic pricing engines for deceptive patterns, unfair data profiling, and hidden junk fees that distort true market costs. Future compliance will likely require brands to provide clear audit trails for automated pricing decisions, adhere to strict caps during emergencies, and offer opt-out mechanisms for behavioral tracking. Companies that view dynamic pricing solely through a short-term revenue lens face significant compliance risks. Proactively aligning algorithmic models with emerging ethical standards and consumer rights is no longer just a legal safeguard; it is a critical strategy for protecting brand reputation and ensuring long-term business survival.

Conclusion

The implementation of algorithmic dynamic pricing and real-time price discrimination represents one of the most significant paradigm shifts in modern commerce, fundamentally altering the relationship between market valuation, consumer perception, and brand equity. What began as a yield-management tool tailored to the specific operational constraints of the airline and hospitality industries has evolved into a ubiquitous, data-driven pricing mechanism that spans across e-commerce, ride-sharing, entertainment, and digital services. Driven

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by sophisticated machine learning models, neural networks, and massive big data infrastructures, contemporary dynamic pricing systems possess the unprecedented ability to track, analyze, and capitalize on consumer behavior in real time. These algorithms continually ingest vast arrays of data streams, including historical purchasing patterns, real-time browsing histories, device characteristics, geographical locations, immediate inventory levels, competitor pricing movements, and macro-environmental fluctuations like weather patterns or time of day. By synthesizing these variables, firms can instantly compute optimal price points designed to maximize immediate profitability or volume on a transaction-by-transaction basis. However, while the microeconomic advantages of this hyper-efficiency are readily quantifiable through elevated revenues and optimized capacity utilization, the macroeconomic and psychological ramifications for long-term customer equity tell a far more complex story. The transition from static, transparent pricing frameworks to fluid, individualized, and highly opaque algorithmic pricing models has fundamentally disrupted traditional notions of market fairness. As a result, firms operating in competitive landscapes must carefully weigh the immediate financial windfalls of automated price discrimination against the long-term, systemic degradation of consumer trust, brand equity, and customer retention.

At the core of the friction between algorithmic dynamic pricing and sustainable consumer retention lies the psychological concept of perceived price fairness, which is heavily governed by equity theory and dual entitlement theory. Equity theory posits that individuals assess the fairness of an exchange by comparing the ratio of their own inputs and outcomes against the inputs and outcomes of another party, which could be either the selling firm or a fellow consumer. When an algorithm adjusts prices rapidly and unpredictably based on a consumer's perceived willingness to pay rather than tangible changes in product cost or intrinsic value, the perceived ratio becomes heavily skewed in favor of the corporation. Dual entitlement theory further illuminates this dynamic by suggesting that consumers believe they are entitled to a reasonable reference price, while firms are entitled to a reasonable profit margin. Under traditional static pricing models, price increases are generally tolerated and viewed as fair if they are explicitly tied to rising cost inputs, such as a surge in raw material costs or labor shortages. Algorithmic dynamic pricing, conversely, routinely violates this implicit psychological contract. When a consumer observes a price double within a matter of minutes simply because demand has increased, or because their digital footprint signals urgency, the price increase is perceived as purely opportunistic and exploitative. This perceived unfairness is not merely a fleeting moment of cognitive dissonance; it triggers profound emotional responses ranging from frustration and annoyance to a deep sense of betrayal and anger. These negative emotions directly undermine the affective component of customer loyalty, prompting consumers to reevaluate their relationship with the brand and actively seek alternative options that offer greater stability and transparency.

Furthermore, real-time price discrimination severely damages the structural dimensions of brand equity, most notably brand trust, brand image, and perceived quality. Brand equity is built upon a foundation of consistency, predictability, and a shared set of values between the organization and its audience. When a brand adopts aggressive algorithmic price discrimination, it trades its identity as a trusted partner for that of a calculating, transactional adversary. The predictability that once anchored the consumer's relationship with the brand is completely dismantled. Instead of associating the brand with a reliable value proposition, consumers begin to view the brand through a lens of skepticism and hyper-vigilance, constantly worrying that they are being manipulated or overcharged by an invisible algorithm. This erosion of trust is particularly devastating in relational markets where long-term customer lifetime value is paramount. Moreover, the instability introduced by dynamic pricing can inadvertently degrade the perceived quality of the product or service itself. According to price-signaling theory, consumers frequently use price as a proxy for quality. When a price fluctuates wildly and arbitrarily, it disrupts this signaling mechanism, leading consumers to question the true intrinsic worth of the offering. If a service can be bought for fifty dollars at 10:00 AM but jumps to two hundred dollars at 5:00 PM without any physical modifications, the consumer begins to view the baseline value as arbitrary and inflated, stripping the brand of its premium positioning and reducing it to a highly commoditized, volatile asset.

The long-term impact of this strategic misalignment on customer retention is characterized by increased customer churn, diminished brand advocacy, and the systematic destruction of customer lifetime value. While dynamic pricing models are highly effective at capturing the maximum consumer surplus from an immediate transaction, they fail to account for the hidden costs of customer alienation. When consumers realize they have been subjected to real-time price discrimination, their propensity to

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engage in negative word-of-mouth increases exponentially, amplified by the reach of digital social media platforms where stories of algorithmic price gouging frequently go viral. This negative advocacy severely hampers the firm's customer acquisition efforts and tarnishes its public reputation. More critically, the psychological friction caused by unpredictable pricing drives even historically loyal customers to actively break their behavioral habits. Loyalty is replaced by a transactional mindset characterized by deal-seeking and strategic waiting, where consumers purposefully delay purchases or jump to competitors the moment a price spike occurs. The firm is then forced to spend increasingly higher amounts on defensive marketing, promotions, and customer re-engagement strategies to combat the rising churn rate. Consequently, the short-term revenue gains generated by the pricing algorithm are frequently offset by the long-term degradation of the customer base, demonstrating that an over-indexing on transaction-level optimization can severely compromise the overarching economic health of the enterprise.

To mitigate these severe systemic risks and harmonize algorithmic dynamic pricing with the preservation of brand equity and customer retention, organizations must transition away from purely extractive, adversarial pricing models toward more collaborative, transparent, and value-aligned frameworks. The first and most critical strategic imperative is the implementation of radical transparency and consumer education. Rather than obscuring the operational mechanics of the pricing algorithm within a black box, firms must proactively communicate the specific, objective criteria that drive price adjustments. If a price increase is necessitated by acute capacity constraints, severe weather, or localized supply deficits, explaining these factors clearly to the consumer helps align the pricing action with the principles of dual entitlement theory, making the fluctuation appear rational rather than predatory. Secondly, firms should implement algorithmic guardrails that cap maximum price spikes and establish firm reference price boundaries. By deliberately sacrificing the absolute highest margins during peak demand spikes, a brand can protect its core customer base from the intense feelings of betrayal and exploitation that trigger permanent brand switching.

Additionally, the integration of loyalty programs and customer-centric value additions can serve as an exceptionally powerful buffer against the negative perceptions of price discrimination. Organizations can utilize the vast troyes of behavioral data gathered by their systems not to extract maximum surplus, but to reward loyal patrons with price locks, predictable flat-rate tiers, or exclusive value-added benefits that offset higher costs. For instance, if an algorithm dictates a higher price due to high demand, the firm can bundle the purchase with complementary services, premium upgrades, or loyalty points, thereby shifting the consumer's focus from a perceived loss to an enhanced value proposition. Ultimately, the long-term viability of algorithmic dynamic pricing relies on a fundamental shift in strategic perspective: moving from the short-sighted optimization of individual, isolated transactions to the holistic cultivation of enduring customer relationships. The firms that thrive in the automated digital economy will not be those with the most ruthlessly aggressive algorithms, but those that successfully leverage data intelligence to deliver dynamic, market-responsive pricing while rigorously safeguarding the core tenets of human trust, fairness, and mutual respect that form the bedrock of sustainable brand equity.

Recommendations:

- **Build Transparency into the System**

Publish your pricing framework clearly. Consumers accept dynamic adjustments when they know what market factors drive changes, such as peak hours or raw material costs.

- **Implement "Worst-Case" Price Ceilings**

Cap your algorithm's maximum price limits. Preventing sudden, extreme price spikes during high-demand surges shields your brand from public backlash and accusations of price gouging.

- **Favor Frame-Based Savings Over Penalties**

Frame real-time changes as a positive benefit. Present fluctuating prices as "early-bird discounts" or "off-peak rewards" rather than imposing higher dynamic surcharges on late shoppers.

- **Grandfather Loyal Customers**

Protect your highest-value buyers from dynamic spikes. Keep pricing structures stable for registered subscribers or long-term loyalty program members to reward continuous engagement.

- **Decouple User Data from Direct Pricing**

Base price changes strictly on market metrics like inventory volume or timing. Avoid tracking private device types or personal browsing history, which can damage consumer trust.

- **Introduce Dynamic Price-Lock Options**

Allow consumers to freeze a quoted price for a short duration. Giving customers time to consider a purchase removes the stress of sudden check-out shifts and improves the checkout experience.

- **Offer Automated Price-Matching Policies**

Commit to refunds if a price drops immediately after a purchase. Guaranteeing value protection

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directly resolves the consumer fear of buying at the wrong moment.

- **Provide Real-Time Customer Alerts**

Notify users via your app or website when demand peaks or drops. Helping shoppers choose cheaper time windows positions your company as a helpful advisor rather than an opportunistic seller.

- **Connect Price and Product Value**

Justify higher cost levels by adding service perks during peak windows. Providing expedited shipping or premium support balances out dynamic price increases.

- **Audit Algorithms Regularly for Bias**

Run consistent technical checks on your pricing software. Ensuring the system evaluates macro trends rather than exploiting vulnerable demographic groups helps maintain legal and ethical compliance.

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Conflicts of interest

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

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Original Article

Strategic Workforce Planning for Sustainable Marketing: Aligning HR Talent Pipelines with Corporate ESG Commitments and Green Marketing Claims

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Abstract:
As Environmental, Social, and Governance (ESG) mandates shift from peripheral corporate social responsibility initiatives to core strategic imperatives, organizations face increasing regulatory scrutiny and consumer backlash over "greenwashing." While green marketing claims are designed to convey sustainability commitments to external stakeholders, their authenticity depends heavily on the internal capabilities, ethical alignment, and strategic execution of the workforce. This paper examines the critical intersection of Strategic Workforce Planning (SWP) and sustainable marketing, investigating how human resource pipelines can be systematically aligned with corporate ESG commitments to ensure green claims remain credible, compliant, and operationally grounded. Integrating upper echelons theory, resource-based view (RBV), and sustainable Human Resource Management (sHRM) frameworks, this research explores the operational mechanisms required to build a sustainability-literate marketing workforce. It analyzes the entire employee life cycle—spanning targeted talent acquisition, ESG-aligned upskilling, performance management metrics, and cross-functional integration between HR, marketing, and sustainability compliance units. The study evaluates how gaps in internal sustainability competence contribute to greenwashing risks, deceptive claims, and subsequent reputational damage. The findings demonstrate that organizational alignment between HR pipelines and ESG strategies directly enhances green marketing performance, consumer trust, and corporate credibility. When marketing teams possess verified sustainability competencies and work within governance structures that reward ethical accuracy over exaggerated performance, green marketing strategies shift from superficial communication exercises to authentic value propositions. Conversely, misalignment between external marketing narrative and internal workforce capability creates operational disconnects that erode brand value. Ultimately, this paper offers a strategic operational model for chief human resources officers (CHROs) and chief marketing officers (CMOs) to co-design talent pipelines that insulate organizations against compliance risks while securing long-term competitive advantage through authentic green marketing.

Key Words: *Strategic Workforce Planning, Green Marketing, ESG Commitments, Sustainable HRM, Greenwashing Mitigation*

Introduction:

The modern corporate landscape is witnessing an unprecedented convergence between strategic human resource management, environmental, social, and governance (ESG) mandates, and authentic green marketing. For decades, corporate sustainability initiatives and marketing strategies operated within rigid silos: sustainability teams managed environmental compliance and carbon disclosures, human resources focused on recruitment and operational staffing, and marketing departments promoted product offerings, frequently prioritizing short-term commercial appeal over rigorous ecological verification. Today, escalating regulatory scrutiny, shifting investor priorities, and heightened consumer demand for corporate integrity have shattered these operational boundaries.

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Modern enterprises face a critical strategic imperative: aligning their internal talent pipelines with ambitious ESG commitments to substantiate their green marketing claims credibly. At the center of this transformation lies a complex, tripartite interplay between strategic workforce planning, corporate sustainability governance, and market-facing brand authenticity. Understanding how these dimensions interact is essential for organizations seeking to navigate the delicate line between genuine ecological transformation and the severe reputational liabilities of corporate greenwashing. Strategic workforce planning serves as the operational engine of this organizational evolution, moving far beyond traditional headcount forecasting to encompass proactive competency mapping and talent architecture. Historically, workforce planning was dictated by immediate financial projections and standard operational requirements, treating labor as a fungible commodity to be scaled up or down based on quarterly business cycles. In the era of mandatory decarbonization and circular economies, this reactive approach is obsolete. Enterprises must now forecast talent needs years in advance, identifying critical skill gaps across data analytics, sustainable supply chain logistics, life-cycle assessment, renewable energy engineering, and ethical governance. This necessitates a structural redesign of internal talent pipelines, requiring organizations to cultivate specialized competencies internally through continuous upskilling while aggressively recruiting external change agents who possess deep technical expertise in sustainability. Without a deliberate, forward-looking talent strategy, corporate ESG commitments remain hollow declarations, disconnected from the operational reality required to execute them.

The internal integration of sustainability competencies directly governs an organization's capacity to deliver authentic green marketing claims. In a marketplace saturated with superficial environmental messaging, consumers, regulatory bodies, and investors have become increasingly adept at identifying greenwashing—the deceptive practice of exaggerating or falsifying the environmental benefits of a product, service, or corporate practice. When a company's marketing department promotes aggressive carbon-neutrality targets or circular product lifecycles without the underlying workforce capability to execute them, the risk of public exposure skyrockets. Regulatory frameworks, such as the European Union's Green Claims Directive and heightened oversight by consumer protection agencies, now demand rigorous empirical substantiation for every environmental assertion made to the public. Consequently, green marketing is no longer merely a creative branding exercise; it is an outward-facing manifestation of internal organizational competency. If the engineers, procurement specialists, product designers, and compliance officers lack the specialized skills required to reduce environmental footprints genuinely, the marketing claims built upon their work become inherently fraudulent.

The psychological and cultural fallout from misaligned ESG claims extends deeply into employer branding, employee motivation, and internal retention. Modern professionals—particularly among younger generational cohorts—increasingly seek employment with organizations whose stated values align with their personal ethical convictions. When companies engage in greenwashing or project an exaggerated sustainability profile to attract top-tier talent and conscientious consumers, they trigger a profound cognitive dissonance within their existing workforce. Employees who witness a stark gap between corporate marketing narratives and internal operational practices experience disillusionment, organizational cynicism, and disengagement. This phenomenon, often termed "greenhushing" or internal green fatigue, damages morale and drives voluntary turnover, particularly among high-performing technical specialists who understand the true difficulty of ecological transformation. Conversely, when an enterprise transparently aligns its workforce planning with authentic ESG commitments, employees feel a deep sense of purpose and pride, transforming internal staff into passionate brand advocates who authentically communicate the company's sustainability mission.

Beyond immediate internal dynamics, the integration of workforce planning and ESG commitments acts as a vital safeguard for long-term brand equity and risk mitigation. Brand equity in the twenty-first century is exceptionally fragile, built upon a foundation of trust, transparency, and demonstrated accountability. When sustainability failures occur—whether through regulatory penalties for misleading green claims, supply chain scandals involving ethical violations, or public exposures of carbon accounting discrepancies—the resulting reputational damage is swift and severe. Investors increasingly penalize firms that fail to integrate ESG factors into their core governance, viewing poor sustainability execution as a fundamental failure of enterprise risk management. Therefore, strategic workforce planning must incorporate cross-functional ESG literacy across all organizational tiers, ensuring that marketing teams, product developers, and executive leadership share

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a unified, scientifically grounded understanding of the company's environmental footprint and strategic capabilities.

Navigating the intricate nexus connecting workforce planning, ESG execution, and green marketing authenticity ultimately dictates the long-term viability of modern commercial enterprises. While marketing optimization offers immense potential for capturing market share among eco-conscious consumers, it must be anchored in rigorous, measurable operational realities. Algorithms and corporate mission statements cannot manufacture sustainability; it requires the dedicated intellectual capital, technical expertise, and ethical commitment of a well-planned, highly skilled workforce. Therefore, the successful implementation of sustainable marketing strategies relies on a symbiotic model—one where human resource leaders, sustainability officers, and marketing executives collaborate seamlessly to build talent pipelines that not only drive commercial growth but actively fulfill the organization's ecological and social promises. Exploring this delicate interplay is vital for organizations seeking to harness the power of green markets not as a transient tactical advantage, but as a permanent, defensible foundation for enduring market leadership.

Building upon this socio-technical foundation, the operationalization of sustainable workforce planning requires a fundamental transformation in how organizations approach continuous learning and cross-functional competency development. Historically, corporate training programs were segregated into rigid functional silos, where marketing teams attended workshops on consumer acquisition, engineers focused on technical specifications, and sustainability officers operated in isolated environmental compliance bubbles. In an era where green marketing claims are subjected to rigorous scientific and legal scrutiny, this functional isolation is no longer viable. Organizations must implement cross-disciplinary learning architectures that embed foundational ESG literacy, life-cycle analysis, and regulatory compliance metrics into the core professional development of every employee. When marketing professionals possess a working technical understanding of carbon accounting, scope emissions, and circular supply chains, they are infinitely better equipped to craft accurate, defensible green marketing campaigns that withstand both consumer skepticism and regulatory auditing.

Furthermore, the alignment of talent pipelines with corporate ESG commitments demands a progressive evolution in executive key performance indicators and compensation structures. For decades, corporate leadership incentives were overwhelmingly anchored to short-term financial returns, volume metrics, and quarterly revenue growth—pressures that frequently incentivized cost-cutting shortcuts, greenwashing, and superficial sustainability reporting. To bridge the chasm between strategic workforce planning and authentic green marketing, enterprises must tie executive compensation and managerial performance evaluations to verifiable ESG milestones and workforce capability targets. When leadership accountability is directly linked to the actual reduction of environmental footprints, the upskilling of internal green talent, and the absolute integrity of external marketing disclosures, corporate culture shifts from compliance-driven theater to genuine ecological stewardship. This structural alignment ensures that sustainability is treated not as a peripheral public relations initiative, but as an indispensable core driver of enterprise value.

Ultimately, navigating the complex intersection of strategic workforce planning, ESG commitments, and green marketing requires organizations to embrace a long-term horizon of corporate responsibility. As global markets transition toward a low-carbon economy, the competitive advantage will not belong to companies that master the art of deceptive marketing, but to those that cultivate genuine operational excellence from within. By systematically aligning human resource talent pipelines with rigorous environmental standards, enterprises can eradicate the risk of greenwashing, protect their brand equity, and inspire their workforce. Through this holistic integration, strategic workforce planning fulfills its highest calling: transforming human capital into the ultimate catalyst for authentic, sustainable market leadership.

Objectives of the Study:

To analyze how to align HR talent pipelines with corporate ESG commitments and green marketing claims, ensuring strategic workforce planning drives sustainable marketing and prevents compliance risks.

Research Methodology:

The current research seeks to align HR talent pipelines with corporate ESG commitments and green marketing claims, ensuring strategic workforce planning drives sustainable marketing and prevents compliance risks.

Sources of Data:

Secondary data collected from journals, research articles, and publications.

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Review of Literature:

Renwick et al. (2013) established that human resource functions act as vital enablers in translating corporate environmental strategies into individual employee actions. Their pioneering work asserts that green human resource management (GHRM) is highly effective when aligned with external eco-marketing strategies. The researchers argue that traditional practices—such as job analysis, recruitment, and performance metrics—must be systemic and planned to support the organization's overarching environmental goals. This foundational alignment ensures that corporate workforce capabilities directly mirror external green branding, laying the necessary framework for modern strategic workforce planning that aims to avoid corporate greenwashing.

Hancock et al. (2024) explored how high-level Environmental, Social, and Governance (ESG) commitments transition into functional workforce practices through a focus on a skills-based talent agenda. They emphasized the power of horizontal alignment, noting that specialized talent acquisition allows firms to fine-tune learning and development strategies to fill critical green skill gaps. The study reveals that a structured internal capability assessment prevents a mismatch between what an organization promises publicly and what its workforce can execute. This turns high-level corporate governance commitments into realistic talent pipelines that reinforce long-term resilience and legitimacy.

Jamil et al. (2023) analyzed the operational links between green human resource practices and external corporate sustainability outcomes. They noted that integrating green training, involvement, and rewards enhances overall corporate ESG performance. Their findings demonstrate that when employee actions are intentionally aligned with ecological goals, the credibility of marketing initiatives dramatically improves. By treating talent development as a bridge between corporate strategy and consumer expectations, businesses can foster an authentic corporate culture. This internal transformation effectively mitigates reputational risks and ensures green claims are backed by true organizational capabilities.

Reese (2024) highlighted that effective strategic workforce planning relies on a continuous three-pillar framework: mapping the current talent state, modeling the desired future state, and building the specific strategies to bridge the gap. In a sustainability context, this proactive process allows human resource leaders to anticipate critical skill shortages linked to evolving green regulations. By using data-driven forecasting, firms can shift from reactive hiring to proactive talent cultivation. This long-term foresight ensures that the employee pipeline possesses the necessary technical and marketing competencies required to meet public environmental targets.

Jacob (2024) investigated the dangerous disparities that emerge when marketing departments and human resource teams act independently of each other. The study demonstrates that disconnected operations cause a major gap between authentic workforce behaviors and public brand promises. When human resource strategies are carefully coordinated with corporate marketing objectives, employees internalize the brand's core values. This internalization enables the workforce to actively fulfill the company's public sustainability claims. The research proves that authentic employee engagement serves as a primary driver for increasing consumer trust and corporate credibility.

Satpathy (2024) explored the explicit relationship between internal human resource practices and external green marketing campaigns. The author emphasizes that a green workforce is essential for designing, building, and delivering authentic green value propositions. Without explicit green human resource practices—such as green recruitment and target upskilling—marketing claims risk being labeled as insincere greenwashing. This research confirms that corporate sustainability strategies achieve a true competitive advantage only when the internal skills of the workforce fully match the green narratives broadcast to the marketplace.

Porter (2025) reviewed how evolving public policies, carbon regulations, and mandatory disclosures impact internal corporate talent allocation. The author illustrates that forward-thinking organizations transform external regulatory pressures into clear internal objectives by aggressively boosting green research and development and talent optimization. By strategically designing workforce pipelines around these regulatory requirements, corporations successfully gain a distinct first-mover advantage. This proactive alignment ensures the workforce is prepared to implement and defend corporate sustainability commitments against strict legal and public scrutiny.

Raffiee and Coff (2026) examined the critical role that ethical leadership plays in embedding sustainability initiatives into modern corporate cultures. Their work details how a skills-based human resources agenda relies on the direct capabilities, perceptions, and daily actions of management. When corporate leaders prioritize transparency and ethical decision-making, it establishes a framework for responsible workforce practices. This leadership commitment helps prevent symbolic compliance, ensuring that

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environmental claims are reflected in the real, daily routines of the workforce.

Adjei-Bamfo et al. (2025) examined the strategic importance of green recruitment and selection at the entry point of the employee lifecycle. Grounded in Person-Organization Fit theory, their findings show that hiring candidates with strong environmental values fosters immediate intrinsic motivation and long-term engagement. Additionally, using eco-friendly, paperless recruitment practices sends a powerful, credible signal to prospective talent. This targeted approach ensures that the incoming corporate talent pipeline is naturally receptive to supporting the brand's green marketing commitments.

Ravi et al. (2024) explored how advanced human resource infrastructure and artificial intelligence revolutionize modern workforce planning. By integrating predictive analytics, competency mapping, and digital simulations, human resource leaders can accurately forecast future skill requirements. This technological edge allows companies to proactively address green skill shortages long before they impact product lines or public campaigns. Consequently, data-driven planning ensures that corporate marketing claims remain fully aligned with real operational capabilities.

Observations and discussions:

- **The Competency Gap in Green Marketing Literacy -** Many marketing professionals understand traditional brand positioning but lack a deep, technical understanding of sustainability metrics and environmental science. When a company commits to net-zero emissions or circular economy principles, HR must step in to build a structured competency framework for the marketing team. Without this baseline knowledge, creative teams are highly likely to accidentally exaggerate environmental benefits, leading to massive legal and reputational damage. Strategic workforce planning solves this by mapping out exactly what technical ESG knowledge is missing across existing marketing roles. HR can then design targeted training programs that teach marketers how to read life-cycle assessments and interpret carbon footprint data. This ensures that every green claim made in advertising is backed by real, verifiable data rather than vague buzzwords.
- **Modernizing Job Architecture for ESG Compliance -** Traditional marketing job descriptions are outdated because they focus entirely on customer acquisition, conversion rates, and standard brand management metrics. To support genuine corporate ESG commitments, human resource leaders must completely redesign job architecture to inject sustainability responsibilities directly into marketing roles. This means creating brand-new specialized positions, such as "Sustainable Brand Managers" or "ESG Communication Directors," who act as dedicated bridges between environmental scientists and creative copywriters. Furthermore, standard marketing roles must have their core duties updated to include compliance monitoring, ethical sourcing of advertising materials, and green agency oversight. By embedding these specific requirements into the organizational structure, companies ensure that sustainability is not treated as an optional side project. Instead, it becomes a core operational duty that shapes day-to-day marketing activities and sets clear expectations for performance.
- **Mitigating Greenwashing Risks Through Cross-Functional Talent Pipelines -** Greenwashing occurs when a company's marketing department operates in a silo, completely disconnected from the operational realities of the corporate sustainability team. To fix this dangerous disconnect, strategic workforce planning must actively build cross-functional talent pipelines that force collaboration between technical experts and creative storytellers. HR can implement structured job rotation programs where sustainability data analysts spend six months embedded within the marketing department, and vice versa. This physical and operational integration creates a built-in compliance check, ensuring that copywriters consult technical experts before launching public campaigns. Additionally, establishing joint committees for campaign approvals ensures that all green claims are rigorously vetted by individuals who understand the scientific data. This cross-functional pipeline transforms the workforce from a collection of isolated departments into an integrated network capable of executing honest marketing.
- **Reskilling and Upskilling the Existing Marketing Workforce -** An organization cannot achieve its sustainable marketing goals solely by hiring new talent; it must aggressively reskill and upskill its current workforce to meet evolving standards. HR departments need to audit the existing marketing team's understanding of modern environmental regulations, green consumer psychology, and eco-friendly digital media channels. Once these gaps are identified,

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workforce planners should establish mandatory, continuous learning paths in partnership with environmental academics and industry compliance experts. Training must cover complex topics like carbon accounting basics, plastic reduction certifications, and the legal definitions of words like "biodegradable" and "eco-friendly." By treating green marketing literacy as a dynamic, evolving skill set rather than a one-time workshop, companies keep their teams sharp and compliant. This ongoing educational commitment protects the brand from regulatory fines while empowering long-term employees to transition smoothly into the green economy.

- **Talent Acquisition Strategies and the Sustainable Employer Value Proposition -** Top-tier marketing talent, particularly among younger generations, actively seeks employment at organizations that demonstrate authentic social and environmental responsibility. To attract the bright minds capable of driving sustainable marketing, HR must align the company's external recruitment marketing with its actual internal ESG practices. This requires building a transparent Employer Value Proposition (EVP) that highlights the company's real progress toward carbon neutrality, fair labor, and ethical governance. Recruiters should deliberately screen candidates for a genuine commitment to sustainability, using behavioral interview questions to assess their ethical decision-making frameworks. However, if a gap exists between the green claims made to candidates and the actual operational reality inside the firm, retention rates will plummet. Authentic talent acquisition strategies ensure that the marketers hired are highly motivated by the mission, resulting in lower turnover and more passionate brand advocacy.
- **Succession Planning and Leadership Development for Ethical Marketing -** Long-term sustainability requires a continuous pipeline of ethical leaders who can defend environmental integrity even under intense pressure to hit quarterly revenue targets. Strategic workforce planning must integrate ESG metrics directly into succession planning, ensuring that future Chief Marketing Officers (CMOs) possess both financial acumen and deep ethical fluency. Leadership development programs should intentionally mentor high-potential marketers on how to navigate complex ethical dilemmas, such as managing supply chain failures or addressing public criticism. These future executives must be trained to treat sustainability data with the exact same level of scrutiny and respect as they treat financial balance sheets. By prioritizing ethical governance in leadership pipelines, an organization protects itself against sudden strategic pivots that might compromise its green commitments for short-term gains. This careful cultivation of leadership talent guarantees that the company's sustainable vision persists across generations of executive management.
- **Performance Management and Aligning Incentives with ESG Goals -** Marketing teams are traditionally driven by quantitative performance metrics like return on ad spend (ROAS), market share growth, and immediate sales volumes. To shift a workforce toward sustainable marketing, HR must completely overhaul the performance management system to balance financial targets with specific ESG key performance indicators (KPIs). For example, a marketing director's annual bonus should be tied not only to revenue generation but also to the accuracy of green claims and the reduction of the department's digital carbon footprint. If incentives remain purely financial, employees will naturally prioritize short-term sales over long-term compliance, directly increasing the risk of deceptive greenwashing. Workforce planning must carefully calibrate these new incentive models to ensure they encourage responsible, sustainable brand growth without stifling creative innovation. Aligning personal financial rewards with corporate sustainability commitments proves to the workforce that the company values ethical practices just as much as profits.
- **Managing the Carbon Footprint of Marketing Operations and Vendor Networks -** Sustainable marketing extends far beyond the words used in advertisements; it requires a workforce that understands how to minimize the physical and digital carbon footprint of marketing operations. Strategic workforce planning must allocate talent resources to manage the environmental impact of media buying, agency partnerships, and large-scale corporate event production. HR needs to train procurement-minded marketers to audit third-party advertising vendors, digital media networks, and print suppliers for their own verified sustainability practices. This includes optimizing digital campaigns to consume less server energy and ensuring physical promotional materials are sourced from strictly certified, circular supply chains. Marketers must be equipped with the analytical skills

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needed to calculate the scope 3 emissions generated by their extensive advertising distribution networks. Developing this highly operational capability within the marketing team ensures that the department's day-to-day business practices do not actively contradict its public green claims.

- **Diversity, Equity, and Inclusion (DEI) as a Core Pillar of the "Social" in ESG Marketing -** The "Social" component of ESG is frequently overshadowed by environmental initiatives, yet it remains absolutely vital for authentic, culturally responsible marketing. Workforce planners must deliberately cultivate a diverse, equitable, and inclusive marketing team that accurately reflects the multicultural global communities the brand serves. A homogeneous marketing workforce suffers from cognitive blind spots, making it highly susceptible to launching culturally insensitive, exclusionary, or tone-deaf advertising campaigns. By embedding DEI strategies directly into the talent pipeline, HR ensures that a wide variety of lived experiences, cultural insights, and ethical perspectives shape every single piece of creative content. This internal diversity prevents exploitative marketing practices and helps the brand communicate with minority communities in a deeply respectful and authentic manner. Ultimately, a diverse workforce guarantees that the social equity claims made in marketing campaigns are a true reflection of the company's internal culture.
- **Change Management and Overcoming Internal Resistance to Sustainable Transformations -** Shifting an established corporate marketing department away from traditional consumerism toward a highly regulated, sustainable model inevitably triggers significant internal friction and resistance. Employees may worry that strict sustainability guidelines will slow down project timelines, stifle creative freedom, or make it harder to hit aggressive sales quotas. Strategic workforce planning must incorporate robust change management frameworks to help the workforce navigate this cultural shift without experiencing burnout or drop-offs in motivation. HR leaders should identify internal sustainability champions within the marketing team to share success stories, run peer-to-peer mentoring, and openly address employee anxieties. Transparent communication from executive leadership is critical to explain *why* these green standards are necessary for the long-term survival and health of the business. By proactively managing this emotional and operational transition, HR transforms potential resistance into enthusiastic buy-in, embedding sustainability deep into the daily corporate culture.

Conclusion:

The integration of strategic workforce planning with corporate ESG (Environmental, Social, and Governance) commitments marks a critical evolution in how modern organizations approach sustainable marketing. Throughout this analysis, it is evident that a company's green marketing claims are only as credible as the internal talent driving them. When HR pipelines are not aligned with sustainability objectives, organizations risk facing "greenwashing" accusations—where public marketing assertions outpace actual operational capabilities. To prevent this disconnect, strategic workforce planning must transition from a traditional staffing function into a core driver of corporate sustainability. By identifying future skill gaps, predicting talent needs, and embedding ESG competencies into the recruitment and training lifecycles, human resources ensures that marketing teams possess the authentic knowledge required to communicate complex environmental initiatives truthfully and effectively.

Furthermore, building an ESG-capable marketing workforce requires a fundamental shift in how talent is upskilled and cross-trained. Sustainable marketing is no longer just about changing logos to green or using recycled paper for brochures; it demands a deep understanding of lifecycle assessments, carbon accounting, ethical supply chains, and evolving regulatory standards. Strategic workforce planning allows organizations to systematically map these new competency requirements against their current employee base. Through targeted training programs, continuous learning pathways, and cross-functional collaboration between sustainability officers and marketing personnel, companies can foster a culture of genuine environmental responsibility. This holistic approach ensures that green marketing claims are not merely superficial public relations talking points, but are instead backed by robust, verifiable internal data and a workforce that understands the science and ethics behind the messaging.

Beyond internal training, a robust talent pipeline must be intentionally designed to attract a new generation of purpose-driven professionals. Today's top talent, particularly among younger demographics, increasingly prioritizes employers whose values align with their own. By visibly weaving ESG commitments into the employer branding and recruitment processes, organizations

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can secure a competitive advantage in the marketplace. Strategic workforce planning must therefore project long-term talent needs that reflect these changing societal expectations. When an organization genuinely embodies its green claims through its internal culture, diversity initiatives, and fair labor practices, it creates a virtuous cycle. Authentic sustainability practices attract high-caliber talent, and this talent, in turn, elevates the quality, integrity, and impact of the company's sustainable marketing campaigns.

Ultimately, the alignment of HR talent pipelines with corporate ESG goals serves as the ultimate safeguard for brand reputation and long-term business resilience. As global regulatory bodies tighten rules around environmental claims, the financial and reputational penalties for misleading marketing will only intensify. Organizations that treat workforce planning as a separate entity from their sustainability strategy will find themselves vulnerable to compliance failures and eroding consumer trust. Conversely, those that treat human capital as the literal engine of their ESG strategy will build a resilient framework capable of navigating future regulatory shifts. By ensuring that every marketer is an educated steward of the company's green mission, strategic workforce planning transforms corporate sustainability from a compliance obligation into a powerful, authentic driver of market value.

Recommendations:

- **Establish Cross-Functional ESG-Marketing Advisory Boards**

Organizations should build a unified council composed of human resources planners, legal compliance officers, and senior brand strategists to govern all public-facing green claims. This structural alignment guarantees that human resources talent pipelines are built directly around actual corporate environmental capabilities rather than abstract goals. By anchoring marketing narratives in verified operational realities, the business can proactively mitigate greenwashing risks while ensuring the talent acquisition roadmap directly supports corporate sustainability milestones.

- **Implement Green Skill Mapping and Internal Auditing**

Human resources departments must execute a comprehensive skills inventory to evaluate the current sustainability literacy across all active marketing and communication teams. This diagnostic audit identifies critical knowledge gaps regarding regulatory compliance, life-cycle assessments, and circular economy principles. The resulting data enables workforce planners to transition from reactive hiring to predictive talent sourcing, ensuring future marketing professionals possess the technical data fluency required to defend environmental claims.

- **Redesign Marketing Job Descriptions around ESG Competencies**

Traditional marketing roles must be systematically rewritten to embed mandatory environmental, social, and governance (ESG) responsibilities into standard performance metrics. Job descriptions for brand managers, content creators, and media buyers should explicitly require experience with green advertising codes and ethical consumer data governance. This programmatic shift filters out unqualified candidates early in the recruitment pipeline and attracts purpose-driven talent who specialize in transparent brand communications.

- **Develop Mandatory Anti-Greenwashing Training Curriculums**

Workforce planners must collaborate with environmental legal experts to design and mandate continuous training programs focused on evolving green marketing regulations. This specialized curriculum should train existing and onboarding marketers on the strict evidentiary standards needed for claims regarding carbon neutrality, compostability, and fair trade. Elevating the baseline regulatory literacy of the communications workforce creates a human firewall that protects the organization from reputational damage and regulatory fines.

- **Align Recruitment Partnerships with Sustainable Universities**

To secure a continuous pipeline of ethical marketing talent, human resources must forge long-term strategic alliances with academic institutions that feature specialized sustainable business programs. By sponsoring green marketing case competitions, offering targeted internships, and co-developing modern curricula, the enterprise builds early brand equity with top-tier graduates. This targeted sourcing strategy reduces long-term recruitment costs and accelerates the onboarding of professionals naturally adept at authentic ESG storytelling.

- **Integrate Carbon Footprint KPIs into Marketing Performance Frameworks**

Workforce optimization requires linking individual marketing campaign performance metrics directly to the company's broader scope emission targets. HR should implement balanced scorecards where marketing executives are evaluated not just on customer acquisition costs, but also on the digital carbon footprint of their media distribution networks. Tying compensation and career progression to these sustainable benchmarks ensures day-to-day creative decisions actively honor corporate environmental commitments.

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- **Create Specialized "Sustainability Liaison" Roles within Marketing**

Organizations should introduce dedicated hybrid roles, such as Sustainable Communication Directors, to act as dedicated translators between scientific ESG data and public creative teams. These specialized professionals are tasked with vetting the scientific accuracy of supply chain data before it is transformed into public relations content. Strategically placing these data-literate gatekeepers within the creative pipeline ensures complex environmental metrics are communicated accurately, simply, and without exaggeration.

- **Leverage Internal Mobility to Infuse Scientific Talent into Communications**

Human resources should establish internal mobility pathways that allow technical environmental engineers, health and safety experts, and R&D scientists to rotate into marketing departments. Infusing technical subject-matter experts into creative writing and public relations teams radically elevates the scientific integrity of product copy. This cross-pollination ensures that green campaigns are deeply rooted in hard engineering facts rather than superficial promotional buzzwords.

- **Modernize Contractor and Agency Procurement Vetting Pipelines**

Strategic workforce planning must extend beyond full-time employees to encompass external creative agencies, freelance copywriters, and media purchasing vendors. HR and procurement must co-create strict ESG screening criteria for all external talent, requiring third-party agencies to demonstrate their own verified carbon reduction practices and ethical creative standards. Aligning the extended contingent workforce with corporate values ensures the brand identity remains uncompromised across all outsourced marketing channels.

- **Build Predictive Talent Models for Evolving Global Climate Regulations**

Human resources analytics teams must continuously evaluate emerging global climate disclosure legislations to predict future marketing compliance talent needs well in advance. By mapping out upcoming legislative changes, workforce planners can proactively hire or upskill compliance-focused marketers before industry-wide talent shortages occur. This forward-looking approach ensures the business maintains an agile, legally compliant marketing department ready to navigate shifting regulatory landscapes seamlessly.

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Financial Awareness and Investor Perception in the Digital Investment Environment: A Study of Indian Investors

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Abstract
India's investment landscape has been significantly reshaped by the swift advancement of digital technology. The reliance on physical intermediaries, paper-based documents, and in-person interactions has been replaced by mobile app trading, online trading platforms, digital payment, robo-advisory, and financial information via the internet. This transformation has made the investment services more accessible, convenient, faster and cheaper. Concurrently, digitalization of investment has also introduced new issues of awareness, risk awareness, information quality, cyber security, digital frauds, and investor decision making. This research paper aims to delve into the connection between financial awareness and investor perception in the context of digital investment in India. It aims to understand how investors interpret digital investment products, their understanding of associated risks and benefits, the way they interpret online financial information and how they make investment decisions via digital platforms. The paper adopts a conceptual and descriptive research approach using secondary literature and existing financial literacy, behavioural finance, digital financial services and investment behaviour studies. The discussion suggests that financial awareness plays an important role in determining investors' confidence, risk assessment, product selection, and ability to use digital investment platforms effectively. But simply raising awareness of finance may not be sufficient to overcome behavioural biases like over-confidence, herd behavior, loss aversion and excessive trading. The paper recommends that the overall financial education, digital financial education, investor protection, cybersecurity awareness, and responsible digital investment practices should be strengthened to build a more informed and resilient investor base in India.
Keywords: *Financial Awareness, Investor Perception, Digital Investment, Financial Literacy, Digital Finance, Investment Behaviour, Indian Investors, FinTech*

Introduction

The Indian financial system has experienced substantial transformation during the last few decades. The economic liberalisation, financial-sector liberalisation, technological advancement, growing internet usage and digital payment infrastructure have had a profound impact on the nature of saving and investing. There are more and more investment activities that were previously focused on the bank branches, financial advisers and brokers, post offices, and paper documentation, which are now being carried out digitally. Dedicated to the financial sector, the mobile platform allows investors to now access shares, mutual funds, bonds, exchange-traded funds, pension products and other financial instruments on their mobile device or via Internet connection. Digital investment platforms have minimized some obstacles that have traditionally prevented individual investors from participating in financial markets. An investor can open an online account, go through know your customer (KYC) paperwork electronically, track the performance of their portfolio, and access market data and execute trades with fairly low transaction costs.

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Mobile applications have also come to life to provide investors with continuous information, enabling them to monitor prices and financial news in real time. Digital investment has been vital in India, especially in a country with a large and growing population, where technological advancements are shaping the investment landscape. The advent of dematerialisation, online brokerage services, digital payments and mobile-based financial applications has helped retail investors in becoming more involved. There has been an increase in the availability of investment avenues such as systematic investment plans (SIPs), online mutual-fund platforms, and direct equity investment, which are now available to the typical person who might have relied on someone else for investment advice.

However, greater accessibility does not necessarily imply greater financial awareness. There is a huge amount of information available to investors in the digital world, but investors vary widely in their understanding and evaluation of the information. Social media platforms, online influencers, financial-content creators, discussion forums and algorithm-driven recommendations have the potential to affect investment decisions. Investors might thus be faced with information that is accurate and well-warned or it might be misleading and incomplete.

Therefore, financial awareness is increasingly gaining significance in the context of digital investments. The investor who is conscious should be familiar with the basic financial concepts, investment goals, risk-return relationships, diversification, costs, taxation, inflation, and the nature of various investment products. Furthermore, an awareness of financial security, authentication, privacy, and fraudulent investment schemes are essential in digital financial awareness in addition to knowledge of the responsible use of financial applications.

There is another element of perception, that of the investor. Investors' perceptions of the benefits and risks of digital investment platforms are shaped by perception. Some investors may perceive digital platforms as convenient, transparent and inexpensive, whereas others may be concerned about cybersecurity, fraud, technical problems, market volatility and lack of personal guidance.

In this scenario, the present paper investigates financial awareness and perception of the investors in the digital investment landscape in India and the implications on investment behavior.

Background of the Study

Digital finance has revolutionized the individual investor-financial markets dynamic. The traditional way of making investment decisions was often through face-to-face communication with financial advisors or brokers. Nowadays, investors have the ability to research investment products on their own and make transactions on digital applications.

The financial-market infrastructure has facilitated this transformation by offering dematerialised securities, electronic trading, online banking and digital payment infrastructure. Regulatory institutions have also helped to enhance the transparency, investor protection and level of market participation.

Financial information is becoming increasingly available, which has led to opportunities and challenges. If you are an investor, you can compare products, check on historical performance and even get educational content almost in real time. Too much information can also be confusing, though. It can be challenging for investors to identify sound investment advice from promotional material or untrustworthy online information.

The digital environment has also boosted the pace of investment decision making. A mobile application can help an investor to complete a transaction within seconds' time. This can be convenient, but can also lead to impulsive trading, as investors can be swayed by short-term price movements and may trade impulsively.

The digitalisation of investment must therefore not be understood in a technological sense. It is a behavioural and financial shift that is driven by both financial awareness and investor perception.

Review of Literature

1. Kumar et al. (2023) explore the intricate connections between the core financial skills, DFL, FC, FA, impulsivity, FDM, and PFWB in a post-COVID-19 scenario in India. The authors examine a sample of 512 respondents using partial least squares structural equation modeling (PLS-SEM) and show that foundational skills directly impact both DFL and FA. The results indicate that DFL is a direct predictor and mediator of sound FDM, and that FA significantly predicts FDM and PFWB. Moreover, DFL and FC sequentially mediate the link between skills and better PFWB, while impulsivity does not significantly contribute to mediation on decision-making outcomes.

2. Singh and Singh (2024) discuss the digital investment landscape, including robo-advisors, cryptocurrency exchanges and online trading platforms, and how these platforms are changing personal finances and financial education for opportunities of financial inclusion. examine how digital investment platforms (e.g., online investment dealer platforms, cryptocurrency exchanges and robo-advisors) are reshaping

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personal finance and financial education and the opportunities they provide for financial inclusion. Although these advances offer the potential for market access and ease of entry, they also pose serious challenges including information overload, regulatory ambiguity and heightened cyber security concerns. To overcome these challenges the authors emphasize the introduction of technology-driven educational materials that can be applied, including gamification, interactive learning units and immediate alerts to help people make the best financial decisions.

3. Kokila and Madhumathi (2026) suggest a theoretical model that integrates three concepts: the Technology Acceptance Model (TAM), the UTAUT paradigm, and financial literacy to explain the adoption of digital financial planning tools by individual investors in India.The authors find that perceived usefulness, perceived ease of use, trust, financial literacy, digital financial literacy, and perceived risk are key factors impacting behavioral intention and platform usage. The model highlights the importance of cultivating a sense of trust and understanding through relational activities and developing digital skills to address risk perceptions, thereby fostering the engagement of retail investors and promoting long-term sustainable adoption of FinTech

4. Solanki et al. (2019) examine the influence of digital technology on individuals' investment decision-making, namely the internet, social media and online applications. The conceptual framework shows that when transaction costs decrease significantly in a digital environment, the reach increases significantly as well, but information overload can create an "illusion of knowledge" problem, which leads to overconfidence and suboptimal portfolio decisions for retail investors. Moreover, uninformed investors are especially vulnerable to behavioral biases that can result from selective corporate news and social media statements. The authors suggest the use of expert-supported Decision Support Systems (DSS) to combine information and direct rational portfolio management, to overcome these cognitive shortcomings.

5. Shetty (2025) explores the connection between financial literacy and investment decisions among young people in India in the post-Digital India context. The study among 150 students aged 18-25 in Dakshina Kannada show that there is a high awareness of digital tools and mobile trading apps, however, financial literacy on the whole is moderate and includes moderate awareness of risk management, inflation, and diversification. A move toward market oriented products such as SIP mutual funds is visible, however, investment decisions are often made based on peer group or social media instead of formal analysis. The author proposes to create structured financial education programmes that will fill the gap between information in the digital age and knowledge-based decision making.

6. Uma (2025) analyzes digital investment applications and their impact on retail investment habits, especially as younger Indians are shifting from traditional investments such as gold and fixed deposits to market-oriented equities and mutual funds. According to the report, 68% of the respondents prefer the digital platforms for trading and financial education, citing figures from the Investor Behavior Index 2025. The benefits of key technological features, such as AI insights, paperless onboarding, low entry barriers and virtual trading, are shown to minimize the entry barriers and promote financial literacy. In general, the study shows the critical role digital apps can play in advancing financial inclusion and income creation.

7. Karan (2023) elaborates on the impact of digitalisation on the financial services sector in India and the resulting rise in retail investor participation. Internet access has become affordable, making retail access to stock markets and mutual funds more widespread, and paperless onboarding and mobile trading platforms have led to a rise in retail participation in the stock markets and mutual funds, particularly in Tier-2 and Tier-3 cities and rural areas. The digital tools have minimized the transaction costs, the transparency of the market and facilitated the adoption of Systematic Investment Plan (SIPs) by a huge number of investors, resulting in the emergence of the massive growth of Assets Under Management (AUM) in the industry. In addition, the emergence of new-age digital assets like cryptocurrencies and NFTs and the need for robust cybersecurity and regulatory frameworks are highlighted.

8. Srinivas et al. (2025) examine the drivers behind Generation Z's adoption of digital investment platforms and wealth management tools in India. Out of all, financial literacy is the highest predictor of the adoption intention and the second highest predictor is trust in digital technologies like AI and blockchain, according to the empirical analysis of 200 young investors aged 18-25.The empirical analysis, which included a sample of 200 young investors aged 18-25, shows that financial literacy is the most important factor influencing the adoption intent, followed by trust in digital technologies like AI and blockchain, and peer influence from social media. Moreover, digital convenience positively moderated the positive effect of peer validation on the digital adoption in moderated regression

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analysis. Out of these, the authors argue that financial literacy and regulatory protection are essential for continued fintech engagement, while hybrid advisory models are as well.

9. Agarwalaa and Sikidar (2025) employed secondary qualitative data from 29 publications to assess the information processing and decision-making of Indian retail investors. Although investors focus on rational economic measures, the authors discovered that cognitive biases, such as herd behavior, loss aversion, disposition effect and overconfidence, have a significant influence on actual investment decisions. Choices for independent analysis are heavily influenced by informal social networks (family, peers, brokers) especially in non-urban areas. While the market has become ever more accessible due to fintech platforms, the volume of information and the lack of financial literacy still leads to poor investment decisions.

10. Bedi (2025) studied financial behavior of the Indian Millennials and Generation Z, particularly the democratization of the capital market through micro-investing by digital fintech platforms and the role of UPI. The author analyzed the secondary data and concluded that youth between 18 and 35 years old become used to saving and disciplining themselves in spending their finances through micro investing. While Millennials are more conservative and prefer to invest in long-term instruments such as SIPs and retirement funds, Gen Z shows a higher risk appetite with their investments into stocks and digital assets influenced by social media. The study finds that micro-investment has a positive triple bottom line impact of improving financial inclusion and promoting capital formation and national economic growth.

11. Rakesh (2026) empirically analyzed the impact of behavioral biases, technology usage, and investor psychology on the quality of retail equity investors' decisions in the Indian stock market. The multiple regression analysis with primary data collected from 101 active retail investors showed that risk perception ($p<.001$, $\beta=0.485$) and technology usage ($p=.008$, $\beta=0.217$) are the most significant positive factors which predict the decision quality, followed by overconfidence ($p=.048$, $\beta=0.156$). The overall model accounted for 53.6% of the variance in decision quality, while loss aversion, anchoring and herding were not statistically significant.

12. Karthik and Ranjith Kumar (2025) examined how digital platform characteristics and behavioral factors affect the adoption of mutual funds by 110 retail investors in India. The authors employed purposive sampling and chi-square analysis to conclude that the perceptions of platform convenience, user-friendliness and transparency are significant factors that positively impact investor engagement over time ($\chi^2=12.10$, $p<0.05$) and satisfaction ($\chi^2=17.08$,$p<0.05$). The sample was very young, with an educational level of 76.4% of young people under 35 years old, and showed that although fintech innovations make it easier to participate in digital investments, financial literacy and trust in financial systems are still important for reducing the perception of risk and maintaining the participation of such investments in the digital sphere.

13. Li (2024) investigated the impact of enterprise digital transformation on institutional investors' investment behavior using A-share listed companies from 2008 to 2021. The author used a multi-period double-difference (DID) model combined with financial report text mining to conclude that the shareholding ratio of institutional investors ($\beta=1.099$) is significantly higher when there is digital transformation. This effect is explained by increased information disclosure quality, decreased information asymmetry and lower investment risks.

14. Li et al. (2024) conducted a study to examine how enterprise digital transformation affects corporate investment decisions and performance, applying data from the listed companies in China from 2007 to 2021. The authors analysed 28,430 firm-year observations and found that digital transformation has a significant effect on the increase in R&D investment ($\alpha_1=0.92$, $p<.01$) and financial investment ($\alpha_1=1.02$, $p<.01$). The results suggest that these decisions have different performance implications, however – increases in R&D have a positive impact on firm performance ($\alpha_2=1.50$, $p<.10$); and higher levels of financial investment have a negative impact on overall firm performance ($\alpha_2=-0.09$, $p<.01$).

15. Shukla and Surti (2026) studied the effect of financial technology innovations on the decision-making process, trading practices and risk attitude of the retail investor in the city of Surat of India. Using SPSS based regression analysis, the authors analyzed 102 retail investors and showed that although trading frequency was found to have a weak effect on overall investment behavior ($\beta=0.234$,$p=.018$), specific features of the platforms (AI recommendations, real time analytics) had a strong positive impact on trading decisions ($\beta=0.366$, $p=.000$). Moreover, perceived benefits are found to be significantly related to the risk perception ($\beta=0.411$, $p=.001$) which implies that qualitative functionality has a stronger effect on investor behaviour than usage frequency.

16. Kumar et al. (2024) compiled a review of the impact of digital financial infrastructure on retail

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investment behavior in the Indian capital market. The authors shared insights on how the government's policies such as Digital India, increasing broadband reach, and UPI integration have sparked the eagerness of millions of retailers to enter the Demat account including a review of macroeconomic data, regulatory changes, and behavioural trends. The authors shared ideas on how the initiatives such as Digital India, expansion of the broadband penetration and seamless UPI integration, have triggered the retail mass participation as seen in the creation of millions of new Demat accounts. The literature suggests that there is a shift in the structure from traditional channels to the digital channels driven by artificial intelligence and robo-advisors as well as mobile trading applications. This has revolutionized retail investors' trading habits, risk management approaches, and asset preferences, resulting in more frequent, informed trading decisions.

17. Srivastav et al. (2024) examined the effect of financial technology and digitalization on investment choice decisions of mutual fund investors. The authors used linear regression analysis of primary survey data from 124 mutual fund investors and found that both digitalization factors ($p<0.001$) and fintech tools ($p=0.012$) positively influence the investor decision making process and that both factors together account for 42.3% of the variance ($R^2=0.423$). They found that there is a shift in behaviour towards digital platforms for a variety of reasons, including convenience, increased accessibility, and the ability to access real-time information.

18. Santhosh and Selvamani (2024) studied some of the factors influencing Indian retail investors to shift to digital platforms for mutual fund distribution with a specific emphasis on behavioral intention and digital adoption. The authors used descriptive statistical analysis and t-test analysis based on the empirical data obtained from a primary survey conducted on a structured questionnaire to evaluate certain of the primary determinants, namely convenience of platforms, security of the systems, accessibility and perceived clarity of the procedures. The empirical results suggest that overall, there was a strong positive sentiment towards self-directed digital investing among all demographic groups, and that there were no statistically significant differences in sentiment among male and female investors when it comes to comfort with investing, security, or regulatory compliance.

19. Otari and Prem (2024) explored the potential of digital technologies for wealth management and how this can enhance financial literacy and investor awareness. To assess the impact of fintech tools, robo-advisory services, and mobile apps on investor decision-making, the researchers employed a mixed-methods approach, employing quantitative analysis of platform metrics, surveys of investors, and qualitative analysis of interviews with experts. The study points to the new opportunities opened up by digital tools for financial services, ensuring real-time data and customized financial education. The benefits are also underscored, though, by the fact that there are many challenges that need to be overcome, such as concerns around data privacy, algorithmic transparency, cyber security concerns and regulatory compliance issues.

20. Zhang (2024) investigated how fintech innovations (robo-advisors, blockchain technology, and social trading platforms) affect investor behavior using behavioral finance theory. Existing literature shows that algorithmic trading platforms, also known as robo-advisors, can reduce problematic cognitive errors such as loss aversion and overconfidence that can lead to poor investment decisions by automating the investment process, but they also have the potential to cause algorithmic over-dependence. Cryptocurrency markets, on the other hand, amplify the risks of speculation, mental accounting and short-term volatility. Moreover, social trading platforms open up the world of trading to everyone, but also foster herd mentality and short-term trading. The author notes that further research into the impact of new digital behaviour risks is required and stable regulations are essential.

21. Vangala (2024) explores the impact of digital tools on financial behaviours among the different age groups and looks at the interaction between technological innovation and demographic factors. The study takes a qualitative approach, conducting 12 semi-structured interviews and two focus groups with participants from each generation: Baby Boomers, Generation X, Millennials, and Generation Z, to assess adoption trends among the generations. The results contradict common notions about older generations' attitudes to digital platforms, showing that there is much more receptivity than is widely believed. On the other hand, younger investors are keen to invest in digital channels but are highly conscious of the risks. Young investors, on the other hand, are looking for personalized, tech-driven experiences, while being aware of the risks involved in digital channels. Drawing on the Technology Acceptance Model and Disruptive Innovation Theory, Vangala stresses the importance of combining human intelligence with algorithmic solutions to create trust and boost engagement.

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Objectives of the Study

The main aims of the study are:

1. To examine the concept and importance of financial awareness in the digital investment environment.
2. To examine the perception of Indian investors about digital investment platforms and financial products.
3. To examine the relationship between financial awareness and investment decision-making. To understand the key opportunities and challenges of digital investment for investors in India.
5. To suggestions measures to increase financial and digital investment awareness among Indian investors.

Research Methodology

The study is descriptive and conceptual in nature. The research is primarily based on secondary sources of information. Academic books, research papers, reports, institutional publications and other credible sources were reviewed relevant to the study on financial literacy, investor behaviour, digital finance and investment decision making.

The study is conceptual and centers around the Indian individual investors who are investing in the digital investment environment. The key variables that are discussed are financial awareness, perceived benefits, perceived risk, digital trust, investment knowledge, information exposure and investor behaviour.

The study does not state the results of a primary survey. Rather, it draws on previous theoretical and empirical studies to gain insight into the connection between investors' perception and financial awareness.

Financial Awareness in the Digital Investment Environment

Financial awareness is the financial concept, the financial products, financial risks, and financial decision-making principles that a person is aware of. Financial awareness has evolved in a digital world, during which it is multi-dimensional. It has knowledge of investment products, risk and return relationships, transaction costs, digital security and critical evaluation of financial information. These dimensions assist investors in making informed and responsible investment decisions.

1 Knowledge of Investment Products

The digital platforms offer a variety of financial products. It's important that investors be aware of the basic features of equity shares, mutual funds, bonds, fixed-income products, exchange traded funds, and pension-related products before investing. Understanding of these products allows investors to make comparisons based on the returns, risks, liquidity and time-horizon they can expect. It also enables them to choose investment options that align with their financial goals.

2 Understanding Risk and Return

Every investment involves some degree of risk. Financial awareness enables investors to understand that potentially higher returns are generally associated with greater uncertainty. An investor must determine his or her investing objectives and risk tolerance before choosing products. Understanding market volatility, inflation risk, credit risk and liquidity risk allows investors to make more realistic expectations about returns and avoid investment decisions based solely on promises of high profits.

3 Awareness of Costs

Digital investment platforms might promise low-cost or commission-free investment services, but investors should note brokerage fees, fund fees, taxes, and applicable fees. It is the cumulative effect of even modest expenses over time that can impact investment results. Financial savvy investors therefore consider the full cost framework for a product to invest in and compare options before choosing to invest through digital platforms.

4 Digital Security Awareness

Investors require more awareness of safe passwords, authentication, strange links, fraudulent calls, fake investment applications, and unauthorised transactions. Thus, cybersecurity awareness is a crucial element of financial literacy. Investors also must be aware of the need to safeguard personal and financial data and check out digital communications before acting. This awareness can help minimize risk to online financial fraud and other cyber risks.

5 The ability to evaluate information

Digital investors get information from various sources. Financial awareness enables individuals to consider whether information is reliable, relevant and suitable for their situation or whether to follow all online information. Investors need to differentiate information that is accurate and factual, promotional material, opinions and claims that are misleading. The capacity to critically analyse digital information can help to mitigate over-reaction and promote more rational and goal-oriented investment habits.

Investor Perception Towards Digital Investment

The perception of investors is their understanding of the benefits, risks and trustworthiness of digital investment services. It plays a crucial role in influencing investors' willingness to engage in online trading and technology-enhanced investment strategies. The factors that might influence the adoption of AI through negative attitudes are risk, privacy and reliability concerns,

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whereas the positive attitude factors may be convenience, ease of use, transparency and security.

1 Perceived Convenience

Convenience is one of the strongest attractions of digital investment. Investors can have accounts and monitor investments from a distance and without having to go to a physical branch or broker. Customers can place orders from anywhere, check their portfolios, get a history and be alerted to their investments anywhere in the world, thanks to digital platforms. This may be a convenience and time saver for busy investors and busy people in general.

2 Perceived Accessibility

Geographical barriers have been minimised through the use of digital platforms. People can trade with an internet connected device and increase their access to investment opportunities. Investors can access financial data, compare financial products and take investment actions without relying solely on the services of the physical broker. Accessibility can be enhanced and can lead to participation from people who have been unable to access traditional financial services due to distance, availability or time.

3 Perceived Transparency

Despite the advantages, some investors are worried about market volatility, cybercrime, privacy concerns, tech issues, and misinformation. These worries can impact on their preparedness to utilize online investment platforms. Oversimplified personal advice, or trust on information found online, can also cause investors to make incorrect decisions. Thus, risk perception might play a crucial role in the uptake and maintenance of digital investment services.

4 Perceived Risk

Some investors' concerns remain about volatility, cyber fraud, privacy concerns, technical issues, and misinformation. This can impact their decision to use digital investment platforms. Investors might also feel they have made the wrong choices due to their own lack of personal advice or too much reliance on information found online. As such, a risk perception can have a substantial impact on the uptake and retention of digital investment services.

5 Trust

Building trust is key to digital financial engagement. Investors require trust in the security, reliability and regulatory framework of digital platforms. However, financial investors may not be using online investment services due to lack of trust. Platform reputation, data protection measures, platform security for transactions, regulatory compliance, and customer support are all factors that can impact trust. Enabling users to trust digital investment platforms by establishing reliable institutional protections and user experiences.

Relationship Between Financial Awareness and Investor Perception

Financial awareness is one of the main factors for investors' perception towards digital investment. A financial savvy investor might be better able to differentiate between the two. This investor may also be aware that digital investment platforms offer up investments but don't remove investment risk.

Investors with financial awareness consider digital investment a means of meeting financial goals, not as a quick way to make money. They are more likely to take the time to think about diversification, investment timeframe, risk tolerance and financial objectives.

Furthermore, those investors who do not have the financial savvy might be more susceptible to behavioral biases and recommendations from investment websites. Ease-of-use applications may make it seem like investing is easy, and frequent info about the market can lead to impulsive trading..

Thus, technology can increase access to investment but financial awareness determines whether that access is used effectively.

Behavioural Factors in Digital Investment

Financial awareness is not enough to eliminate behavioural biases. There are several psychological and emotional factors that affect decisions when it comes to digital investments. These biases can be exacerbated by the access to real-time information, social media debates, online investment platforms, and instant trading facilities. Behaviours are important to understand as investors can sometimes make decisions emotionally, socially influenced or due to previous experiences, rather than making a thoughtful financial decision.

1 Herd Behaviour

Investors may follow popular investment trends because many other people are investing in the same asset. This inclination can be exacerbated by social media, which can quickly promote investment patterns. Popular stocks, trending investments, and conversations about investments between traders and investors on online platforms can give the appearance that an investment is safe or successful just because a lot of people are investing in it. Consequently, investors may ignore their own financial objectives, risk tolerance, and investment knowledge and make decisions based primarily on the behaviour of others.

2 Overconfidence

Convenience of market information can lead to over-confidence among investors. Individuals may

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believe that frequent monitoring or short-term market predictions can consistently generate superior returns. The 24/7 availability of market data, financial news, analysis and commentary on digital investment platforms can lead to an enhanced sense of control for investors. Investors that are overly confident may over-trade, underestimate risks or overestimate their own judgment. This can lead to unnecessary transactions and may have a negative impact on long-term investment results.

3 Loss Aversion

Investors may react strongly to losses and hold unsuitable investments because they are reluctant to realise a loss. Loss aversion means that the impact of a loss on a person's psychology is greater than the satisfaction of an equivalent gain. The emotional responses may be heightened when investors can see portfolio losses immediately in a digital investment environment. As a result, some investors may choose not to sell investments that are not doing well even if the overall circumstances have grown increasingly unfavorable, in the faith that the prices might rebound.

4 Recency Bias

Investors' expectations can be impacted by recent market performance. Investors may feel confident that past performance will continue because of the strong returns in recent months. Recent information is easily seen on digital platforms, which give investors real-time data on market prices, returns, ranking and investment performance. This can lead investors to focus on short-term price fluctuations over the past performance and fundamentals. Consequently, they can be driven to invest heavily in assets that have been successful in the recent past but have not taken into account potential shifts in the market or future risks.

5 Fear of Missing Out

Digital communication can push pressure to engage in many popular investment opportunities. Investors can be tempted to make investment choices without proper assessment because they are afraid of missing out on some gains. This psychological pressure can further be intensified by social media platforms, investment communities online, financial influencers, and notices on trending investments. Investors might think that they are not doing so well and that others are making a ton of money. This may lead to impulsive decision making; too much trading; and a poor understanding of risk, especially when investment options are described as being limited or time sensitive.

Opportunities Presented by Digital Investment

Digitalisation has created several opportunities for Indian investors.

First, digital platforms have improved access to financial markets. Secondly, the processes of transactions are also faster and more convenient. Thirdly, investors are able to get information and compare investment options with greater ease. Fourth, Digital tools can complement systematic investing and portfolio monitoring. Fifth, technological innovation has facilitated competition between providers of financial services, which can enhance the quality of financial services and lower financial service barriers to some transactions.

The digitalisation of financial services can also contribute to financial inclusion by making investment services accessible to those who were not able to access traditional financial institutions.

Challenges of the Digital Investment Environment

The digital investment offers many advantages, but also several challenges. The rapid growth of online investment platforms, mobile applications, social media and digital financial services has made investment more accessible and convenient. The improvements have, however, also resulted in new risks arising in the areas of information, technology, security, investor behaviour, and unequal access. In the digital investment landscape, the following challenges are especially pertinent.

1 Information Overload

Excessive financial information may be presented to investors which makes it challenging to identify the reliable information. Digital platforms offer 24-hour access to financial news, market updates, expert analysis, investment tips, ads and social media commentary. This large volume of information may create confusion and make the investment decision-making process more complicated. Investors may find it difficult to distinguish between relevant, credible, and promotional information, potentially resulting in inappropriate investment choices.

2 Cybersecurity Threats

The cyber risks associated with online financial transactions include the risk of being vulnerable to phishing, identity theft, fraudulent communications, and more. Mobile applications and online platforms are becoming more common for investors to manage their accounts, transfer funds, and make investments. Confidential information can be accessed and stolen by cybercriminals via deceptive messages, fake websites and unauthorised access. These risks may lead to financial losses and the compromise of personal data. Therefore, investors need adequate awareness of cybersecurity practices and should

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carefully verify digital communications before taking financial actions.

3 Misinformation

Information regarding investments on social media platforms may not be accurate, balanced or appropriate for the individual investor. Investment opinions, recommendations, market predictions and financial claims can go viral on social media platforms. The information provided in this document may be incomplete, speculative, and based on various opinions or unverifiable sources. Investors who heavily depend on such information could underestimate investment risks or form unrealistic expectations for investment returns. Therefore, information should be cross-checked with credible and authorised financial sources before making investment decisions.

4 Excessive Trading

Low-friction digital trading can encourage investors to trade more frequently than necessary. Digital investment apps have enabled people to make better investments and earn returns on their money in just a few clicks on their mobile phones. This accessibility also makes participation more popular, but can lead to short term speculation and impulsive trading. Trading regularly can lead to additional transactional expenses and market risks for the investor. Investors can thus benefit from a disciplined approach to investing, focusing on their financial goals and not on every short-term price fluctuation.

5 Digital Divide

Internet connection is not always reliable or smart phones or digital financial skills are not equally available to everyone. Income, education, geographical location, technological infrastructure, Factors that can affect a person's ability to be digitally literate are and digital literacy. investment. Some techno-savvy people might not grasp the use of Making investments, online transactions, and recognizing digital threats. This digital divide can create unequal opportunities for financial engagement and keep out social groups. Leveraging the advantages of the wider digital investment opportunities.

6 Emotional Decision-Making

Emotionally driven investing decisions can be influenced by real-time price changes and notifications. Investment platforms continue to provide information about the market all the time in the digital format. prices and performance of investment portfolios, profits, losses and changes in performance. Frequent exposure to such information may lead to an increase in anxiety when markets are declining and/or an excess in anxiety when markets are rising. It is a good time to be optimistic when prices are on the rise. Investors might thus invest or sell securities for fear, Due to the excitement or short-term changes in the market, rather than studying it well. Cultivating financial The key is to increase awareness and establish a long-term investment plan to help reduce emotionally driven Decisions. choices.

Discussion

The Digital Revolution in India's investment landscape is a huge achievement for retail investors. financial engagement. Technology is not the solution to better investment performance, however. Knowledge, financial awareness, risk perception, behavioural discipline of investors. It is important to recognize that there are a variety of factors that affect investment decisions, including risk and return.

Financial awareness helps investors to know the difference between investment and speculation, have a sense of risk/return trade-offs, choose suitable products and have investment perspectives. Digital literacy goes hand-in-hand with financial literacy, assisting investors in navigating online platforms safely

The increasing role of social media also deserves attention. Financials can help raise awareness when accurate and informative, but false statements can lead to substantial risk for novices. Investors should thus get used to checking the financial facts with credible sources before taking action.

Suggestions

The following measures may improve financial awareness and investor perception:

1. Strengthen Financial Education: Financial education should be part of the curriculum in schools, colleges and universities and should be incorporated into community programmes. It should include fundamental concepts like saving, investment, risk, return, diversification, inflation, taxation and financial planning. Financial education in practice can help people to know the investment options and make choices. Awareness programmes can also be rolled out on an ongoing basis to build financial awareness and minimize the reliance on the information sources.

2. Support Digital Financial Literacy: Investors should learn about online fraud, password protection, security of digital transactions, authentication and privacy. It should also cover the concepts of secure applications, two factor authentication, suspicious links, and responsible use of investment platforms online. These skills can lower the risk of investment losses due to cybercrime and facilitate investors' easier and safer engagement in digital financial services.

3. Improve Investor Education: The financial benefits, costs, limitations and risks associated with

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investment products should be easily understood by financial institutions and regulators. All financial terms should be translated into simple words, illustrated, explained in video format, and be presented in educational materials. Investors should also be provided with clear details of brokerage fees, fund costs, taxation, liquidity, and possible losses. Investor education can enhance investor decision-making, and minimize investor misunderstanding with financial products.

4. Promote long-term investment attitudes: Investors need to be reminded to disregard short-term price fluctuations and stick to longer-term investment objectives. Investing for the long term can help individuals filter out the noise of the market and prevent emotional investing. They should be motivated to set clear investment goals like retirement planning, education, or wealth building. Consistent investment and the proper management of portfolios can help to ensure the stability of the finances and minimize needless trading.

5. Promote Source Verification: Investors should research financial data before taking action on recommendations from social media or information found online. They should check any information with reputable sources like the regulatory authorities, recognised financial institutions, official company statements and credible financial publications. Opposable assurances, guaranteed returns, promotional messages and anonymous recommendations should be taken with a pinch of salt. The effects of misinformation on investment decisions can be mitigated with critical evaluation of information.

6. Increase Cybersecurity Awareness: Investors should be alerted to fraudulent links, impersonation, fake applications, suspicious communication, etc., through consistent campaigns. Investors should be advised to check websites and apps prior to providing financial or personally identifying information. Furthermore, awareness programs should help people understand the need for password and authentication code protection, as well as their accounts. Enhanced cybersecurity education enhances investor confidence and lowers cyber risk to investors.

7. Encourage Diversification: Investors should diversify and not overly invest in specific securities or asset classes. Financial education programmes must include information about how investments can be diversified to manage investment risk by investing in a variety of assets, sectors or financial instruments. Investors should consider their financial goals, risk tolerance, investment horizon, and financial capacity while constructing portfolios. Poor performance in one investment can be minimized through a balanced approach.

8. Create Responsible Digital Platforms: Investment applications should be clear about the risks and should offer educational tools to investors, but not any possible temptation to "frivolous" or "excessive" trading. The key information, fees, risk disclosure and investment implications should be clearly communicated on digital platforms prior to the transaction. Risk warnings, education materials, portfolio analysis tools, and reminders on responsible-investment principles can help to improve the decision-making process. The investor protection and financial welfare should be the priority of the platform instead of promoting unnecessary trading frequency**.**

Conclusion

The digitalization of the investment landscape in India has paved the way for unprecedented investment opportunities for individual investors. Digital platforms have enhanced accessibility, convenience, speed, and information availability. However, these benefits are accompanied by new challenges related to cybersecurity, misinformation, behavioural biases, information overload and excessive trading.

Financial literacy is thus gaining more and more significance. An investor with financial awareness can better analyze investment options, understands risk, comprehends financial information and make financial decisions aligned with personal financial goals. In the digital world, financial awareness needs to be supported by digital literacy, knowledge about cyber security and awareness of cyber security behaviours.

The attitude of investors is also a key factor in the process of digital investment adoption. Investors' willingness to use digital platforms is affected by convenience, transparency, security, and trust and risk perceptions. The relationship between financial awareness and perception, in turn, influences investment behaviour.

For India, the development of a digitally enabled but financially informed investor base should be a major objective. The role of the regulators, education, financial service providers and technology platforms all have significant roles. Future of digital investment should not only be growing the digital investor base, but developing the informed, responsible secure and financially resilient investor.

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Original Article

Agricultural Marketing Reforms in India

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Abstract:

Agricultural marketing significantly influences farm income in India, as production increases do not guarantee higher returns. This paper reevaluates India's agricultural marketing reforms, focusing on Agricultural Produce Market Committees (APMCs), market expansion, reliance on intermediaries, market access, information asymmetry, post-harvest sales, grading and packaging, and digital initiatives like the National Agriculture Market (e-NAM). The study employs a descriptive and analytical approach using secondary data, including various government publications and e-NAM records, and compares regulated markets across different years, highlighting percentage changes and CAGR indicators. The evidence indicates that while regulated markets have expanded over time, this growth has not uniformly addressed farmer market access issues. Key challenges include distress sales, inadequate infrastructure, and reliance on intermediaries, suggesting that market quantity and quality require distinct policies. The e-NAM initiative has enhanced price discovery and market integration, with 1,656 mandis linked by March 2026 and over 1.80 crore farmers involved. The paper advocates for reforms that transition towards a multi-channel, farmer-centric system encompassing various market types and regulatory strategies.

Keywords: *Agricultural Marketing; APMC; e-NAM; Farmer Producer Organisations; Market Access; Price Discovery; Intermediaries; Market Infrastructure; India*

Introduction:

Agricultural marketing refers to the institutional and economic process that facilitates the movement of agricultural produce from producers to consumers, processors, and exporters. This process encompasses activities such as assembling, transportation, grading, standardization, storage, financing, price discovery, bargaining, processing, and payment. In India, the marketing stage is crucial due to the predominance of small-scale producers who often encounter high transaction costs and limited bargaining power. India's regulated-market institutions arose to address issues in unregulated agricultural trade, such as arbitrary weighing, information asymmetry, and weak producer bargaining power. Agricultural Produce Market Committees became key to regulating wholesale transactions. However, regulation alone did not ensure competitive and integrated markets. The article discusses persistent issues in India's agricultural marketing, including post-harvest distress sales, market interlinkages, inadequate grading, and weak APMC functions. These challenges are significant in current policy discussions as the sector evolves with e-NAM, FPOs, digital payments, and a potential national policy framework. The paper argues that the core challenge is not merely the number of markets but rather effective access, competition, infrastructure, information, bargaining power, and institutional accountability.

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Objectives of the Research Study:

- To examine the structural weaknesses of agricultural marketing reforms in India.
- To assess the long-term expansion and uneven distribution of regulated agricultural markets.
- To analyse the institutional strengths and weaknesses of the APMC system.
- To examine the potential and limitations of e-NAM and digital market information.
- To assess the role of FPOs and physical marketing infrastructure in strengthening farmer bargaining power.
- To propose a farmer-centric framework for the next generation of agricultural marketing reforms.

Research Methodology:

The study employs a descriptive, analytical, and policy-review methodology using secondary data from Government of India publications, e-NAM records, and other official policy materials. The dataset includes market counts from selected states for the years 1971, 1981, 1990, 2000, and 2023. The historical table serves as a reproduced secondary dataset, and the author must verify each historical observation against the original Directorate of Marketing and Inspection reports before submission to a peer-reviewed journal.

Historical Expansion of Regulated Agricultural Markets:

The article highlights significant long-term growth in regulated agricultural markets in India, with figures rising from 2,754 in 1971 to 7,064 in 2023, marking a 156.5% increase and a compound annual growth rate (CAGR) of approximately 1.84%. It notes, however, that state-level trends vary considerably.

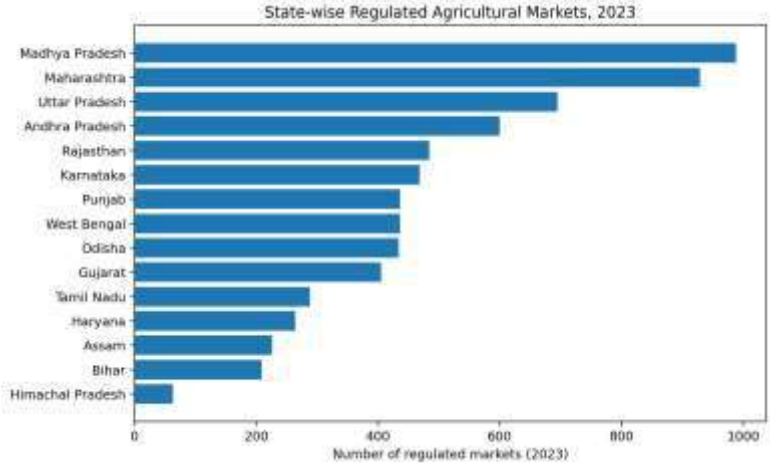

Figure 1. State-wise number of regulated agricultural markets, 2023. Source: Historical table reproduced from the supplied article; underlying source cited there as Directorate of Marketing and Inspection, Ministry of Agriculture & Farmers Welfare.

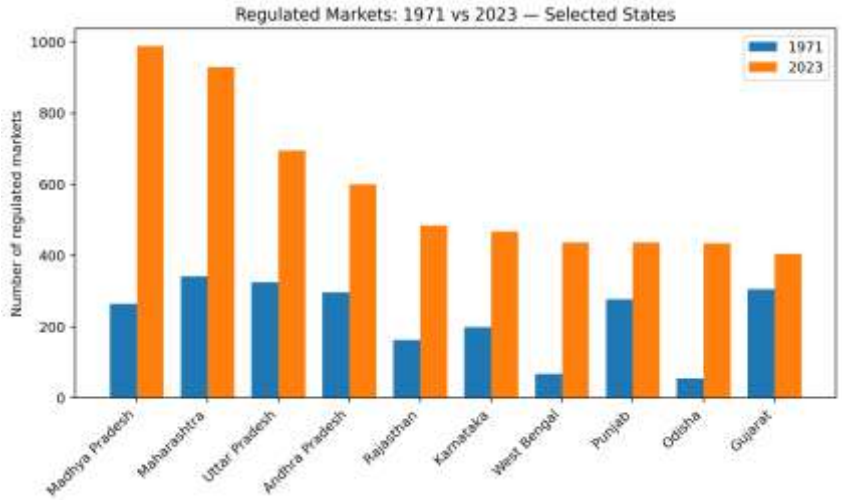

Figure 2. Regulated markets in 1971 and 2023: selected states.

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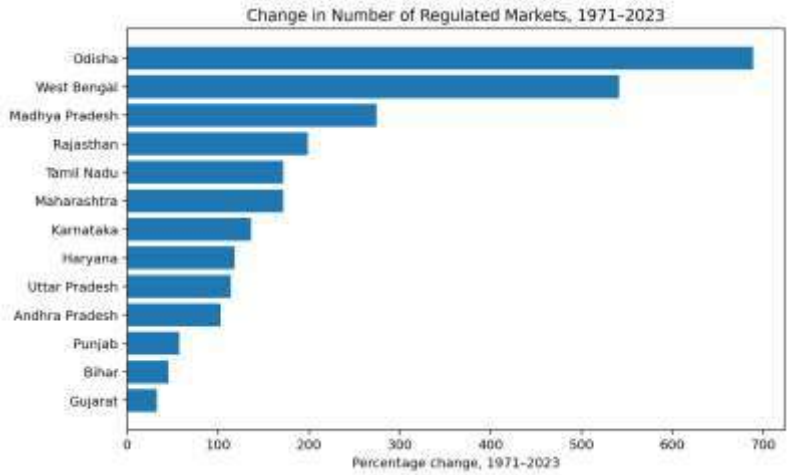

Figure 3. Percentage change in regulated markets, 1971–2023, for states with a non-zero 1971 base.

State-Wise Descriptive Evidence:

State	1971	1981	1990	2000	2023
Andhra Pradesh	296	539	468	681	600
Assam	0	16	32	35	226
Bihar	144	443	798	873	209
Gujarat	306	227	348	396	405
Haryana	121	178	257	284	264
Himachal Pradesh	0	35	42	35	63
Karnataka	198	319	397	473	468
Madhya Pradesh	264	329	432	616	988
Maharashtra	342	453	763	646	929
Odisha	55	68	130	144	434
Punjab	277	347	662	654	436
Rajasthan	162	328	379	480	484
Tamil Nadu	106	245	276	290	288
Uttar Pradesh	325	617	635	684	695
West Bengal	68	233	337	544	436
India	2754	4605	6227	7227	7064

Table 1. Number of regulated agricultural markets, 1971–2023. Source: Dataset reproduced from the supplied article; Directorate of Marketing and Inspection reports as cited therein.

The analysis reveals that the growth of regulated markets varies significantly across regions. Madhya Pradesh, Maharashtra, and Uttar Pradesh have extensive market networks as of 2023, while Odisha and Assam show significant percentage increases from lower bases. This variation emphasizes the limitations of using a national market-count indicator to gauge market access effectively. Additionally, caution is warranted in interpreting percentage growth; small historical bases can yield high percentage increases alongside modest absolute market networks, while larger agricultural areas may necessitate denser markets despite appearing to have smaller growth percentages.

Structural Weaknesses in Agricultural Marketing

1. Post-harvest distress sales

Farmers often sell their produce immediately after harvest due to various constraints such as perishability of goods, the need for debt repayment, household liquidity requirements, lack of storage facilities, and limited access to working capital. Consequently, the capacity to delay sales becomes a critical factor in enhancing their bargaining power.

2. Credit–commodity market interlink ages

Informal credit provided by traders or commission agents can lead to institutional linkages in production finance and marketing services. These connections may restrict farmers' autonomy regarding the timing and selection of their buyers during sales.

3. Intermediation and transaction costs

Intermediaries play a crucial role by offering services such as aggregation, transport, finance, information, and risk-bearing. The primary policy goal should be to minimize unnecessary and opaque intermediation instead of broadly

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eliminating intermediaries that serve important economic functions.

4. Grading, assaying and packaging

Quality differentiation is crucial for effective price discovery in agricultural markets. Inadequate farm-level grading, packaging, and assaying can lead to the mispricing of heterogeneous produce, resulting in insufficiently differentiated prices. This highlights the importance of improving quality assessment techniques to ensure proper market valuation.

5. Information asymmetry

Farmers need timely access to essential information concerning prices, arrivals, buyer requirements, quality premiums, transport costs, and alternative markets. In the absence of such usable information, the presence of multiple markets may fail to provide real bargaining power for the farmers.

6. Uneven market infrastructure

Economic accessibility of a market is influenced by various critical components, including roads, warehouses, cold chains, assaying laboratories, loading facilities, and digital connectivity. These elements collectively facilitate the efficient movement and management of goods, thereby affecting market viability.

7. Governance and professionalisation of APMCs

APMCs (Agricultural Produce Market Committees) serve to safeguard producers by fostering transparent auction processes and implementing regulated practices. However, certain challenges such as licensing barriers, insufficient competition, inadequacies in infrastructure, and governance issues may hinder market efficiency in specific areas.

8. APMC Reform: Beyond the Binary Debate:

The policy debate surrounding agricultural marketing is frequently simplified into a contrast between Agricultural Produce Market Committees (APMC) and private markets, a framing that lacks analytical depth. A more effective farmer-centric approach should encourage competition across various platforms, including APMC markets, private wholesale markets, direct procurement, Farmer Producer Organizations (FPO) aggregation, processors, exporters, and digital platforms. It is essential that this system upholds transparent regulations regarding weighing, grading, payment, quality standards, contracts, and dispute resolution.

9. E-NAM and the Digital Transformation of Agricultural Marketing

E-NAM, launched in 2016, is an online trading platform aimed at integrating physical wholesale mandis to enhance transparent and competitive price discovery. As of March 2026, it has integrated 1,656 mandis across 23 States and 4 Union Territories. The platform has registered over 1.80 crore farmers, 2.73 lakh traders, and 4,724 Farmer Producer Organisations. Since its inception, the cumulative trade has reached 13.25 crore metric tonnes, valued at ₹4.84 lakh crore.

Proposed Farmer-Centric Agricultural Marketing Architecture:

- Village-level aggregation and FPO formation
- Scientific grading, assaying and standardised packaging
- Storage and warehouse-receipt based marketing
- Multiple competitive channels: APMC, private market, direct procurement, FPO, processor and exporter
- e-NAM-enabled digital price discovery and electronic payment
- Transparent market fees, commissions and weighing
- Competition monitoring and buyer concentration safeguards
- Time-bound payment and accessible grievance redressal
- Local-language digital literacy and market-information support

Policy Recommendations:

1. Professionalise APMC governance and evaluate mandis using measurable service-quality indicators.
2. Promote genuine competition among APMC, private, direct and digital marketing channels.
3. Develop village and cluster-level aggregation centres linked to FPOs.
4. Expand assaying, grading, packaging and quality-certification infrastructure.
5. Scale warehouse and cold-chain facilities to reduce forced post-harvest sales.
6. Strengthen warehouse-receipt finance and working-capital access so farmers can defer sales.
7. Integrate e-NAM with reliable physical logistics, assaying and payment systems.
8. Use competition policy to monitor buyer concentration and unfair procurement practices.
9. Publish transparent, machine-readable market data on prices, arrivals, and quality and transaction costs.
10. Build local-language digital literacy and market advisory systems for small and marginal farmers.

Conclusion:

India's agricultural marketing reforms have led to significant changes, yet challenges persist, including spatial inequality and infrastructure deficits. The rise of e-NAM and Farmers' Producer

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Organizations (FPOs) offers a chance to enhance competition and collective bargaining. While digital technology can aid information flow and transactions, it cannot address storage, transport, or infrastructure needs on its own. A future-focused agricultural marketing system should prioritize farmers, integrating multiple channels and digital tools. APMCs should shift from regulation to market services, private markets must follow competition principles, and FPOs should strengthen their role in aggregation and commerce, all while ensuring e-NAM is supported by solid infrastructure. This strategy aims to translate production increases into improved farmer incomes.

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Original Article

Legal Information Literacy among Law Students: Developing a Competency Framework for Academic Law Libraries

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Abstract:
Legal information literacy is an important skill in law students as learning the law through effective legal education requires students' competency of identifying, locating, evaluating, interpreting, using and citing properly authority resources. Law research field is significantly changed due to the exploding of online legal databases, digital archives, electronic journals, websites (governmental, case law and others). But access to it does not guarantee the competency needed to evaluate the authenticity, accuracy, authority, relevance and currency of legal information. This study would propose to ascertain the level of legal information literacy among law students and establish competencies needed for efficient locating and utilization of legal information. The competencies examined would include awareness of legal information sources, access strategies to legal information, evaluation of legal resources, use of primary and secondary legal materials, legal citation issues, along with awareness of the issues such as authenticity, currentness, copyright, plagiarism and ethical use of information resources. Structured questionnaire may be used to collect data from both undergraduate and post-graduate law students. Both the descriptive statistics and relevant inferential statistics will be used to test the data and results may be discussed in detail. Based upon findings of this study with regards to the gaps in competency requirements the study puts forth a Legal Information Literacy Competency Framework for Academic Law Libraries. This Framework is useful to be applied as a basis for designing an information literacy programs and services such as library orientations, instructions on how to perform legal research and how to access information bases and research- support functions in university colleges and law.

Keywords: - *Legal Information Literacy, Law Students, Legal Research, Academic Law Libraries, Information Literacy, Legal Information Resources, Competency Framework, Digital Legal Resources.*

Introduction

Information literacy is becoming an indispensable feature of higher education, due to student reliance on variety of online information sources to acquire knowledge, conduct research, and make various academic decisions. In professional fields like law, information literacy develops a particular aspect because investigation in law means locating and finding relevant authoritative sources and further assessing and analyzing them; "legal research has become inherently an information literacy undertaking of discovering, finding, assessing, and understanding authoritative legal resources", stressed by Bracci and Friesen (2024). As Bracci and Friesen pointed out in the Contemporary online legal research context that skills of information literacy must develop with knowledge of legal research tools and sources. A law student is to search various statues and case law; legislation and regulations; the constitution and treaties; law reviews, commentaries and law reports; journals and other learning materials. Therefore, quality in the field of legal research requires more than simply finding out available information; law students need to separate accurate information from that which is incorrect, and modern from what is out of date.

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Michels and Rosborough (2024) illustrate the need to gauge law students' ability in law research skills and information literacy competence; in specific, toward the application and retention in law research skill development. Information literacy at law colleges is defined as the ability to recognize when and then where legal information is needed, locate, analyze, evaluate, verify, use, and communicate legal information appropriately and ethically. The shift to digital information environments have caused changes in the required information literacy skills for law students. Printed law reports and legal encyclopedias now exist along with on-line databases and other electronic sources like the Journals, Institutional Repositories, Government databases, digital archives etc. The importance of developing and integrating instruction of academic library resource use instead of primarily focusing on web search was discussed and emphasized through various means in the study by Parkin and Sehgal (2025).

Though the legal information field has unparalleled access to resources it is equally fraught with challenges from various perspectives due to inaccurate and outdated information in the system, ineffectual legal resources (unofficial versions of judgments and case notes, summaries etc.), unreliable internet-based resources and difficulties in discerning official vs non-official sources. Incorporation of critical information literacy concepts in legal education including the ability for law students to explore the structures of legal information and information production as well as how authoritative sources are made such as by Ward (2024). The role of academic law libraries extends beyond their traditional activities like collection development, reference services, circulation as well as provision of legal databases. This may evolve to playing a role in legal information literacy instruction and development of research skills. Parkin (2025) identified information literacy and library induction as key considerations in law school library services while Mnubi-Mchombu and Mbangula (2024) considered the attitudes of law students to the information & digital-literacy programme considering topics such as effective searching of OPAC's and electronic databases as well as information literacy and usage patterns. Khare and Khan (2026) determined awareness and use of information technology with law students' use of legal information. Empirical studies measuring awareness and usage were carried out by them. Indian studies measuring students ' usage of library as opposed to general web search while utilizing legal resources are limited though a 2025 study in the Journal of research & Development has assessed the relationship between the searching pattern of law students in law college libraries and law literature which involves in using of digital information in law libraries which include research strategies and information skills for legal data base in case law search etc.

Background of the Study

Legal research is one of the major aspects in legal education which necessitate students on how to find identify, locate, evaluate and effectively use authoritive legal information. Today, with the wide availability of the online legal database, e-journals, digital repositories, Government legal portal etc Law students need competences that is required to enable them carry out effective information searching and evaluation. Legal Information Literacy skills is defined as the skills required to find, evaluate, select sources and sources available within the scope of available resources and how they can develop effective search strings. Law students can find suitable sources and make an efficient use of legal database while assessing authoritativeness and up-to-date nature of legal information, synthesized from the various sources and applied adequate citation and ethics. A well-established library would not necessarily mean law students have well developed research skills in law. Information literacy and continued assistance in research skills have been underscored in recent studies. It implies there is a necessity for a competency-based approach, enabling academic law libraries to identify students' competencies, resolve their competency gaps and undertake systematic Legal Information Literacy Instruction (Khare & Khan, 2026). Thus, this study attempts to design a Legal Information Literacy Competency Framework for Academic Law Libraries.

Statement of the Problem

With the explosion of digital legal resources transforming the research process, student legal information literacy skills-specifically the ability to locate, evaluate, and verify legal information and put it to use in a practice context may be insufficient; the ability to recognize reliable authority, to distinguish between primary and secondary source materials, to critically assess on-line information and to conduct effective citations need to be understood within the larger context of identifying gaps in competency so that a framework can be built to enhance these skills within academic law library environments.

Objectives of the Study

- To examine the concept and significance of legal information literacy in contemporary legal education.
- To identify the key competencies required by law students for effective legal information searching, evaluation, verification, and use.

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- To examine the role of academic law libraries in developing legal information-literacy competencies.
- To propose the LIL-AL (Legal Information Literacy–Academic Library) Competency Framework for strengthening legal research skills among law students.

Research Gap

A body of recent research, including assessment of the legal research skills, information seeking behaviors, information use, digital literacy and online uses of law students, is available. In contrast, a relatively meager investigation was carried out into measurement of legal information literacy as a multidimensional competency in respect to discovering and searching information, information evaluation and validation, and information application and information ethics. Similarly there is little research that has developed empirically valid law student and academic law library-specific competency framework for measurement legal information literacy skills. Thus, this study is aimed at measuring law students' legal information-literacy competencies, developing a legal information-literacy competency framework for academic law libraries.

Conceptual Framework

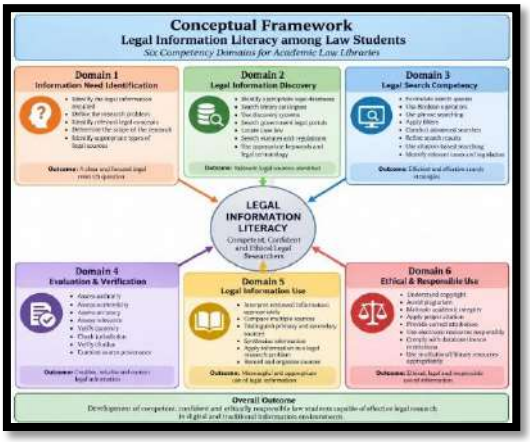

Figure 1. Conceptual Framework of Legal Information Literacy Competencies among Law Students

The Proposed LIL-AL Framework for Legal Information Literacy Competency in Academic Libraries

The framework is composed of six consecutive domains of competence, advancing the process through discovery to ultimate success through responsible legal research competence.

1. Understanding a Legal Information Need
2. Recognizing legal information sources
3. Locating and Searching for Legal Information
4. Evaluating and Assessing Legal Information
5. Integrating, synthesizing, and applying information
6. Using legal information responsibly

Domain	Core Competency	Expected Outcome
1. Information Need Identification	Define research problem and information requirements	Clear research need
2. Source Identification	Identify primary and secondary legal sources	Appropriate sources
3. Discovery & Search	Search databases, catalogues, portals and legal resources	Relevant information retrieved
4. Evaluation & Verification	Assess authority, accuracy, currency, authenticity and jurisdiction	Reliable legal information
5. Interpretation & Synthesis	Compare, interpret and apply information	Meaningful legal research
6. Ethical & Responsible Use	Citation, copyright, plagiarism and responsible resource use	Ethical information use

Table: 1 LIL-AL Framework for Legal Information Literacy Competency in Academic Libraries

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Legal Information Literacy: Key Competency Areas

Legal information literacy involves the skills not only of finding legal sources but is a mix of information, digital, analytic and ethical competencies for effective legal searching. With these information and digital skills there are many layers involved, so for law students, it's useful to view legal information literacy within six interconnected spheres:; to determine and articulate a need for information; to identify the potential locations of the required information and suitable legal sources in which to find it; how to seek and find the information, for example searching of a database or the use of an index; how to critically appraise the sources and verify the information gained; how to accurately interpret the found information in the context of the legal issue and then how to apply it appropriately and an appropriate use of the legal information, i.e. Ethically.

- **Recognition of Legal Information Requirements -** Recognizing and identifying what legal information is required is the first part of legal research. The student should be in a position to recognize the legal problem, the question on which research needs to be done, the extent of the problem, and the kind of information that is likely to help him resolve the problem.
- **Identification of Legal Information Sources -** The Identification of Legal Information Sources Law students must be able to differentiate between primary and secondary legal sources. Laws, statutes, court decisions, constitutions and rules are primary source materials whereas textbooks, commentaries, journals and encyclopedias or journal articles and treatises are secondary source materials. The selection of a suitable resource is important.
- **Electronic Discovery of Legal Information Search -** Today, information is largely discovered electronically via databases, library catalogues, institution archives, government sites and on-line legal sources. A law student should be capable of effectively determining key words, employing Boolean operations, setting appropriate filters, performing advanced searching and identifying cases and statues of relevance.
- **Assessment and corroboration of legal material -** The authority of any legal research will rest on the authority of the source materials. Students must consider authority, genuineness and originality of materials, reliability, applicability, timeliness of the material, the context and geographical location where applicable and the place and origin of each source. Especially important in verifying web material.
- **Interpretation, Synthesis and Application -** Legal information has to be understood, related and interconnected to the research problem. The student has to compare different documents, to find out the applied legal principles, to synthesize facts and information and then, to relate and apply the gained information in a concrete case to a legal research problem.
- **Ethical and Responsible Use -** Responsible legal research requires appropriate citation, attribution, respect for copyright, avoidance of plagiarism, and compliance with the terms of electronic-resource licences. Academic law libraries can play an important role in developing these practices among students.

Role of Academic Law Libraries

Academic law libraries promote student legal information literacy and research skills. Role of law library goes beyond physical access to resources to offering programmed instructions and practical skills building.

- **Orientation to law library:** Familiarize students with legal information resources and library services.
- **Databases training:** Provide an ability in retrieving law cases, statues, journals etc from the databases.
- **Research guides:** Guide steps through the entire processes of finding legal information sources.
- **Legal research workshops:** Develop skills for advanced legal searching, assessment of resources and methods of researching.
- **One-on-one research assistance:** Give students support in finding researchable information and troubleshooting research problems.
- **Ongoing skills training:** Regular training reinforce students' skills in locating, evaluating information, in citation and their use in ethical.

Need for Legal Information Literacy Competency Development

The expanding universe of digital legal information requires more than basic information seeking from law students. Students have to be able to read, evaluate sources; authenticate legal information and select appropriate reliable materials for academic and professional endeavors.

- **Learning Skill Gaps -** Students can have lots of legal databases at disposal, but at the absence of skill to make the best out of such databases; competence-based learning provides guidance to fill learning skill gaps.

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- **Training Critical Skills -** Students have to learn how to test for: authority, accuracy, authenticity, relevancy, currency and jurisdiction of legal data before applying to any task. Competence-based learning is crucial in strengthening this aspect.
- **Enhancing Digital Legal Research -** Competent learning can lead to skill at the disposal of law students regarding contemporary digital learning; advanced search mechanisms, filtering systems, keywords development, searching in the citation lists, database navigation etc. This is so important as modern day legal research has come a long way on these digital databases.
- **Empowering Research Independence -**With the development of the student competence, law students can be said to be independent and confident when carrying out legal research and have less reliance on word of mouth or secondary unreliable sources of legal information.
- **Instruction embedded into the curricula -** Legal Information literacy should not be a one time training in a library and then nothing. Library orientation must, at all stages, permeate throughout courses in legal research, assignments in the legal courses, moot courts, seminars, internships, and dissertations etc.
- **Developing role for the Librarian as a researcher's educator -** The role of law librarian can extend from being merely information providers/finders, but to research educators and information specialist, working closely with the law faculty in order to deliver practical instructions on law research, and individualistic support for research.
- **Continuous Assessment and improvement -** The student's competencies should be regularly assessed in order to ascertain areas of deficiencies and progress or enhancement made. This will subsequently result to the recalibration of library trainings accordingly.

Key Components of an Effective Legal Information-Literacy Programme

An effective programme should focus on:

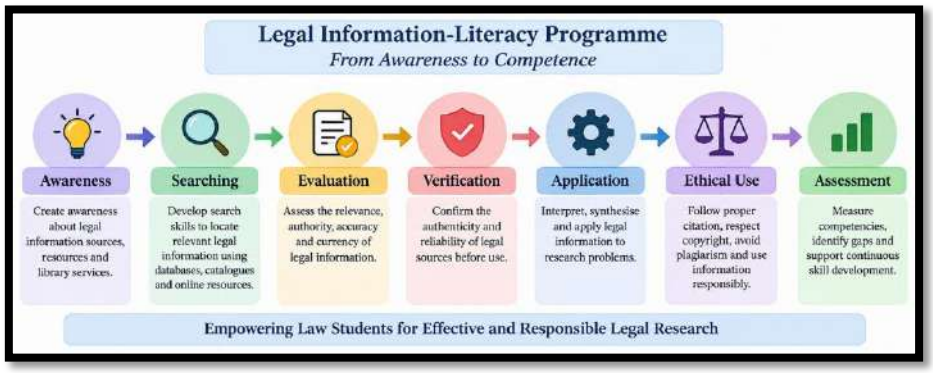

Figure 2: Key Components of an Effective Legal Information-Literacy Programme

Anticipated Impact on Legal Education

The study anticipated to positively affect the legal education by providing a systematically organized and a competency-based approach to library information literacy. It would facilitate the law librarians and faculty to: discern student deficits in the application of legal research skills, Enhance the ability of students in utilizing both digital and non-digital legal resources, foster the capacity for responsible and critical consumption of legal information, and Enable effective law students' research endeavors. The proposed LIL-AL framework will be helpful to increase library and law faculty collaboration and enhance the development of systematic legal research programs.

Recommendations and Suggestions

Law academic libraries must conduct comprehensive and ongoing legal information-literacy instruction instead of a one-shot library orientation. There should be training on how to search the legal databases, determining which sources are primary and secondary sources of law, assessing and validating information obtained from the web, how to cite appropriately and responsibility to use the law. Librarians should partner with law professors in developing activities such as writing assignments, moot courts, seminars, research projects, and assignments. Performance should be periodically assessed as well in order to detect shortcomings and improve the library's instruction programs. The suggested LIL-AL Framework is flexible to work on all levels of academic study, from entry level, to advanced, depending on academic levels.

Conclusion

Developing students' legal information literacy skills has become integral to modern legal education, where law students must cope with an

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ever growing universe of information in print and electronic forms. Conducting effective research demands not only access to information sources but also the skills to define one's information needs, find adequate sources of law, search efficiently, evaluate a source's authority and accuracy, confirm an information resource, analyze and interpret information sources and utilize sources in a proper ethical manner. This study reiterates the crucial part that academic law libraries play in fostering such competencies, by orienting students systematically, providing instruction in using specific databases, offering research workshops and tutorials, presenting research guides and offering one on one research assistance, thereby filling the students' existing gaps in legal research skills. The proposed LIL-AL Framework serves as an organized means for inculcating legal information literacy through six significant areas, i.e. Determining of information need, determining sources of information, discovery and search for information, evaluation and verification of information and a balanced view (interpret and synthesize), to determine legal research with integrity and in an accountable manner. It's an instrument academic law library can use to formulate their on-line information literacy programs which are designed in a sequential, student-centered manner. Last but not least, a enhanced legal information literacy could foster well-developed independent, critical, reliable, confident and ethically sound legal researchers. These six dimensions offer more grounds for law librarians, law faculty, students to work closely together thus enhancing the status of an academic law library to be a key component of a legal education and research endeavor.

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Conflicts of interest

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

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Original Article

Green Synthesis of Organic Compounds Using Eco-Friendly Solvents: A Sustainable Approach

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Abstract
The extensive use of hazardous volatile organic solvents in chemical synthesis has become a major concern for environmental sustainability and human safety. The present investigation focuses on the development of green synthetic protocols for organic transformations employing environmentally benign media such as distilled water, bio-ethanol, and Polyethylene Glycol-400 [PEG-400]. The study targets the synthesis of pharmaceutically relevant heterocycles, specifically dihydro pyrimidinone derivatives and Knoevenagel products, under mild and eco-compatible conditions. The reactions were catalysed by p-toluene sulfonic acid [p-TSA], a relatively non-toxic catalyst, and the products were purified and confirmed by TLC, melting point determination, FT-IR and proton NMR spectroscopy. Experimental observations revealed that the aqueous-ethanol [1:1] and PEG-400 systems afforded superior yields in the range of 85-92%, while reaction duration was reduced to less than one hour compared to 4 hours in conventional solvents like DMF. The approach significantly improves atom economy, lowers the E-factor, and complies with the principles of Green Chemistry. This protocol offers a sustainable alternative for laboratory-scale organic synthesis.

Keywords*: Sustainable synthesis, Green solvents, PEG-400, Aqueous ethanol, Atom economy, Heterocyclic compounds.*

Introduction

Organic solvents account for a major fraction of waste generated in chemical laboratories and industries. Traditional solvents such as dichloromethane [DCM], dimethylformamide [DMF], and chloroform are characterized by high volatility, toxicity, and non-biodegradability. Their large-scale usage contributes to environmental pollution and occupational health hazards.

The concept of Green Chemistry, formulated by Anastas and Warner in 1998, provides a framework for designing chemical processes that reduce or eliminate hazardous substances. The fifth principle of green chemistry specifically advocates for the use of safer solvents and reaction conditions.

In recent years, considerable attention has been given to alternative green media. Water is considered an ideal green solvent due to its abundance, non-toxicity, and non-flammability. Ethanol is a bio-renewable solvent with low toxicity, while PEG-400 is a biodegradable polymer-based solvent with excellent thermal stability and reusability. The present work investigates the applicability of these solvents for the efficient synthesis of organic scaffolds that possess biological significance.

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Rationale of the Study

1. Conventional solvents are environmentally unsustainable and require replacement with greener options.
2. There is a need to systematically compare the efficiency of different green solvents for the same organic transformation.
3. Development of a simple, economical, and safe synthetic method that can be easily implemented in http://M.Sc. teaching laboratories.
4. To promote waste minimization and energy efficiency in line with sustainable development goals.

Objectives

1. To carry out the synthesis of selected heterocyclic compounds via green synthetic routes using water, ethanol, and PEG-400.
2. To optimize critical parameters like catalyst concentration, temperature, and solvent composition.
3. To evaluate and compare reaction efficiency in terms of percentage yield, reaction time, and product purity.
4. To study the recyclability potential of PEG-400 and aqueous ethanol systems.
5. To characterize the final products through analytical and spectral techniques.

Hypothesis

H1: The use of ethanol-water mixture and PEG-400 as reaction media will result in higher or comparable product yields relative to traditional organic solvents.
H2: Green solvent systems will lead to a significant reduction in reaction time and environmental impact as measured by E-factor.
H0 [Null Hypothesis]: Green solvents do not show any significant improvement in reaction efficiency compared to conventional solvents.

Methodology

a) Method: Laboratory-based experimental and comparative analysis.
b) Research Design: Controlled experimental design. A model Biginelli condensation and Knoevenagel condensation were selected. Each reaction was performed under identical molar ratios but in different solvent environments to allow direct comparison.
c) Materials and Tools:
Chemicals Required: Aromatic aldehydes, ethyl acetoacetate, urea, malononitrile, p-TSA. All chemicals of analytical grade.
Solvents Used: Double-distilled water, absolute ethanol, PEG-400.
Instruments: Magnetic stirrer with heating, reflux condenser, Thin Layer Chromatography setup, melting point apparatus, FT-IR spectrophotometer, 400 MHz 1H-NMR spectrometer.
d) Experimental Procedure:
_Synthesis of 3,4-dihydropyrimidin-2-one:
In a 100 mL round-bottom flask, benzaldehyde [10 mmol], ethyl acetoacetate [10 mmol], urea [15 mmol] and p-TSA [10 mol%] were mixed in 10 mL of PEG-400. The reaction mixture was heated at 80°C with continuous stirring for 50-60 minutes. Reaction progress was monitored by TLC using hexane: ethyl acetate [7:3] as eluent. Upon completion, 20 mL of cold water was added to precipitate the product. The crude product was filtered, washed, and recrystallized from hot ethanol. The same procedure was replicated using DMF, ethanol, and water-ethanol [1:1] [1H]
e) Evaluation of Green Chemistry Metrics:
Atom Economy [%] = [MW of desired product / Sum of MW of all reactants] x 100
Environmental Factor = Total mass of waste generated / Mass of isolated product

Analysis and Data Analysis

Table 1: Optimization of Solvent, Temperature and Reaction Time

Solvent Used	Temperature	Time Taken	Isolated Yield	Appearance
DMF	110°C	4 h	65–70%	Light yellow solid with pungent smell
Ethanol	80°C	2 h	80–83%	Off-white solid
Water + Ethanol (1:1)	80°C	70–80 min	86–89%	White crystalline solid
PEG-400	80°C	45–55 min	90–93%	Pure white crystals, easy filtration

Table 2: Spectral Interpretation

Technique	Frequency / Chemical Shift	Assignment
FT-IR (KBr)	3255 cm^{-1}	N–H stretching
FT-IR (KBr)	1720 cm^{-1}	Ester C=O stretching

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FT-IR (KBr)	1650 cm^{-1}	C=C stretching
FT-IR (KBr)	1215 cm^{-1}	C–O stretching
^{1}H-NMR (400 MHz, DMSO-d_6)	δ 9.22	NH
^{1}H-NMR (400 MHz, DMSO-d_6)	δ 7.75	NH
^{1}H-NMR (400 MHz, DMSO-d_6)	δ 7.18–7.33	m, 5H, Ar–H
^{1}H-NMR (400 MHz, DMSO-d_6)	δ 5.18	CH
^{1}H-NMR (400 MHz, DMSO-d_6)	δ 3.98	OCH_2
^{1}H-NMR (400 MHz, DMSO-d_6)	δ 2.28	CH_2
^{1}H-NMR (400 MHz, DMSO-d_6)	δ 1.08	CH_3

Table 3: Statistical Analysis

Parameter	Description
Number of repetitions	3
Statistical parameter	Mean yield and standard deviation
Statistical test	One-way ANOVA
Significance level	$p < 0.05$
Purpose	To validate significant differences in yield among the reaction conditions

Result: PEG-400 gave the highest isolated yield (**90–93%**) with the shortest reaction time (**45–55 min**) and produced **pure white crystals with easy filtration**, indicating it as the most favorable solvent condition among those investigated.

Conclusions

The present study successfully establishes that eco-friendly solvents can effectively replace hazardous conventional solvents without compromising product yield. PEG-400 emerged as the most efficient medium, providing the highest yield [92%], shortest reaction time, and reusability for up to three consecutive cycles without significant loss of activity. The aqueous-ethanol system also proved highly effective and economical. The proposed method reduces chemical waste, improves operational safety, and aligns with sustainable chemistry goals, making it ideal for academic and small-scale industrial applications.

Acknowledgment

The authors express their sincere gratitude to the Department of Chemistry, Shripatrao Chougule Arts and Science College, Malwadi-Kotoli, India, for providing the necessary academic support and facilities to carry out this study on green synthesis using eco-friendly solvents.

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Nil.

Conflicts of interest

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

Recommendations

1. The green protocol should be extended to other multicomponent reactions such as Hantzsch and Mannich reactions.
2. Further research should explore the use of Deep Eutectic Solvents [DES] and glycerol as green media.
3. Educational institutions should incorporate green synthesis experiments into the http://M.Sc. Organic Chemistry practical syllabus.
4. A detailed life-cycle and cost-benefit analysis should be performed for industrial scale-up.

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Original Article

Artificial Intelligence and the Future of Human Resource Management: Building a Skilled Workforce for Viksit Bharat @2047

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Abstract
*Artificial Intelligence (AI) is transforming Human Resource Management (HRM) through AI-enabled recruitment, workforce analytics, employee development, performance management and talent management. In the context of **Viksit Bharat @2047**, AI can play a significant role in developing a skilled, adaptable and future-ready workforce. This paper examines the role of AI in HRM and its contribution to workforce reskilling, digital literacy, analytical skills and human-AI collaboration. The study adopts a descriptive and analytical research approach based on secondary literature, policy reports and an illustrative quantitative framework. The paper proposes an **AI–HRM–Skills–Viksit Bharat framework**, highlighting the importance of continuous learning, ethical AI governance and human-centred skills. It concludes that responsible integration of AI with effective reskilling and upskilling strategies can strengthen workforce productivity, employability, innovation and India's journey towards **Viksit Bharat @2047**.*

Keywords: *Artificial Intelligence, Human Resource Management, Reskilling, Workforce Skills, Viksit Bharat @2047*

Introduction

Artificial Intelligence (AI) is transforming Human Resource Management (HRM) through applications such as recruitment, employee engagement, performance management, learning, workforce planning and retention. However, AI adoption is not only a technological change; it requires a workforce equipped with **digital, analytical, creative, leadership and emotional-intelligence skills**. The *World Economic Forum Future of Jobs Report 2025* highlights AI, big data and technological literacy as rapidly growing skills, while emphasising the continuing importance of human capabilities. For India, AI-driven skill development and reskilling are essential for achieving the vision of **Viksit Bharat @2047**. NITI Aayog also stresses the importance of skilling and reskilling in preparing India's workforce for technological transformation. Therefore, the key challenge is to **integrate AI with human capabilities** and build a skilled, adaptable and future-ready workforce that can contribute effectively to India's development by 2047.

Review of Literature

Jarrahi (2018) highlighted that AI can enhance human decision-making and information processing, while human judgement remains essential in complex and uncertain situations. Tambe, Cappelli and Yakubovich (2019) examined AI in HRM and identified challenges related to data quality, fairness, accountability and employee acceptance of algorithmic decisions. Davenport et al. (2020) argued that AI should primarily **augment rather than replace human managers**, combining technological capabilities with human judgement. Vrontis et al.

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(2022) highlighted the growing importance of AI applications in HRM and emphasised the need for appropriate resources, skills and organizational strategies for successful AI adoption.

The World Economic Forum (2025) reported that **39% of workers' core skills are expected to change by 2030**, with AI, big data and technological literacy becoming increasingly important. At the same time, creativity, analytical thinking, resilience and leadership remain essential.

NITI Aayog has emphasised **AI-enabled inclusive growth, skilling and reskilling**. Its *Reimagining Skilling for Viksit Bharat @2047* report further stresses the need for future-ready human capabilities to manage technological and workforce transformation.

Overall, the literature indicates that **successful AI-driven HRM requires a balance between technology and human capabilities**, particularly skills development, ethical decision-making and continuous reskilling for achieving **Viksit Bharat @2047**.

Objectives of the Study

1. To examine the role of **AI in HRM**.
2. To assess the impact of AI on **workforce skill development**.
3. To identify key **skills required for an AI-enabled workforce**.
4. To examine AI-HRM and **workforce readiness**.
5. To identify **challenges of AI adoption** in HRM.
6. To propose an **AI-HRM framework for Viksit Bharat @2047**.
7. To suggest **policy and managerial measures** for responsible AI-based workforce development.

Hypotheses of the Study

I. Null Hypothesis (H0)

H0: There is no significant relationship between AI-enabled Human Resource Management practices and workforce readiness.

II. Alternative Hypothesis (H1)

H1: There is a significant positive relationship between AI-enabled Human Resource Management practices and workforce readiness.

Research Methodology

1 Research Design

The study follows a **descriptive, analytical and conceptual research design**.

2 Sources of Data

The study uses: Government reports, NITI Aayog publications, World Economic Forum reports, International academic literature, Peer-reviewed journal articles, AI and HRM research studies

For demonstrating quantitative statistical techniques, an **illustrative survey dataset of 300 respondents** is used.

3 Sampling

For an actual empirical study, respondents may include: HR professionals, Managers, Employees, Business executives, Management teachers, MBA/M.Com students, Technology professionals, An appropriate sample can be selected through stratified or purposive sampling depending on the research setting.

4 Sample Size: Illustrative model sample: **n = 300**

Statistical Tools

The following statistical techniques are recommended: Percentage analysis, Mean, Standard deviation, Pearson correlation, Simple linear regression, t-test, ANOVA, where applicable, Chi-square test, where categorical variables are used.

Illustrative Data Analysis

Important: The following tables are an **illustrative model dataset (n=300)** prepared to demonstrate how the analysis can be presented. These values must be replaced with actual survey responses before journal submission.

Table 1: Respondents' Perception of AI-enabled HRM

Statement	Agree/Strongly Agree (%)	Mean
AI improves recruitment efficiency	78.0	4.02
AI improves employee training	74.7	3.91
AI improves workforce planning	76.3	3.96
AI improves performance management	70.7	3.78
AI supports career development	72.3	3.84
AI helps identify skill gaps	81.0	4.10

Interpretation: The illustrative responses indicate generally positive perceptions of AI-enabled HRM. Identification of skill gaps receives the highest mean score (4.10).

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Table 2: Perceived Importance of Future Skills

Skill	Respondents identifying it as important (%)
AI and digital literacy	88.0
Analytical thinking	84.7
Adaptability	86.0
Communication	79.3
Creativity	81.0
Leadership	77.7
Emotional intelligence	75.3
Cybersecurity awareness	72.0

The pattern is consistent with international evidence that technological skills and human-centred capabilities must increasingly coexist.

Table 3: Perceived Organizational Benefits

Benefit	Percentage
Faster recruitment	82%
Better skill-gap identification	81%
Personalized employee learning	78%
Improved workforce planning	76%
Better performance analytics	73%
Reduced administrative workload	79%
Improved employee decision support	69%

Figure 2: Perceived AI-HRM Benefits

Table 4: AI-HRM Challenges

Challenge	Respondents (%)
Lack of AI skills	83
Data privacy concerns	78
Algorithmic bias	74
High implementation cost	69
Employee resistance	65
Lack of organisational readiness	72
Cybersecurity risks	76
Lack of ethical guidelines	71

These concerns are consistent with the academic literature identifying fairness, accountability, privacy and employee reactions as important AI-HRM challenges.

Table 5: Selected Global Workforce Strategies in Response to AI

Workforce Strategy	Employers (%)
Upskilling/reskilling existing employees	77
Recruiting AI-tool design/enhancement skills	69
Recruiting employees able to work with AI	62
Reorienting business models toward AI opportunities	49
Transitioning employees from AI-disrupted roles	47
Reducing workforce because of AI automation	41

Source: World Economic Forum, *Future of Jobs Report 2025*.

Figure 3: Global Employer Strategies for AI Transformation

Mathematical and Statistical Analysis

1 Pearson's Correlation Coefficient

To measure the relationship between AI-enabled HRM and workforce readiness, Pearson's correlation coefficient can be calculated as:

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[r=\frac{n\sumXY-(\sum) (\sumY)} {\sqrt{[n\sumX^2-(\sumX) ^2] [n\sumY^2-(\sumY) ^2]}}]
For the illustrative data set: [r=0.72]
This indicates a **strong positive relationship** between AI-enabled HRM and workforce readiness.

2. Regression Analysis

The regression equation is:
[Y=a+bX]
Where:

- Y = Workforce Readiness
- X = AI-enabled HRM
- a = Constant
- b = Regression coefficient

For the illustrative model:
[Y=1.21+0.72X]
The coefficient of determination is:
[R^2= (0.72) ^2=0.5184]
Therefore:
[R^2=51.84%]
This suggests that, in the illustrative model, approximately **51.84% of the variation in workforce readiness is statistically associated with AI-enabled HRM**.
The remaining:
[100-51.84=48.16%]
may be associated with other factors such as education, organizational culture, leadership, employee motivation, infrastructure, socioeconomic conditions and prior digital capability.

3. Significance Test of Correlation

The t-statistic can be calculated as:
[t=\frac{r\sqrt{n-2}}{\sqrt{1-r^2}}]
Given:
[r=0.72] [n=300]
Therefore:[t=\frac{0.72\sqrt{298}}{\sqrt{1-0.5184}}]
[t\approx17.91]
Degrees of freedom:
[df=n-2=298] At the 5% level of significance, the critical t-value is approximately:
[t_{0.05}\approx1.97]
Since:
[17.91>1.97]
the null hypothesis is rejected.

Hypothesis Testing

Table 6: Hypothesis Testing

Hypothesis	Statistical Result	Decision
H0: No significant relationship between AI-enabled HRM and workforce readiness	t = 17.91	Rejected
H1: Significant positive relationship exists	r = 0.72, p < 0.001	Accepted

Decision: - Since the calculated t-value of **17.91** is substantially higher than the critical value of approximately **1.97**, H0 is rejected and H1 is accepted in the illustrative model.

Conclusion of Hypothesis:- There is a statistically significant positive relationship between AI-enabled HRM and workforce readiness.

Again, this statistical conclusion applies only to the illustrative model data. It should be claimed as an empirical finding only after testing actual collected responses.

Proposed AI-HRM Skill Development Model for Viksit Bharat@2047

The study proposes five strategic pillars:

Pillar 1: AI Literacy - Every employee should possess basic knowledge of: Generative AI, Prompting, Data interpretation, AI-assisted productivity, Responsible AI

Pillar 2: Digital and Analytical Skills- Employees should develop:, Data literacy, Analytical thinking, Digital communication, Cybersecurity awareness, Problem-solving capabilities

Pillar 3: Human-Centred Skills - AI should not replace:Creativity, Empathy, Leadership, Ethical judgement, Communication, Teamwork

Pillar 4: Continuous Reskilling - Organisations should introduce: Annual skill-gap assessments, AI learning programmes, Micro-credentials, Digital certifications, Job-transition programmes

Pillar 5: Responsible AI Governance- Organisations should establish: AI ethics policies,Data privacy standards, Bias monitoring, Human oversight, Transparency mechanisms, Employee grievance mechanisms

Findings of the Study

The study finds that **Artificial Intelligence is transforming Human Resource Management from an administrative function into a more strategic, analytical and predictive function**. AI can improve recruitment, workforce planning, skill-gap identification, personalised learning and career development. However, continuous **reskilling, upskilling and AI literacy** are essential, while human skills such as creativity, leadership, resilience and analytical thinking remain important. The study also highlights challenges related to **privacy, bias, transparency, cybersecurity and employee trust**. Therefore, AI should be used mainly for **human augmentation rather than replacement**. For achieving **Viksit Bharat @2047**,

stronger industry-academia collaboration and future-oriented education and skill-development programmes are essential.

Suggestions and Recommendations

Organizations should develop an **AI-HRM strategy**, regularly assess skill gaps, promote continuous **reskilling and AI literacy**, and establish strong **AI ethics, data privacy, and human oversight** mechanisms. Educational institutions should integrate **AI, Generative AI and HR analytics** into management curricula, provide practical certifications, establish innovation centres, and strengthen **industry–academia collaboration**. Government and policymakers should promote **AI and digital literacy, inclusive reskilling, AI research and innovation, responsible AI standards, data protection, and MSME support**, while developing a national framework for **AI-enabled workforce transformation aligned with Viksit Bharat @2047**.

Conclusion

Artificial Intelligence is transforming Human Resource Management by improving recruitment, talent management, learning, performance management and workforce planning. For **Viksit Bharat @2047**, India must focus not only on AI adoption but also on preparing people through continuous reskilling, upskilling and AI literacy. A human-centred approach combining **AI literacy, digital skills, analytical thinking, creativity, leadership, ethics and lifelong learning** will help strengthen India's human capital and build an AI-ready workforce.

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Conflicts of interest

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Original Article

The Averaging-Down Trap: A Psychological Perspective

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Abstract
Individual investment decisions are not always guided exclusively by new information, expected returns, and objective risk assessment. When a stock declines after an investor has committed capital, the investor may respond by increasing the position through averaging down. Although averaging down can represent a rational response to revised valuation, it may also reflect escalation of commitment when additional resources are committed primarily because of the investor's previous investment and the desire to recover an existing loss. This paper examines the psychological mechanisms that can contribute to such escalation, focusing on sunk-cost effects, loss aversion, self-justification, anchoring, confirmation bias, and the disposition effect. It proposes that escalation occurs when a forward-looking investment decision becomes increasingly dominated by the psychological importance of the investor's historical purchase price and the desire to reach a break-even point. The paper distinguishes rational averaging from psychologically driven escalation and develops a conceptual framework for understanding persistent commitment to declining investments.

Keywords: *Escalation of commitment, behavioural finance, averaging down, sunk cost, loss aversion, self-justification, anchoring, confirmation bias, disposition effect*

Introduction

Investment decisions are conventionally understood as forward-looking choices based on expected returns, risk, valuation, and available alternatives. However, behavioural finance demonstrates that investors' decisions can also be influenced by psychological reference points, emotions, and cognitive biases. One particularly relevant phenomenon is escalation of commitment, whereby decision makers continue or increase their commitment to a previously selected course of action despite disappointing outcomes. Research describes escalation as the tendency to commit additional resources to a failing course of action following an earlier investment. The phenomenon has direct relevance to individual stock investment. When an investor purchases a stock and its price subsequently declines, the investor may choose to purchase additional shares in order to reduce the average acquisition price. Such averaging down is not inherently irrational. If a fresh assessment indicates that the stock's future expected value justifies additional investment, the decision may be economically defensible.

The psychological problem arises when the principal reason for further investment becomes the investor's previous commitment itself: *"I have already invested, therefore I should continue until I recover my loss."* This paper conceptualizes such behaviour as a potential form of escalation of commitment and examines the psychological mechanisms underlying it.

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From Averaging Down to Escalation

The critical distinction between rational averaging and escalation lies in the basis of the subsequent investment decision. Rational averaging involves reassessing the investment using current information, future prospects, risk, valuation, and alternative opportunities. Escalation, in contrast, occurs when the earlier investment becomes psychologically influential in determining the subsequent decision.

The investor's attention can consequently shift from a forward-looking question— "Would I buy this stock today?"—to a backward-looking question— "How can I recover what I have already lost?" This represents a psychologically important transformation. The investment is no longer evaluated solely as a current opportunity; it becomes a means of repairing a previous decision.

Thus, averaging down should not automatically be interpreted as escalation. The relevant issue is whether past commitment is exerting an inappropriate influence on present commitment.

Key Psychological Mechanisms

1 Sunk-Cost Effect

A central mechanism is the tendency to allow unrecoverable past investment to influence current decisions. Once capital has been invested, that expenditure is economically sunk. Nevertheless, investors may feel psychologically compelled to continue because abandoning the position would make the previous investment appear to have been wasted.

Consequently, additional investment can become an attempt to *justify* the earlier investment rather than an independent evaluation of the current opportunity. Research on escalation has repeatedly examined the relationship between sunk costs and subsequent commitment.

2 Loss Aversion

Loss aversion provides another important explanation. Prospect theory suggests that individuals experience losses differently from equivalent gains and may become particularly sensitive to avoiding the realization of a loss. In investment settings, this can create reluctance to sell a declining position and can encourage continued exposure in the hope of eventual recovery.

The psychological objective may therefore shift from maximizing future investment value to avoiding the psychological pain associated with realizing a loss.

3 Self-Justification

An investor who personally selected an investment may experience psychological discomfort when subsequent evidence contradicts the original decision. Selling the stock can require acknowledging that the initial judgment was incorrect. Additional investment may therefore serve a self-justifying function: if the position eventually recovers, the original decision can be interpreted as temporarily unsuccessful rather than fundamentally mistaken.

Research on escalation identifies self-justification as an important mechanism through which individuals maintain commitment to earlier decisions.

4 Anchoring and the Break-Even Reference Point

The investor's original purchase price can become a psychologically powerful anchor. Instead of evaluating the stock solely according to its present and expected future value, the investor may evaluate it relative to the historical acquisition price.

The resulting objective becomes reaching the break-even point. The question consequently changes from *"What is the best use of my capital now?"* to *"What will allow me to get back to my purchase price?"*

This shift is significant because the historical purchase price is personally meaningful but does not, by itself, determine the stock's future economic value.

5 Confirmation Bias

Once an investor becomes committed to recovering a declining investment, confirmation bias may reinforce the commitment. Information supporting the original investment thesis may receive greater attention, while contradictory evidence may be discounted or rationalized.

The investor may therefore move from evaluating evidence to defending an existing belief. This can make escalation self-reinforcing: continued commitment increases psychological attachment, which increases the motivation to interpret subsequent information favourably.

6 Disposition Effect

Escalation in declining stocks also overlaps with the well-documented disposition effect—the tendency of investors to realize gains relatively readily while holding losing investments for longer. The phenomenon has been extensively documented in individual and experimental investment settings.

However, disposition effect and escalation of commitment should not be treated as identical. Holding a losing stock represents continued commitment; purchasing additional units because of the previous commitment represents a further escalation of resources.

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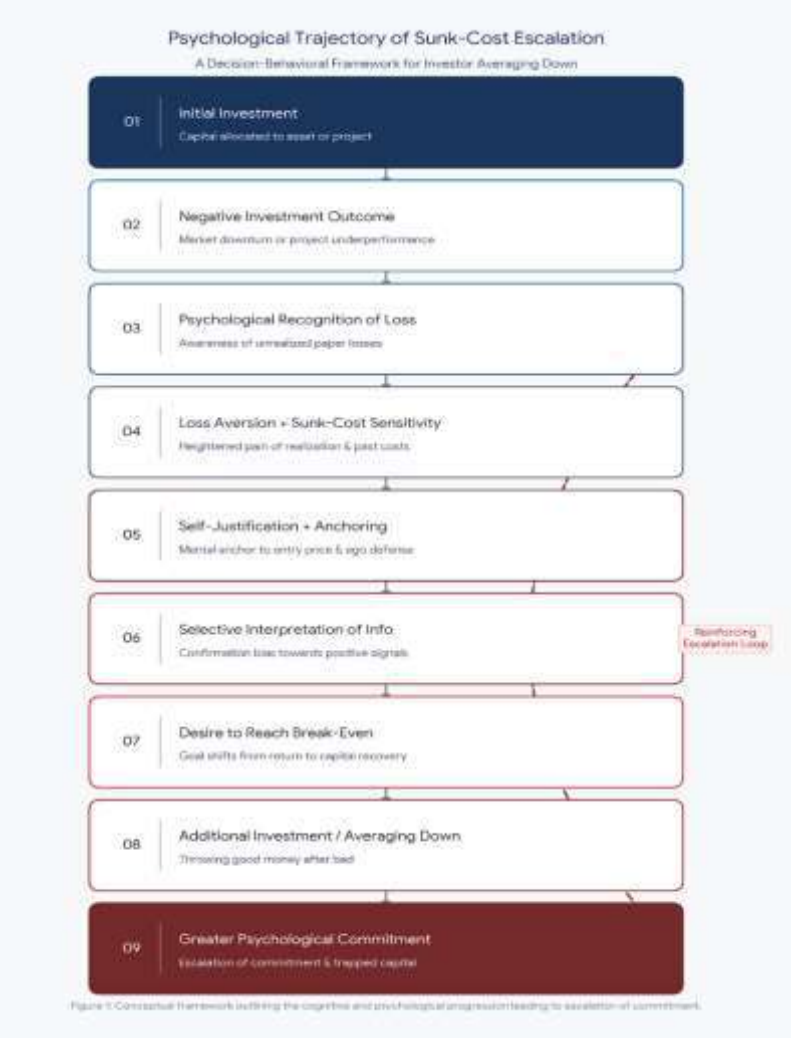
A Conceptual Framework

The psychological process can be represented as follows:



This process can become circular. As commitment increases, the psychological cost of abandoning the investment may also increase, potentially encouraging further commitment. The investor may consequently become increasingly concerned with *recovering the past* rather than *optimizing the future*.

Distinguishing Rational Persistence from Psychological Escalation

A critical implication is that continued investment should not automatically be interpreted as irrational behaviour. Escalation cannot be established merely because an investor continues investing after an adverse outcome; alternative explanations such as changing expected returns, relative risk, and investment opportunities must also be considered.

The distinguishing question is therefore:

Would the investor make the same investment decision today if the previous investment had never occurred? If the answer is yes because current information supports the investment, continued commitment may represent rational reassessment. If the answer is no, but the investor continues primarily because of the desire to recover the earlier loss, the behaviour is more consistent with psychological escalation.

Conclusion

Escalation of commitment provides a useful behavioural-finance lens through which persistent investment in declining stocks can be understood. Averaging down is not inherently an example of escalation; rather, it becomes potentially escalatory when prior investment, perceived loss, psychological attachment, and the desire to reach a historical break-even point increasingly dominate the assessment of future investment prospects.

The central psychological danger is therefore not simply that an investor experiences a loss. It is that the past investment begins to dictate the future investment decision. Sunk-cost sensitivity, loss aversion, self-justification, anchoring, confirmation bias, and the disposition effect can interact to sustain this process.

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For investment decision-making, the most important discipline is consequently to separate the past cost of the investment from the current decision about the future. The relevant question is not whether the investor can recover the original purchase price, but whether committing additional resources remains justified by the investment's future prospects and alternatives.

In this sense, the critical boundary between averaging down and escalation is psychological: the moment an investor begins investing to rescue a past decision rather than to pursue a justified future opportunity.

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Original Article

Synthesis and Characterization of M-Type Barium Hexaferrite by Co-Precipitation Method

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Abstract
M-type barium hexaferrite ($BaFe_{12}O_{19}$) is a technologically important hard ferrite because of its high coercivity, chemical stability, thermal stability and comparatively low cost. Nanostructuring and control of particle morphology are important for tailoring its properties for magnetic recording, microwave components, sensors and permanent-magnet applications. In the present work, $BaFe_{12}O_{19}$ was synthesized by a conventional co-precipitation route using barium nitrate and ferric nitrate as precursor salts and ammonium hydroxide as the precipitating agent. The hydroxide precursor was repeatedly washed to approximately neutral pH, centrifuged, vacuum dried at 80 °C for 6 h, ground and finally sintered at 900 °C for 6 h. X-ray diffraction (XRD) confirmed formation of the M-type barium hexaferrite phase in both samples. For the samples, the average crystallite size is 54 nm. The reported lattice parameters were a = 5.1757 Å and c = 23.1866 Å for the sample. Scanning electron microscopy (SEM) showed agglomerated and non-uniform grains in the reference sample. The results indicate that formation of the M-type crystal structure under the adopted processing conditions is Possible.

Keywords: *Barium hexaferrite; $BaFe_{12}O_{19}$; M-type hexaferrite; co-precipitation; XRD; SEM; crystallite size; nanomaterials.*

Introduction

Hexagonal ferrites constitute an important class of ferrimagnetic ceramic materials that combine magnetic anisotropy, electrical resistivity, chemical stability and useful high-frequency characteristics. Among these materials, barium hexaferrite, $BaFe_{12}O_{19}$, commonly denoted as BaM, is an M-type hexaferrite with a hexagonal magnetoplumbite-related structure. It is widely studied because its magnetic properties make it suitable for permanent magnets, magnetic recording, microwave components and other electromagnetic applications. Literature reports identify $BaFe_{12}O_{19}$ as a technologically established material with high uniaxial magnetic anisotropy, useful magnetization and good chemical stability. [1–4] The crystal structure and microstructure of $BaFe_{12}O_{19}$ are strongly dependent on synthesis route and thermal history. Conventional solid-state processing can produce large particles because the reaction proceeds through solid-state diffusion at elevated temperature. Chemical routes such as co-precipitation, sol-gel processing, hydrothermal synthesis and combustion routes provide improved control over precursor homogeneity and particle dimensions. Co-precipitation is particularly attractive because it is comparatively simple, inexpensive and uses aqueous solutions, while important process variables such as precursor concentration, pH, temperature, stirring and calcination conditions can be controlled. [1,5,6] Sample is processed through precipitation, washing, centrifugation, vacuum drying, grinding and sintering at 900 °C for 6 h.

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The project report concluded that the M-type phase was successfully formed. The objective of the present research-paper version is therefore to organize and scientifically discuss the experimental work reported in the supplied project document. The manuscript emphasizes the synthesis procedure, structural characterization by XRD, morphological characterization by SEM

Materials And Methods

1 Materials

Barium nitrate and ferric nitrate were used as the barium and iron precursors, respectively. Ammonium hydroxide was used as the precipitating agent. Double-distilled water (DDW) was used as the solvent and washing medium. Polyethylene glycol (PEG) was introduced in the PEG-assisted experiment. The supplied report specifies 3 g PEG dissolved in 100 mL DDW prior to dissolving the barium and ferric nitrate salts. [9]

Material	Role	Reported condition
Barium nitrate	Ba2+ precursor	0.1 M; Ba:Fe = 1:12
Ferric nitrate	Fe3+ precursor	0.1 M; Ba:Fe = 1:12
Ammonium hydroxide	Precipitating agent	Added until pH ≈ 13
Double-distilled water	Solvent/washing medium	100 mL for precursor solution

2 Stoichiometry and precursor preparation

For M-type barium hexaferrite, the target composition is $BaFe_{12}O_{19}$, corresponding to a nominal Ba:Fe ratio of 1:12. The supplied project reports preparation of 0.1 M barium nitrate and ferric nitrate solutions in this ratio using 100 mL DDW. It reports masses of 2.6132 g barium nitrate and 48.48 g ferric nitrate for the stated preparation. The solutions were stirred for 1 h before precipitation. [9]

3 Co-precipitation procedure

The precursor solution was treated with ammonium hydroxide under stirring. A brown precipitate formed and the pH reached approximately 13. Stirring was then stopped and the precipitate was allowed to settle for approximately 15 min. The supernatant was removed and replaced with DDW. The mixture was stirred again for approximately 10 min and allowed to settle. This washing cycle was repeated until the pH became approximately 7. The washed precipitate was separated from the remaining liquid by centrifugation at 1500 rpm. [9] The wet precursor was vacuum dried at 80 °C for 6 h. After drying, the material was ground using a mortar and pestle to obtain fine powder. Finally, the powder was sintered at 900 °C for 6 h. [9]

4 Simplified reaction pathway

The aqueous process can be viewed as precipitation of iron and barium hydroxide-containing precursor species in strongly alkaline medium, followed by dehydration/decomposition and solid-state reaction during thermal treatment to form $BaFe_{12}O_{19}$. A simplified overall representation is:

Ba^{2+} + 12 Fe^{3+} + OH^- → mixed hydroxide precursor → (900 °C) → $BaFe_{12}O_{19}$ + volatile species

The equation is intentionally presented as a simplified process representation rather than a balanced mechanistic reaction, because the supplied report does not identify the complete intermediate phase assemblage. Literature on co-precipitated $BaFe_{12}O_{19}$ likewise indicates that precursor chemistry and thermal decomposition pathways can be complex. [5,6]

Characterization Methods

1 X-ray diffraction

X-ray diffraction was used to identify the crystalline phase and evaluate the structural parameters of the synthesized material. The supplied report indexed the observed diffraction peaks to planes including (104), (008), (107), (114), (200), (202)/(203), (205), (206), (1010), (1110) and related reflections. The presence of the characteristic M-type reflections was taken as evidence for BaFe12O19 formation. [9]

The crystallite size was calculated using the Debye–Scherrer relation:

$$D = 0.9\lambda / (\beta \cos\theta)$$

where D is the mean crystallite size, λ is the X-ray wavelength, β is the full width at half maximum (FWHM) of the selected diffraction peak expressed in radians, and θ is the Bragg angle. The Scherrer value represents coherently diffracting crystallite size and should not automatically be equated with the complete particle or grain size visible in SEM.

Lattice parameters were obtained from interplanar spacings using the hexagonal-cell relation employed in the supplied report. The reported values were a = 5.1757 Å and c = 23.1866 Å for the PEG-free sample and a = 5.1548 Å and c = 23.0253 Å for the PEG-assisted sample. [9]

2 Scanning electron microscopy

SEM was employed to examine particle morphology and grain-size distribution. The supplied report indicates that the PEG-free material exhibited grains spanning approximately 20 nm to 5 μm, with agglomeration and unequal grain distribution. It also notes nanosized particles in the 50–100 nm range. For the PEG-containing material, grains were again reported over a broad size range, with nanosized disc-like features of approximately 50–100 nm. [9]

Results And Discussion

1 XRD analysis of $BaFe_{12}O_{19}$

The XRD pattern of the sample prepared and sintered at 900 °C for 6 h shows the characteristic reflections assigned to M-type BaFe12O19. The supplied report specifically identifies reflections associated with the (008), (107), (114), (200), (202) and (203) planes and

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describes a strong (114) reflection as evidence for formation of the hexaferrite phase. The reported lattice parameters are a = 5.1757 Å and c = 23.1866 Å. [9]

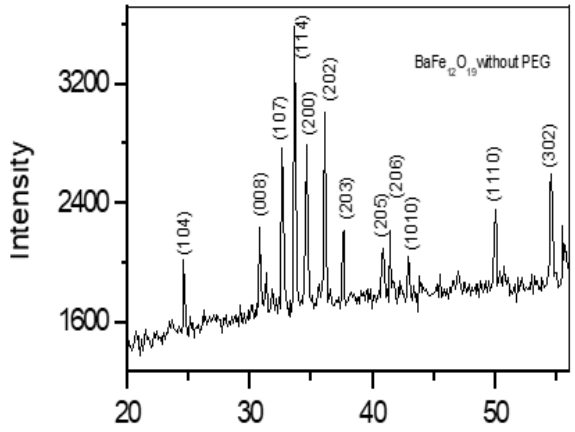


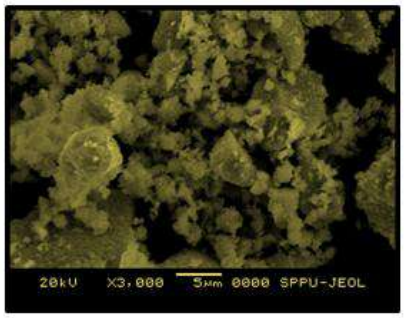
Fig. XRD pattern for $BaFe_{12}O_{19}$, sintered at 900 °C for 6 h.

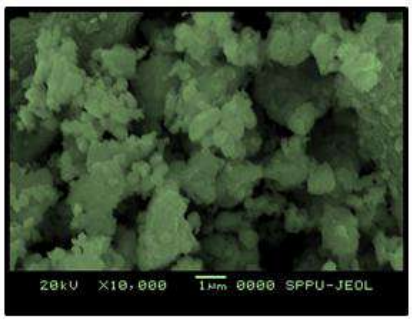
Table To find crystallite size 'D'

Sr.No	(hkl) plane	FWHM β (rad)	θ	cosθ	'D' nm
1	107	0.003471	32.6225	0.9597	47.41
2	114	0.003086	33.5997	0.9572	53.94
3	200	0.003189	34.6372	0.9546	52.84
4	202	0.002752	36.1500	0.9506	62.39

The reported average crystallite size for this sample is 54 nm. The individual Scherrer estimates listed in the project for selected reflections were approximately 47.41 nm for (107), 53.94 nm for (114), 52.84 nm for (200), and 62.39 nm for (202), demonstrating that the reported average is representative of the selected reflections rather than a direct measurement of the entire SEM particle population. [9]

2 Scanning Electron Microscopy (SEM)





The SEM observations reported in the project reveal a broad grain-size distribution, ranging from approximately 20 nm to 5 μm, together with agglomeration and unequal distribution of grains. The presence of both larger agglomerates and nanoscale particles is consistent with the difference between crystallite size obtained from XRD and apparent particle/grain size obtained from microscopy. A single particle may consist of several coherently diffracting crystallites, and sintering at 900 °C can promote grain growth and agglomeration. [9]

Applications And Significance

The scientific importance of controlling $BaFe_{12}O_{19}$ crystallite size lies in the strong relationship between microstructure and magnetic behavior. M-type barium hexaferrite is used in permanent magnets and has also been investigated for magnetic recording, microwave components, radar-absorbing materials, sensors and other electromagnetic applications. [2–4] The supplied project report also lists magnetic storage media, radar-absorbing material, permanent magnets, speakers, motors/generators, inductive components, magnetic sensors and drug-delivery-related applications. [9] A reduction in crystallite size is potentially valuable for applications where fine powders, controlled morphology or high surface area are desired. However, smaller size does not automatically mean better magnetic performance. Coercivity and magnetization can vary with particle size, domain state, crystallographic anisotropy, defects, phase purity and agglomeration. Consequently, a complete materials-performance study should combine structural and morphological characterization with VSM measurements.

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Conclusions

M-type barium hexaferrite (BaFe12O19) was synthesized by the co-precipitation method using barium nitrate and ferric nitrate precursors and ammonium hydroxide as precipitating agent. A PEG-assisted sample was prepared by introducing 3 g PEG into 100 mL DDW before precursor dissolution. Both samples were washed to approximately neutral pH, centrifuged, vacuum dried at 80 °C for 6 h, ground and sintered at 900 °C for 6 h. [9]

XRD results reported in the supplied project confirm formation of the BaFe12O19 M-type phase in both samples. The average crystallite size decreased from 54 nm for the PEG-free sample to 42 nm for the PEG-assisted sample, corresponding to an approximately 22.2% reduction. The reported lattice parameters were a = 5.1757 Å and c = 23.1866 Å without PEG and a = 5.1548 Å and c = 23.0253 Å with PEG. [9]

SEM observations showed agglomerated, non-uniform grains in the PEG-free sample and nanoscale disc-like features in the PEG-containing sample. The combined XRD and SEM observations support the conclusion that PEG did not prevent formation of the M-type structure under the adopted thermal conditions but was associated with a reduction in crystallite size and a change in morphology.

For a journal-level extension of the work, it is recommended to repeat the synthesis at several PEG concentrations and molecular weights, include phase-quantitative Rietveld refinement, record FTIR and thermal-analysis data, and measure magnetic hysteresis using VSM to determine Ms, Mr and Hc. Such data would establish more directly how PEG concentration and polymer chemistry affect the functional properties of BaFe12O19.

Future Scope

- Investigate several PEG concentrations rather than a single 3 g/100 mL condition.
- Compare PEG molecular weights (for example, low-, medium- and high-molecular-weight grades) under otherwise identical synthesis conditions.
- Optimize pH and precipitant addition rate to improve compositional homogeneity.
- Use XRD Rietveld refinement to quantify phase fraction, lattice parameters and microstrain.
- Perform FTIR and TGA/DTA to study PEG interaction and decomposition.
- Use TEM/HRTEM and SAED to determine primary particle size and crystallinity.
- Use SEM-EDS to verify Ba: Fe:O elemental distribution.
- Measure VSM hysteresis loops and report saturation magnetization, remanence and coercivity.
- Study microwave absorption and dielectric properties where application-specific performance is required.

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Conflicts of interest

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

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Original Article

AI For Sustainable Development Opportunities & Innovation

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Abstract

Artificial Intelligence is increasingly being explored as a tool for accelerating progress toward sustainable development. AI can analyse large datasets, identify patterns, forecast events, optimise systems and support decision-making across agriculture, energy, water, healthcare, education, cities, industry and environmental management. Recent research shows that AI-for-SDG research is expanding rapidly, while also revealing gaps in social inclusion, governance and assessment of AI's own environmental footprint. This project examines the major opportunities for AI-enabled sustainable development, including smart agriculture, renewable-energy optimisation, climate and disaster forecasting, intelligent waste management, sustainable cities, healthcare and education. It also discusses innovation pathways such as machine learning, computer vision, remote sensing, generative AI, digital twins and edge AI. The study emphasises that technological capability alone is insufficient: responsible AI requires reliable data, transparency, privacy, human oversight, equitable access, energy-efficient computing and lifecycle environmental assessment.

Introduction

Sustainable development requires solutions that simultaneously consider economic prosperity, social inclusion and environmental protection. The United Nations Sustainable Development Goals provide a common framework for addressing poverty, hunger, health, education, inequality, clean energy, sustainable cities, responsible consumption, climate change and ecosystem protection. Artificial Intelligence can contribute by turning large and complex datasets into predictions, classifications, recommendations and optimisation decisions. The United Nations notes that AI has potential applications ranging from healthcare diagnostics and crop monitoring to crisis mapping and humanitarian assistance. UNDP similarly describes responsibly designed AI as a potential accelerator of the SDGs. However, AI is not automatically sustainable. Training and operating AI systems can require significant computing resources, electricity, water and hardware. Bias, privacy risks, unequal access and lack of transparency can also worsen existing inequalities. Therefore, the central research question is not simply whether AI can be used for sustainability, but how AI can be designed and deployed so that its overall social, economic and environmental benefits exceed its costs.

Research Objectives

The objectives of this project are:

- To explain the relationship between AI and sustainable development.
- To identify opportunities for AI across selected SDGs and sectors.
- To examine emerging AI innovations that can support sustainability.
- To analyse benefits, limitations, ethical concerns and environmental impacts.
- To propose a practical framework for responsible AI-for-sustainability projects.

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• To identify future research directions for students, researchers, governments and industry.

AI And the Sustainable Development Goals

AI can contribute directly or indirectly to many of the 17 SDGs. UN reports and research literature document applications across food systems, water management, energy, infrastructure, cities, climate action and ecosystem monitoring. A 2026 systematic review found that SDG 13 (Climate Action), SDG 11 (Sustainable Cities) and SDG 9 (Industry, Innovation and Infrastructure) receive substantial attention in AI-for-SDG research, while socially complex goals such as gender equality and reduced inequalities receive comparatively less attention. Examples include: SDG 2 through crop disease detection and yield prediction; SDG 3 through predictive analytics and medical decision support; SDG 4 through personalised learning; SDG 6 through water-quality and demand monitoring; SDG 7 through renewable-energy forecasting and grid optimisation; SDG 9 through industrial optimisation; SDG 11 through traffic, waste and urban planning; SDG 12 through resource and supply-chain optimisation; SDG 13 through climate modelling and disaster prediction; and SDG 15 through biodiversity and land-use monitoring.

Major Opportunities

1 Sustainable Agriculture:

Computer vision, satellite imagery and machine learning can identify crop diseases, estimate crop health, optimise irrigation and improve resource allocation. These systems can reduce unnecessary water, fertiliser and pesticide use when validated locally.

2 Clean Energy:

AI can forecast solar and wind generation, predict equipment failures, balance demand and supply, and improve energy efficiency in buildings and industrial facilities.

3 Climate and Disaster Resilience:

AI can combine weather, satellite and sensor data to support flood, wildfire, drought and heat-risk forecasting. Early-warning systems can improve preparedness and resource deployment.

4 Water Management:

AI can assist with leak detection, demand forecasting, water-quality monitoring and optimisation of treatment processes.

5 Sustainable Cities:

Intelligent transport systems can reduce congestion and emissions. AI can support urban planning, waste collection, energy management and infrastructure maintenance.

6 Circular Economy and Waste:

Computer vision can automate material identification and sorting. Predictive models can improve collection routes and help industries reduce material losses.

7 Healthcare and Education:

AI can support diagnostics, public-health forecasting, personalised learning and administrative efficiency, provided that safety, privacy and human oversight are maintained.

Innovation Areas

Machine Learning and Deep Learning:

Useful for prediction, classification, anomaly detection and optimisation.

Computer Vision:

Enables analysis of satellite images, drone imagery, medical images, waste streams and industrial equipment.

Generative AI:

Can support scientific knowledge discovery, sustainability reporting, scenario analysis, education and communication, but outputs require verification.

Digital Twins:

Virtual representations of cities, factories, energy systems or infrastructure can be used to test scenarios before real-world deployment.

Edge AI and IoT:

Processing data closer to sensors can enable real-time monitoring while reducing unnecessary data transfer.

AI for Scientific Discovery:

AI can accelerate material discovery, climate research, energy-system design and optimisation of complex processes.

Open and Local AI Ecosystems:

Locally relevant datasets, open standards, shared infrastructure and local-language tools can help reduce dependence on a small number of technology providers.

Benefits And Expected Impact

AI can increase efficiency by optimising energy, water, transport, production and logistics. It can also improve early detection of environmental hazards, enable more precise resource allocation and support evidence-based policy. In developing regions, appropriately designed AI can help extend limited expert capacity—for example, through remote sensing, decision-support systems and low-cost monitoring. AI for Sustainable Development — Research Project | Page 6The strongest impact is likely when AI is combined with domain expertise, reliable infrastructure and institutional capacity. Research published in Nature Sustainability indicates that the AI-for-SDG literature is growing

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rapidly, but relatively few studies fully integrate advanced AI methods with deep sustainability expertise. This suggests that interdisciplinary collaboration is a major innovation opportunity.

Challenges And Risks

Data quality and availability:
Poor, incomplete or geographically biased datasets can produce unreliable results.

Bias and inequality:
Models may reproduce social or geographic inequalities, especially when training data under-represent vulnerable communities.

Privacy and security:
Health, location, financial and other sensitive data require strong safeguards.

Energy and environmental footprint:
AI systems have impacts across hardware manufacturing, data centres, electricity use and end-of-life equipment. UNEP recommends comprehensive assessment of AI's environmental impacts across its lifecycle.

Digital divide:
Benefits may concentrate in countries and organisations with better computing infrastructure, skills and capital.

Transparency and accountability:
High-impact decisions require explainability, monitoring, human responsibility and mechanisms for appeal.

Overreliance on AI:
AI should support—not automatically replace—professional judgement, community knowledge and democratic decision-making.

Responsible And Sustainable AI Framework

A sustainable AI project should follow a lifecycle approach:

1. Define the sustainability problem: Identify the SDG target, users, affected communities and measurable outcome.

2. Assess whether AI is necessary: Avoid using AI where a simpler method is more effective or efficient.

3. Build representative data: Document data sources, limitations, consent and quality.

4. Design for efficiency: Use appropriate model size, efficient inference, renewable electricity where feasible and hardware efficiently.

5. Validate in the real context: Test accuracy, fairness, robustness and unintended consequences.

6. Keep humans accountable: Establish clear responsibility, oversight and escalation procedures.

7. Measure total impact: Track social, environmental and economic outcomes—not only model accuracy.

8. Continuously monitor: Reassess performance, bias, security and environmental costs after deployment.

Proposed Research/Implementation Model

For an academic or community-level project, a practical model can be developed around one local sustainability problem such as waste segregation, crop disease detection, water-quality monitoring or household energy prediction.

Phase 1 – Problem selection:
Choose one measurable sustainability challenge and map it to an SDG.

Phase 2 – Data collection:
Collect images, sensor readings, public datasets or survey information with appropriate permissions.

Phase 3 – Model development:
Compare baseline statistical methods with one or more machine-learning approaches.

Phase 4 – Evaluation:
Measure accuracy, precision/recall where appropriate, energy use, cost, fairness and usability.

Phase 5 – Prototype:
Build a simple dashboard or mobile/web interface for the intended users.

Phase 6 – Impact evaluation:
Estimate resources saved, emissions avoided, response time improved or other sustainability outcomes.

Phase 7 – Governance:
Document privacy, limitations, human oversight, maintenance and responsible-use rules.

Future Scope

Future research should move beyond demonstrations of technical feasibility toward measurable real-world sustainability outcomes. Promising areas include low-energy AI, climate-resilient infrastructure, AI-assisted circular manufacturing, biodiversity monitoring, local-language AI, trustworthy generative AI, privacy-preserving learning, federated learning and AI systems designed for low-resource environments. Recent research also indicates that AI-for-SDG work is geographically and thematically uneven. Future studies should therefore increase participation from developing countries, integrate local and Indigenous knowledge where appropriate, improve research on social goals such as inequality and gender equality, and systematically assess the environmental footprint of AI itself.

Conclusion

Artificial Intelligence offers significant opportunities to accelerate sustainable development by improving prediction, optimisation, monitoring and decision-making. Its applications span agriculture, energy, water, cities, industry,

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healthcare, education and environmental protection. At the same time, AI can introduce new environmental, social and governance risks. The central conclusion of this project is that AI should be treated as an enabling technology rather than a sustainability solution by itself. Successful AI-for-sustainable-development initiatives require interdisciplinary expertise, trustworthy data, inclusive access, responsible governance and continuous measurement of real-world impact. The most valuable innovation will be AI that is not only powerful, but also efficient, equitable, transparent, safe and aligned with human and planetary well-being.

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Original Article

The Integration, Utility, and Ethical Challenges of Artificial Intelligence Tools in Academic Libraries

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Abstract

Artificial intelligence has progressed from experimental trial to core operational infrastructure across contemporary academic libraries. Drawing upon peer-reviewed Library and Information Science (LIS) literature, ACRL and IFLA publications, and practitioner surveys from 2020 through 2025, this review examines the current deployment of AI technologies within information retrieval, metadata creation, reference triage, and patron analytics. Using Rogers' Diffusion of Innovations theory, the paper explains the marked disparities in institutional adoption rates across global higher education. Furthermore, an ethical governance lens highlights persistent challenges regarding algorithmic bias, data privacy, and citation hallucination. The analysis indicates a pronounced geographic and resource divide: well-funded research institutions in the Global North are rapidly transitioning librarians from traditional information intermediaries to educators of AI literacy and prompt design, whereas resource-constrained libraries face structural hurdles to adoption. To address these challenges, this study synthesizes an integrated operation–adoption–ethics framework, providing administrators, educators, and policy makers with a unified approach for responsible AI implementation alongside key directions for future empirical research.

Keywords: *artificial intelligence; academic libraries; algorithmic bias; AI literacy; diffusion of innovations; prompt engineering; data privacy; hallucination; library and information science*

Introduction

1 Background and Context

The public release of ChatGPT in late 2022 marked a critical inflection point for academic librarianship, compelling the discipline to rapidly confront longstanding questions regarding automated information systems. Within weeks of its introduction, Library and Information Science (LIS) scholars began evaluating the implications of generative AI for scholarly discovery, reference methodologies, and information literacy (Lund & Wang, 2023). Rather than representing an isolated rupture, generative models are best understood as the latest phase in a long continuum of technological shifts within academic libraries, which have progressively evolved from card catalogs to online public access catalogs (OPACs) and integrated discovery layers. At present, AI applications in library environments primarily cluster into four operational domains. First, natural language processing enhances information retrieval systems through semantic search and context-aware relevance ranking. Second, machine learning assists metadata workflows for cataloging and digital collection management. Third, conversational virtual assistants perform initial query triage for reference services. Fourth, predictive analytics platforms process patron behavioral metrics to guide collection acquisition and facility planning (Lund & Wang, 2023). While these implementations yield clear operational efficiencies, they also introduce significant technical, pedagogical, and ethical dependencies.

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Specifically, institutions face vendor lock-in, opaque proprietary search algorithms, and privacy risks associated with routing patron queries through external infrastructure. Simultaneously, the professional responsibilities of academic librarians are undergoing significant adaptation. Historically, librarians acted as primary intermediaries between researchers and institutional collections. The emergence of conversational search engines and automated text synthesis shifts this focus toward instruction, equipping users with skills to formulate effective prompts and critically evaluate algorithmic outputs (Lo, 2023). Although the ACRL Framework for Information Literacy (2016) already prioritized metacognition and critical evaluation, expanding these principles to cover algorithmic search tools requires ongoing structural updates across LIS graduate curricula. Furthermore, technological adoption across higher education remains markedly uneven and ethically complex. Well-resourced research universities typically deploy advanced AI systems early, while under-resourced institutions—particularly within the Global South—face structural barriers to adoption (Lund, Omame, Tijani, & Agbaji, 2020). Compounding these equity challenges are unresolved ethical vulnerabilities, including systemic training data bias, patron privacy erosion caused by third-party data tracking, and the documented tendency of generative models to synthesize plausible yet non-existent citations (Lund, Wang, Mannuru, Nie, Shimray, & Wang, 2023; McGowan et al., 2023).

2 Problem Statement

Although scholarship addressing AI in academic libraries has expanded rapidly, existing research remains fragmented across three distinct domains that seldom intersect. The first domain documents specific tool implementations, such as automated cataloging or reference chatbots, while neglecting organizational adoption dynamics. The second domain examines institutional readiness and technology acceptance, yet frequently lacks a unifying theoretical framework. The third domain analyzes ethical vulnerabilities—such as algorithmic bias, patron privacy, and citation hallucination—in isolation from operational realities. This fragmentation impedes the formulation of cohesive institutional policies, professional training curricula, and equitable deployment strategies. To bridge these gaps, this review examines operations, institutional adoption, and ethical governance as an interconnected ecosystem grounded in foundational library values: intellectual freedom, confidentiality, and equitable access to information.

3 Research Questions

Four primary research questions structure this inquiry:

1. **Operational Implementations:** How are academic libraries deploying AI across information retrieval, metadata generation, reference support, and user analytics, and what factors distinguish effective implementations from those that encounter operational barriers?
2. **Role Transformation:** How is the professional role of academic librarians evolving from traditional information provision toward instructing patrons in AI literacy and prompt engineering?
3. **Adoption Dynamics:** What adoption patterns, analyzed through the lens of Diffusion of Innovations theory, account for the uneven global uptake of AI tools across higher education institutions?
4. **Ethical Governance:** What ethical risks—specifically algorithmic bias, data privacy breaches, and source hallucination—stem from AI integration, and how can existing institutional and professional governance structures mitigate them?

4 Institutional and Disciplinary Significance

This review contributes to LIS scholarship in three key respects. First, it unifies previously disparate literature into a single conceptual framework that connects operational workflows, changing professional identities, and ethical governance. Second, by applying Rogers' (2003) Diffusion of Innovations theory alongside empirical data on librarian adopter categories (Lund, Omame, Tijani, & Agbaji, 2020), it highlights persistent global equities in AI adoption—an aspect often understated in literature focused primarily on North American and European research universities. Third, it provides actionable guidance for library leadership, addressing policy formulation, vendor licensing, and curricular design. Together, these contributions offer a comprehensive baseline of current evidence while outlining critical priorities for ongoing research.

Structure of the Review

The remainder of this article is structured around the three core themes identified in the research questions: operational practices, institutional adoption mechanisms, and ethical governance. Section 3 outlines the literature search strategy,

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Section 4 details the integrative methodology, and Sections 5 through 9 present the substantive synthesis, concluding with the proposed integrated framework.

Literature Review Strategy

To ensure analytical rigor, literature was evaluated topically rather than chronologically. Sources were categorized into empirical investigations, conceptual frameworks, and professional association reports, with findings weighed according to their evidentiary context.

1 Theme One — Library Operations and AI-Enabled Service Delivery

This theme addresses core operational functions. It examines semantic discovery layers that process natural-language queries, machine-assisted metadata generation requiring human verification (Lund & Wang, 2023), virtual assistants performing first-tier reference triage (Adetayo, 2023), and predictive analytics informing collection management and physical space optimization.

2 Theme Two — User and Institutional Adoption (Diffusion of Innovations)

This theme applies Rogers' (2003) five innovation attributes—relative advantage, compatibility, complexity, trialability, and observability—to AI uptake in libraries. Drawing on empirical studies of library personnel (Lund, Omame, Tijani, & Agbaji, 2020), this section analyzes the widening adoption gap between major research universities and under-resourced institutions, particularly within the Global South, while highlighting organizational drivers such as leadership support, training pipelines, and budgetary constraints.

3 Theme Three — Ethical Governance and Risk

This theme investigates systemic ethical risks, including training data bias, third-party data tracking, and citation fabrication—a recognized flaw in generative LLMs that directly threatens scholarly accuracy (Lund, Wang, Mannuru, Nie, Shimray, & Wang, 2023; McGowan et al., 2023). It evaluates emerging governance responses, including institutional AI policies, vendor transparency protocols, and professional codes of conduct.

Methodology

This study employs an integrative review design, combining descriptive synthesis of current operational practices with conceptual analysis of professional roles and ethical governance. Relevant literature was gathered from LIS databases (LISTA, Web of Science, Scopus) and repository publications (ACRL, IFLA) published between 2020 and 2025. Search parameters targeted artificial intelligence, generative AI, algorithmic bias, and information literacy in academic library environments. Non-English publications and general AI literature lacking direct LIS applicability were excluded. Selected literature was coded across the three thematic domains to build the integrated framework presented in Section 8. Key limitations include the exclusion of unindexed grey literature and vendor technical documentation, as well as the rapid evolution of AI software which may alter specific system capabilities over time.

Current Implementations of AI in Academic Libraries

Artificial intelligence applications in academic libraries currently center on four primary operational areas:

- **Information Retrieval:** Modern discovery layers rely on semantic search algorithms and machine learning relevance scoring to capture user intent beyond simple keyword matches.
- **Automated Metadata Generation:** Machine-learning tools generate cataloging descriptions and digital asset tags at high volumes. Due to variable output quality, most institutions maintain human-in-the-loop validation processes.
- **Reference Chatbots:** AI assistants handle routine directional and informational queries. Empirical findings indicate that while automated triage improves response efficiency, patron satisfaction varies based on query complexity (Adetayo, 2023).
- **User Analytics:** Machine learning models analyze circulation, database usage, and facility usage to inform collection management and space allocation. However, collecting detailed user analytics creates an ongoing tension with traditional patron privacy commitments.

Impact on Library Operations and the Evolving Librarian Role

As automated tools handle routine cataloging and basic search tasks, academic librarianship is increasingly reorienting toward instruction and critical evaluation. Librarians are transitioning from traditional information gatekeepers into educators of AI literacy, teaching patrons to evaluate machine-generated outputs critically. Prompt engineering has emerged as an essential competency, with instructional models like the CLEAR framework (Concise, Logical, Explicit, Adaptive, Reflective) being incorporated into information literacy programs (Lo, 2023). This shift necessitates updates to LIS graduate education and professional development, while fostering new specialized roles such as AI Literacy Librarians and Data Ethics Specialists.

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Challenges and Ethical Considerations

The integration of AI presents several critical ethical challenges:

- **Algorithmic Bias:** Systems trained on skewed historical datasets can perpetuate systemic biases, underrepresenting non-Western and marginalized scholarship.
- **Data Privacy:** Third-party AI tools processing search histories and user interactions conflict with established library standards regarding patron confidentiality.
- **Source Hallucination:** Generative models frequently fabricate references and citations (McGowan et al., 2023), undermining academic integrity and reference reliability.
- **Equitable Access:** Resource disparities threaten to broaden the technological divide between well-funded institutions and under-resourced libraries (Lund, Omame, Tijani, & Agbaji, 2020).

Addressing these issues requires robust governance, including institutional usage policies, strict vendor data-handling agreements, and transparent disclosure of AI integration across library services.

Discussion: Toward an Integrated Framework

Synthesizing operational, adoption, and ethical literature reveals that these areas constitute a single, interdependent ecosystem. Operational effectiveness is contingent on institutional adoption capacity, which in turn is bounded by an institution's ability to govern ethical risks. This relationship suggests a theoretical refinement to Diffusion of Innovations theory: ethical risk acts as a moderating factor in the adoption process. Consequently, administrators should evaluate AI tools through a combined lens of operational value, organizational readiness, and governability. Future research priorities should include longitudinal studies on AI adoption, cross-national comparative analyses involving the Global South, and empirical evaluations of AI literacy frameworks such as the CLEAR model.

Conclusion

Artificial intelligence is transforming academic libraries across operations, professional identities, and risk management. Addressing the adoption gap between institutions while mitigating algorithmic bias, privacy risks, and citation hallucination requires coordinated action across the profession. Libraries must invest in structured AI literacy education, enforce vendor accountability, and pursue empirical research on long-term equity. The integrated framework presented in this paper provides a practical foundation for administrators, librarians, and policy makers working to implement AI ethically and effectively.

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Original Article

Culture, Identity and Resistance in Dalit Autobiographies

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Abstract:
This paper examines the representation of cultural practices in Vasant Moon's Growing Up Untouchable in India: A Dalit Autobiography and Urmila Pawar's The Weave of My Life: A Dalit Woman's Memoirs. It explores how everyday practices such as community life, food, occupation, labour, family traditions, rituals, festivals, women's work, and religious practices shape Dalit identity and preserve collective memory. The study adopts a qualitative, comparative, and textual approach and draws on perspectives from Dalit studies, cultural studies, autobiography studies, and Dalit feminist criticism. The analysis shows that Moon and Pawar do not present Dalit culture merely as a record of poverty and social exclusion. Instead, they present their communities, traditions, and everyday experiences as important parts of their identity and cultural history. Moon's representation of the Dalit vasti presents it as a space of community, memory, relationships, and shared experiences. Pawar's representation of women's labour connects family memory, cultural practice, and literary expression. The study further examines how everyday practices challenge caste-based ideas of purity and impurity and how Ambedkarite consciousness contributes to a new sense of dignity, equality, and self-respect. The paper argues that the representation of Dalit culture becomes an act of self-expression, cultural recovery, and resistance.

Keywords: *Dalit Literature, Dalit Autobiography, Cultural Practices, Self-Assertion, Resistance, Identity, Ambedkarite Consciousness*

Introduction

Individual and Collective identity is largely shaped by the cultural practices that human beings follow in their lives. Culture is an umbrella term which includes not only literature, art and formal religious practices but also everyday activities such as food, dress, festivals, occupations, language, family customs, rituals, songs, stories, social relationships, and community traditions. For marginalized communities, these practices acquire a particular significance because dominant social structures frequently attempt to define, control or stigmatize their cultural identities. The powerful often dominate and exploit the powerless in various ways. Marginalized communities are particularly vulnerable to exploitation because of poverty, hunger, limited access to education, and the constant struggle for basic livelihood. Their exclusion from the mainstream is largely rooted in the lack of economic and social resources necessary for their development and upbringing. Dalit literature emerged as a response to such cultural and social marginalization, first in Maharashtra and then in other parts of India. Though Dalit lives were presented by non-Dalit writers primarily through their own perspectives, Dalit writers began to narrate their own lived experiences. The autobiography was the only medium through which the Dalit writers could have transformed their lived experience into testimony, memory and resistance. They used this form of literature not merely for portrayal of individual life but the community life.

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Vasant Moon's **Growing Up Untouchable in India** and Urmila Pawar's **The Weave of My Life** are important examples of this tradition. Moon's autobiography delineates his childhood memories, his active participation in socio-political activities in young age in the Dalit *vasti* of Nagpur and gradually expands from individual experience into a representation of the community and its social and political transformation under the influence of Dr. Babasaheb Amebedkar. Pawar's memoir moves from her childhood in rural Maharashtra through education, marriage and life in Mumbai, private and public aspects of her life, and she fuses the experiences of several generations of Dalit women.The cultural practices mentioned in these autobiographies are especially significant. These practices take their readers to a social world that mainstream literary representations have ignored completely. Food, work, community life, rituals, family practices, and changes in religion become important areas where people shape and express their identity. Culture in these autobiographies is manifold. It preserves memory and community identity, it challenges the cultural hierarchy that connects certain practices, occupations and communities with inferiority.

The present paper asserts that the representation of Dalit culture itself constitutes an act of self-assertion, protest, and response. By writing about their communities, work, families, customs, and traditions, Moon and Pawar make their voices heard and assert their Dalit identity.

Objectives of the Study

1. To examine cultural practices in the selected autobiographies.
2. To analyse the role of culture in shaping Dalit identity and community life.
3. To explore everyday practices, occupation, and labour as forms of resistance.
4. To examine the impact of Ambedkarite consciousness on Dalit cultural practices.

Hypotheses of the paper:

1. Dalit cultural practices in both autobiographies help in asserting identity and self-respect.
2. Everyday cultural practices preserve collective memory and strengthen community identity.
3. Ambedkarite consciousness transforms Dalit identity by promoting dignity, equality, and resistance to caste discrimination.

Research Methodology

The study adopts a qualitative, comparative and textual approach.

The primary texts for the study are: Vasant Moon's *Growing Up Untouchable in India: A Dalit Autobiography* and Urmila Pawar's *The Weave of My Life: A Dalit Woman's Memoirs*, translated by Maya Pandit.

The analysis focuses on cultural practices such as: community life, food, occupation and labour, family traditions, rituals and religious practices, festivals and celebrations, women's work, language and memory, Ambedkarite cultural transformation and collective identity.

The study employs perspectives from Dalit studies, cultural studies, autobiography studies and Dalit feminist criticism.

Culture and Dalit Identity

The similar and central concern in both the autobiographies is the relationship between culture and identity. The caste system constructed identities hierarchically. Diverse communities are assigned occupations, spaces and social positions, and these assignments are frequently presented as natural or hereditary. Cultural practices associated with marginalized communities can consequently be stigmatized.

Dalit autobiography challenges this process by presenting Dalit culture from within.

The publisher describes the book as "Moon's story is about his *vasti* or neighborhood and a community of people considered to be at the bottom of the caste hierarchy. It reveals a complex yet rich slum culture where Dalits are not seen merely as victims but as a community with strong bonds, striving and struggling to shed their sense of inferiority" (Moon, back cover) The Dalit *vasti* in Moon's autobiography possess a distinctive cultural and social environment. It's not merely a geographical location but a space of community, memory, relationships and shared experience.

The description of vasti's everyday life by Vasant Moon is a cultural intervention. Moon effectively relates the readers the story of his community, its history and cultural world; and that this world deserves recognition.

Pawar similarly reconstructs the cultural world of her childhood through memories of family, community, labour, and rural life. As Baby Kamble says, "the suffering of my community has always been more important than my own individual sufferings. I have identified myself completely with my people" (Pandit xv). Pawar's autobiography recounts her story along with that of her community. The autobiographical act thus becomes an act of cultural recovery.

The Dalit Vasti as a Cultural Space

The *vasti* in Moon's autobiography is particularly important. Spatial segregation is one of the

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mechanisms through which caste hierarchy is maintained. Dalits historically lived in separate settlements, physically distancing them from dominant communities. Moon's *vasti* is rather different. It is as Eleanor Zelliot describes, "There is much in his story of his childhood vasti that would probably be true of any poor urban neighborhood: hunger and deprivation, of course, but also much help from neighbors; a sense of "us" and "them"; easy acceptance of petty crime and vi-olence; the saving grace of sports; the even more important factor of an or-ganized group for youngsters led by caring adult". (Zelliot xv)

Yet Moon's representation of the *vasti* complicates this negative understanding.

The *vasti* is certainly marked by poverty and social exclusion, but it is also a space for friendship, family, shared experience, collective celebrations, informal education, and cultural continuity. Thus, the *vasti* becomes a counter-cultural space.

The author does not abandon the cultural space of his childhood in order to construct his identity. Instead, he records and preserves it. He narrates how this *vasti* shaped his life and it can not be forgotten in the concluding chapter of his autobiography. He writes "Here I came into being and grew, from small to big. This community gave me food and gave me the store of experience with which I have made my life's journey. I have been going to back to Nagpur every one or two months since I left. I can never refrain from taking a darshan of the vasti." (Moon, ch. 29) Thus, this vasti becomes a cultural space for him.

Labour and Occupation as Cultural Practices

Perhaps one of the most significant aspects of both autobiographies is their representation of labour. The caste structure was often associated with certain occupations. Communities were assigned specific menial tasks that reinforced ideas of purity and impurity. Dalit autobiographies challenge this hierarchy by representing labour from the perspective of those who perform it. Moon's narrative depicts the economic and social realities of the Dalit community and its struggle for advancement. Moon describes the difficult working conditions faced by his mother. He recalls how she struggled to earn enough to support the family: "Mother went out daily to look for work and came back only at seven or eight in the evening. Occasionally she would get one or two rupees' worth of labour. She would feed us a bit and, then go out again the following day" (Moon, 22). This description shows the poverty and hardship faced by Dalit women, whose labour was essential for the survival of their families.

Pawar's memoir gives particular significance to the labour of Dalit women.

Pawar connects her mother's traditional work with her own act of writing. She writes, "My mother used to weave aaydans. I find that her act of weaving and my act of writing are organically linked. The weave is similar. It is the weave of pain, suffering and agony that links us." (Pawar x) This comparison shows how the traditional labour of her mother and Pawar's writing are connected through their shared experiences of pain and struggle. Writing thus becomes a way of expressing and preserving the experiences of Dalit women.

An occupation historically associated with poverty and social marginalization becomes the central metaphor of a literary work. The basket becomes a symbol of women's labor, economic survival, creativity, cultural heritage, maternal memory, resilience, and literary creation. Pawar's mother physically weaves bamboo strips to create useful objects. Pawar metaphorically weaves memories into an autobiography.

Conclusion:

The study of Vasant Moon's *Growing Up Untouchable in India* and Urmila Pawar's *The Weave of My Life* shows that cultural practices are central to the formation of Dalit identity along with other factors such as consciousness, Ambedkarite consciousness, education and acceptance of new way of life. Food, family, community life, occupation, labour, rituals, festivals, and religious practices are not merely details of everyday life. They preserve memories, express community identity, and give voice to experiences that have often been ignored in mainstream representations.

Moon's representation of the *vasti* shows how a space marked by poverty and social exclusion can also become a space of friendship, shared experience, collective memory, and cultural continuity. His memories of the *vasti* connect his individual life with the life of his community. Pawar similarly connects personal experience with the experiences of her family and community. Her representation of her mother's labour shows how women's work carries memories of suffering, survival, creativity, and cultural tradition.

The study also demonstrates that labour and occupation are closely connected with caste and cultural identity. By representing the work performed by Dalit communities, Moon and Pawar bring attention to the dignity, hardship, and importance of labour. Pawar's comparison between her mother's weaving and her own writing further shows how lived experience can be transformed into literary expression.

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Finally, the autobiographies show the importance of Ambedkarite consciousness in changing the understanding of Dalit identity. The narratives move beyond imposed ideas of inferiority and emphasize dignity, equality, self-respect, and resistance to caste discrimination. Thus, these autobiographies do more than record individual lives. They preserve community memories, recover cultural experiences, and assert the value of Dalit voices and traditions. The representation of Dalit cultural practices therefore becomes an important form of cultural self-expression, recovery, and resistance.

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Original Article

V.S. Naipaul's "The Mimic Men": A Man's Search for Identity

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Abstract:

Naipaul's The Mimic Men is very famous novel. The novel is significant for various reasons. It presents and examines a newly- independent county in the Caribbean, the island of Isabella, with pessimistic view.., the previous colony has now become independent but the formerly colonized people of the island are failure to establish order and govern the country properly. In this novel Colonial education and cultural colonization have presented the English world, with its rich culture, customs and traditions, religion and race to be inferior to those of their rich, educated masters and they are trying to identity, match with the empire. Its very bad thing that they are far away from their original culture, tradition and real society they cannot identify themselves with those remote rules. They cannot match with new things. They suffer from alienation placelessness, fragmentation and loss of identity. They become mimic men who imitate and reflect the colonizer's life style, values and views. They are failure to solve these psychological problems after independence is achieved. Through Ralph Singh, protagonist of the novel Naipaul has presented real picture of the society.

***Key words**: colonized, colonial, loss of culture, customs, traditions, religion, identity crisis, psychological problem, alienation etc.*

Introduction: -

V.S. Naipaul was born on August 17, 1932 in Chaguanas, a small town in Trinidad, into all family of Indian Brahmin origin. His father, Seepersad Naipaul was a correspondent for the Trinidad Guardian and short story writer. His father had encouraged Naipaul in his writing aspirations. Naipaul addresses the prominent issues faced by the world in general and the Third World countries in particular. The issues that he picks up for fictional exploration and construction pertain to the prevailing confusion regarding the identity of the communities and nations, the wrong direction of different movements for various purposes these countries. He has presented the problems faced by the post-modern society like rootlessness, disillusionment and prevalent racial discrimination.

Naipaul's feeling of alienation stems however from a spiritual crisis-basically the result of the twin problems of an aversion to the Trinidadian society in which he was born and an infructuous diaspora to London where he sought to launch his publishing career but felt isolated and alienated. Even after living in London for three decades, he feels himself distanced from the cultural spatial milieu of London.

The Mimic Man was published in 1967. In this novel Naipaul presents the subject of West Indian politics. This novel is a political novel, dealing with the society is an island called Isabella. This novel is also called as an autobiographical novel Autobiography of Ralph Singh. The relevance of this novel is with everybody belonging to a country which goes through a period of rapid political change after having achieved independence from foreign rule. Trinidad people achieved independence from the British rule.

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In this novel Ralph Singh is the protagonist of the novel, born and raised on Isabella. The novel is written in the first-person narrative describes the story of a colonial politician, Ralph Singh, Shipwrecked first on his native island, and then in England: He is the representative of a generation which achieved power after Independence and can only mimic the authenticity of selfhood. He had tried a lot in so many places but he did not get success. The novel begins with Ralph Singh,"an exiled or rather a withdrawn politician, fatigued by disillusion rather than failure, writing his memoirs in an asceptic, placeless London Suburb."[1] He sets out to write down his experiences in the hope of fashioning an order out of the various unrelated adventures and encounters. He takes effort like an artist to create something to search some positive meaning in muddled state of affairs, where he had spent life. This is his autobiography written with real consciousness.

Ralph Singh, the narrator of The Mimic Men is a forty-year old colonial minister who lives in exile in London. By writing his memoirs, Singh tries to impose order on his life, reconstruct his identity, and get rid of the crippling sense of dislocation and displacement. Singh is the representative of displaced and disillusioned colonial individuals, and colonization, is depicted as a process that snatched away their real identity, culture, history and originality. In this novel Naipaul shows the relationship between the socio-political and the psychological consequences of imperialism. All his life Singh fought against corruption. In the process his self is falsified. In an individual the mimicry is caused by loss of sense of belonging. The constantly shifting character of life is the cause of baselessness rootlessness and even meaninglessness. Naipaul tresses the metaphysical alienation of man which is very significant thing in modern literature.

The novel is not in the form of a linear, chronological memoir because the narrator, in his attempts to salvage his wrecked like, impasses a deliberate order on the events and experiences of his life to reconstruct the meaning of his life. Singh, the exiled politician describes his journey backward and forward between Isabella and England linking past and present, colonial life and London childhood and adult life, illusion and reality and, success and failure. Through this writing. activity the narrator tries to impose order on the world. The disorder, emptiness and forlornness become part of his existence right from the beginning. He knows: "To be born on an island like Isabella, an obscure New world transplantation, second-hand and barbarous, was to be born to disorder".[2] Singh has observed that in Isabella to be poor is a disgrace. His father is a teacher, he prefers to lay claim to his mother's family, they are rich, who owns the Bella Bottling works. Ralph's father remains a poor, ill-paid teacher while his mother's rich industrialist family regret their decision of having such a son-in-law. Ralphs mother quietly accepts her won guilt; She is old fashioned and has little education. From his childhood, Ralph becomes aware of this "odd" pairing called husband and wife. For him childhood is a period of "incompetence, bewilderment, solitude and shameful fancies."[3] From his childhood psychologically Ralph is suppressed and lived under tension and duality. He did not understand exactly what to do and how to come out of these situations. For every individual identity is very important, without identity man can't live. But Ralph changed his identity from Ranjit Singh to Ralph Singh. He sees himself as a chieftain Shipwrecked on an unknown island awaiting rescue, "here the island was like a place still awaiting Columbus and discovery."[4] Singh is living in fantasies. He lives in a world of Aryana's, Rajput's, Knights, horsemen and wanderers, a world of endless plains and tall bare mountains. The reality of Isabella is different, it brings Singh on the earth from snow covered mountains to desolate beach. In his character Naipaul presents a sense of the missing world. For Singh Isabella is not proper place. He is quite nervous, because he expected so many good things from Isabella place. He is doing mimicry by using mask. He performs different roles for different people. He assumes the role of an actor, that is safe for him. He dramatizes his relationship with his father, his friends and different women. He identifies himself with Brownie, Cecil - his cousin, Hok- the Chinese boy and with Deschpsneufs who are the makers of the slave colony. They belong to the world of mimicry. Like Singh idealizes his Hindu past and culture, he is in fact unable to understand Hinduism. Singh is quite confused to see an Indian world that is in contrast with the noble and ideal realm of imagination. Hindu rituals have lost their meaning in Isabella as the people have lost their connection with India, its white, customs, rituals and tradition. Like Singh, his Chinese friend, Hok reads books on his own origin, China and realizes his past and is humiliated when it is discovered that he has black ancestors. Browne, Singh's black revolutionary friend, also fantasizes his origin and his room is full of pictures of black leaders. Each boy is trying to adjust with life with his own racial origin and the ethnic group to which he belongs, on the novel therefore implies that the emotional security and a real sense of identity are unachievable in heterogeneous societies of the Caribbean.

Naipaul has very badly pointed out the example of Hok. He refuses to recognize his mother. The scene serves as an example to show the racial wounds in the West Indian Society. This is very shocking that he ignores his mother because she is a Negro, whereas he, being of mixed blood, does not look like a Negro.

Ralph considers his married life a mere "episode" Sandra is not beautiful but charming enough to attract him. Even he sees the magnitude of her social ambition which attract him more and more. He hopes that she could guide him through life's uncertainties. Marriage with Sandra created some hopes, and confidence in his mind and he leaves Isabella hoping to set right the ruined pieces of his life through new relationship, the bond of marriage. When Sandra meets Ralph's mother, she disapproves of his marriage with a foreign girl. Ralph is very much surprised and shocked by his mother's decision. Ralph becomes nervous because he is failure in the society and even at home, this creates sense of alienation in him. "The initial seeming warmth, acceptance and approval gradually disappeared in course of time for... Isabella is an unstable, shallow, mixed and chaotic society."[5] Finally Ralph marries with Sandra at Willesden registry office. His marriage provides an occasion to return to the island of Isabella. It is followed by his success in business with the money acquired from Bella plantation.

Meanwhile Sandra's appearance and behaviour goes from unacceptable to disgraceful. She is attracted to Americans and they to her, especially her breasts. Marriage of Ralph and Sandra is failure. Ralph's fear is reflected, "it was the fear of the man who feels the veils coming down one by one muffling his deepest responses [----]".[6] With England and his English wife he has not good experiences. To fill the gaps and to search comfort for mind he turns to India as the centre of his dream. He thinks Aryan culture is his own to explain his experience.

Naipaul through Singh is presenting experiences of modern man, who is facing the problems like Singh in this world. He depicts man is always living under pressure, tension, insecurity, suppressed mind and fear of change and alienation. Here the characters tries escape from the self, to deny the continuity of life. But each individual must face the challenge, difficulties and reality instead of escaping and only failure comes when "moving out of ourselves, we look of extensions of ourselves". With this realization, Ralph Singh tries to create something good to come out of this self-crisis, to overcome his fear of life, to make sense of exile.

Although Singh cannot completely solve his psychological problem, so he decided to write his memoirs. Finally, he realizes that his experiences and his feeling of abandonment and displacement cannot be separated from his colonial, backgrounds. He realizes that colonial societies like Isabella suffer from lack of cultural and racial homogeneity. Finally, he comes to know that there is no superior, proper, ideal place with which he can identify himself.

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AI Generated Literature and Changing Concepts of Authorship

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Abstract:

The present research paper deals with AI generated literature and changing concepts of authorship in the period where AI has replaced every sphere of human life. The emergence of generative artificial intelligence has altered assumptions about literary text as the production of human creativity because AI is able to produce poems, stories, essays and other literary forms in response to the simple prompts. As a result, the conventional distinctions between author and reader have become more complicated now. However, the developments questioning the role of authorship into literary studies are not new; rather 20th century literary theory has already challenged the idea of the author as the sole creator of textual meaning. Roland Barthes' The Death of Author, Michel Foucault's What Is an Author, T. S. Eliot's theory of impersonality and W. K. Wimsatt and Monroe Beardsley's critique pertaining to intentional fallacy displaced the image of the author and demonstrated that literary meaning is produced through language and discourse without considering the intentions of an author. Generative AI further intensifies these theoretical questions by introducing non-human agents into the process of textual production. Thus, the present paper attempts to put forth the role of AI in production of literary text within the frameworks of theories mentioned above.

Keywords: *Artificial intelligence, Generative AI, AI generated literature, author, authorship.*

Introduction:

The present research paper explores the role of AI in shaping literary artifacts, especially, during the digital era that witnessed transformation due to the rapid developments in technology. The proliferation in the field of artificial intelligence has revolutionized as well as affected almost all fields and disciplines in the life of human beings; the literary field is also not excluded. In fact, the journey of literary history depicts changing concepts of authorship or authorial control over literary production. It points out the anonymous writers during the oral traditions and moves towards the individual writers who gave distinctive voice, consciousness, intention, style and creative identity to the literary production. At the turn of 20th century, the role of author as the only controller of literary meaning has been questioned which is further complicated with the developments in generative artificial intelligence that has an ability to generate prose and poetry imitating literary genres, producing coherent narratives, formulating metaphors and responding to the stylistic instructions. In these conditions, the question of authorship becomes prominent as human agents play a significant role in the production of literature with the help of artificial intelligence by giving instructions or prompts to systems that generate literature. Traditionally, literary production is always associated with the author whose imagination, experience, intention and creativity play a central role in the production of meaning of text.

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The question of authorship or identity of author as the originator or creator of literary work has become prominent when the theoretical orientations of the writers like T. S. Eliot, Roland Barthers, Michel Foucault, W. K. Wimsatt pointed out extinction of author and rise of reader along with cultural and institutional function in generating meaning of text. T. S. Eliot argues that "the progress of an artist is a continual self-sacrifice, a continual extinction of personality" (Eliot 44). Similarly, Roland Barthes declares that "the birth of the reader must be ransomed by the death of the Author" (Barthes 148). These claims unsettle the position of author as the creator of literary entities which has been further complicated with developments in generative AI that makes possible the distribution of authorship. AI generated literature replaces traditional model of literary text and its authorship as text can now be produced, transformed or complicated through the interactions between human writers and computational systems. Hence it is necessary to understand whether AI is an author, a tool, or a collaborator in the process of literary production.

The changing Concepts of authorship:

Literary history since the ages has been centered on the figures of authors who not only give birth to creative work but also establish traditions, trends and currents in the history of literature. The names of the authors like Geoffery Chaucer, William Shakespeare, Christopher Marlowe, Jane Austen, Charles Dickens, Virginia Woolf and countless many bring to forth the role of authors in developing not only the artifact but also socio-cultural, geographical identities granting creativity, originally, ownership and authority to the creator of the work. The association between authorship and individuality is further strengthened during the romantic tradition where a poet is considered as an individual genius whose creative work expresses an authentic inner self. Consequently, literature is directly connected with biography, personality, originality, inspiration and individual experience. A poem is read as an evidence of the author's personality and the novel has become an extension of the novelist's worldview whereas the dramatic work has become the ground for conflicting forces that the playwright created. Hence, literary work can be considered as an object originated from the consciousness of individual creator.

The modern literary criticism challenged position of author in the process of creating meaning of literary text. Structuralism emphasized systems of language rather than individual consciousness; psychoanalysis complicated conscious intention; Marxist criticism situated literary production within material and ideological structures; feminist criticism questioned the universal subject represented by the traditional author; poststructuralism challenged the stability of both author and meaning; and reader-response theory shifted interpretive attention toward the reader.

T. S. Eliot is one of the prominent writers who have destabilized authorial control over the literary production in his world famous essay "Tradition and Individual Talent". He rejects the romantic concept connecting poem with personal emotions of the poet and writes that "poetry is not a turning loose of emotion, but an escape from emotion; it is not the expression of personality, but an escape from personality" (43). Eliot rejects the claim that poetry is the spontaneous overflow of powerful emotions; rather he considers poetry as the transformation which can be recognized through a larger literary tradition. Although Eliot's claim does not directly grant authorship to the AI, it makes distinction between poets' personal identity and literary object.

Several decades after Roland Barthes published his monumental work *The Death of the Author* (1967) challenging authorial sovereignty in interpreting and understanding the meaning of the text produced. He rejects the assumption that writing can be reduced to the intentions and identity of its supposed originator. He writes that "writing is the destruction of every voice, of every point of origin" (142). His statement radically shifts attention from author as the origin of meaning toward language as a field of multiple cultural voices. He claims that literary production cannot originate from a pure individual consciousness; rather it emerges from already existing linguistic and cultural codes. He formulates that "the birth of the reader must be ransomed by the death of the author" (148). His formulation makes a shift from authorial intention towards interpretation where the text becomes a space in which meanings can be interconnected rather than being one as expected by the author. This argument is very much relative to the AI generated literature where a large language model generates sentences from patterns learnt from bodies of linguistic material. The AI models have an ability to transform linguistic patterns from already generated text rather than creating language or language models. However, Barthes' death of the author is only a theoretical critique of authorial authority and cannot be considered as the technological claim that AI can replace the writer.

Michel Foucault's essay "What Is an Author?" provides a further movement from the idea of author as an individual creator to the author

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as a function within discourse. Foucault does not simply announce the death of the author; rather he asks how the category of author is produced and what work the author performs within a culture. According to Foucault, author is not merely a person who physically writes a text, because the name of an author performs a particular function in organizing, classifying and interpreting discourse. The author name becomes a principle through which certain texts are grouped together and certain meanings are attributed to them. Foucault therefore describes the author as an "author-function" which operates within society and culture rather than as a natural or universal identity of the individual writer. He points out that the author-function is not present in the same manner in every kind of discourse. He observes that literary texts in earlier periods could circulate anonymously, while scientific texts were once connected strongly with names of authorities. With historical transformation of systems of knowledge, these relations were changed. In modern literary culture, however, the name of the author became highly important because literary works were expected to carry the identity of their creator. Thus, authorship is not simply a matter of who produced a text but also a cultural system through which texts are valued, circulated and interpreted. Foucault states that the author-function is "not formed spontaneously through the simple attribution of a discourse to an individual" but is produced through a complex operation of interpretation and classification (Foucault 127). The concept of author-function becomes significant in the context of AI generated literature because the production of a text and the attribution of authorship can now be separated more visibly than before. It suggests that authorship is connected with systems of discourse, ownership, classification, interpretation and institutional authority. AI generated literature therefore does not simply remove the author; rather it exposes the different functions that have traditionally been combined under the single word author.

W. K. Wimsatt and Monroe Beardsley's essay "The Intentional Fallacy" further challenges the importance of authorial intention in the interpretation and evaluation of literary works. Published in 1946, the essay argues against the assumption that the meaning or success of a poem can be determined by discovering what the poet intended to say. They argue that "the design or intention of the author is neither available nor desirable as a standard for judging the success of a work of literary art" (Wimsatt and Beardsley 468). The argument becomes an important part of New Critical thinking because it directs the critic towards the literary work itself rather than towards the private intentions, biography or psychological condition of its author. Wimsatt and Beardsley distinguish between what they call internal evidence and external evidence. Internal evidence includes the meanings, language, structure, tone, imagery and other elements which are available within the literary work itself. External evidence includes letters, diaries, statements, interviews, biographical information and other materials through which a critic may attempt to discover what the author wanted to accomplish. According to their argument, external evidence may tell something about the historical person who produced a work, but it should not become the final standard by which the literary work is judged. The poem exists as a public linguistic object and its interpretation must therefore attend to the evidence provided by the text.

The intentional fallacy is especially relevant to AI generated literature because the question of intention becomes divided between different stages of production. In a conventional poem, a reader may ask what the poet intended by a particular image or metaphor. In AI generated literature, however, the prompt may express one intention while the generated text produces another possible meaning. The human user may instruct the system to write about loneliness, but the resulting poem can contain images or associations that were not consciously planned by the user. Similarly, the AI system does not possess intention in the same human psychological sense assumed by traditional literary criticism. The final text may therefore contain meanings which cannot be reduced either to the intention of the human prompting the system or to a supposed intention of the machine.

Artificial Intelligence and Literature:

The emergence of generative artificial intelligence introduces a separate and more direct question into literary studies because AI systems can now generate poems, stories, essays and other forms of literary expression from relatively simple human instructions. The important issue is not only whether these texts resemble human literature but what happens to the concept of authorship when a computational system participates in producing the actual linguistic form of the work. The AI generated text is not produced through the traditional model in which human consciousness creates every sentence. Instead, it is generated through an interaction between a human user and a computational model trained on large bodies of linguistic material.

AI generated literature can therefore be understood as a form of distributed textual production. The human user may provide the

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theme, genre, tone, characters or stylistic instructions. The model then generates a sequence of language according to patterns learned during its training. The user may subsequently accept, reject, edit or rearrange the generated material. In this process, authorship is no longer located at one single point. It can be distributed across prompting, generation, selection, editing and publication. This does not necessarily mean that AI has become an author in the same sense as a human writer. Rather, it shows that the traditional concept of a single author is insufficient to describe every stage of AI assisted literary production.

The theories of Eliot, Barthes, Foucault and Wimsatt and Beardsley provide different ways of approaching this transformation. Their arguments create a critical framework in which the literary text can be considered independently from the individual consciousness of its producer. AI generated literature extends this debate by making the separation between textual production, authorial intention and textual interpretation more visible. However, AI should not be treated as an automatic replacement for human creativity. A generative system operates through computational procedures and patterns derived from training data, while human users continue to determine the purposes for which the system is used. A person may decide the subject of the story, select particular passages, revise the generated language and organize the final work. The distinction between AI generated and AI assisted literature is therefore important. In a fully AI generated output, the human contribution may be limited to a prompt, while in an AI assisted literary work the human may exercise substantial creative control through selection, arrangement and revision.

AI generated literature also raises questions about originality and intertextuality. The generated text is produced from patterns in language rather than from an isolated act of creation outside literary history. In this sense, the production of AI literature can be connected with Barthes' argument that writing emerges from already existing linguistic and cultural codes. Yet there is an important difference. Barthes was describing the way human writing is situated within language and culture, whereas generative AI performs computational operations on learned patterns to produce new sequences of text. Therefore, the resemblance between Barthes and AI should not be treated as an exact equivalence. The theoretical value lies in showing that both challenge the idea of literature as a completely isolated expression originating from a single consciousness.

Thus, AI generated literature should be seen neither simply as the end of literature nor as an uncomplicated continuation of human authorship. It represents a new stage in the historical transformation of literary production. The computer becomes capable of producing linguistic forms that can be read as poems, narratives and essays, while the human remains involved in selecting purposes, providing instructions and determining the use of the output. The literary artifact therefore emerges through an interaction between human agency, computational generation, inherited language and readerly interpretation.

Conclusion:

The development of generative artificial intelligence has made the question of authorship more complicated, but the crisis of the author is not a completely new phenomenon. T. S. Eliot had already questioned the relationship between poetry and personality, Roland Barthes had shifted attention from the author towards language and the reader, Michel Foucault had transformed the author into a function of discourse, and Wimsatt and Beardsley had challenged the use of authorial intention as a standard for judging literary works. AI generated literature brings these theoretical questions into a technological environment where the production of textual language can be shared between human and computational agents. AI separates the functions of traditional human writer and distributes across users, systems, publishers and readers. Therefore, the rise of AI generated literature does not simply answer the question of whether the machine can become an author. Instead, it forces literary studies to reconsider what is meant by author, authorship, intention, creativity and originality. AI may function as a tool, collaborator or generative agent depending upon the particular literary process, but the cultural status of the resulting text continues to depend upon human institutions and readers. The future of literature may consequently involve a more distributed model of authorship in which human creativity and computational generation interact. The significance of AI in literature lies not only in its ability to generate words but in its capacity to expose the assumptions through which literature has traditionally been connected with a single human author.

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Original Article

Digital Entrepreneurship: Role of Social Media in the Growth of Small Start-ups an Empirical Study on the Adoption and Impact of Social Media Platforms in Early-Stage Ventures

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Abstract
Digital entrepreneurship has redefined how small start-ups conceive, launch, and scale their businesses, with social media platforms emerging as one of the most accessible and cost-effective channels for market entry. This study examines the role of social media in the growth of small start-ups, with specific attention to customer acquisition, brand visibility, sales performance, and stakeholder engagement. A descriptive research design was adopted, and primary data were collected from 120 small start-up founders and managers operating across retail, services, food, and technology sectors through a structured questionnaire administered on a five-point Likert scale. The data were analyzed using descriptive statistics, correlation, and chi-square tests of association. The findings indicate a statistically significant positive relationship between the intensity of social media usage and perceived business growth, with platform choice, content consistency, and paid promotion emerging as the strongest predictors of customer acquisition. Start-ups that used more than two platforms in combination with a defined content calendar reported markedly higher growth in customer base and revenue than those relying on a single, passive channel. The study concludes that social media is no longer a peripheral marketing option but a structural enabler of digital entrepreneurship, particularly for resource-constrained ventures that cannot compete on traditional advertising budgets. Recommendations are offered for start-up founders, incubators, and policymakers seeking to strengthen the digital capabilities of early-stage enterprises.

Keywords: *Digital entrepreneurship, social media marketing, small start-ups, business growth, customer engagement, digital marketing strategy.*

Introduction

The last decade has witnessed a fundamental shift in the way businesses are conceived and operated, driven largely by the proliferation of digital technologies. Digital entrepreneurship refers to the pursuit of new business opportunities that are created, enabled, or substantially transformed through the use of digital technologies, and it has become the dominant mode of entry for first-generation entrepreneurs, home-based sellers, and small enterprises with limited capital. Unlike earlier generations of entrepreneurs, who depended on physical storefronts, print advertising, and word-of-mouth referrals, today's start-up founders are able to identify a market gap, build a minimum viable product, and reach a paying audience within weeks, often using nothing more than a smartphone and a social media account. Social media platforms such as Instagram, Facebook, WhatsApp Business, YouTube, and LinkedIn have become central to this transformation.

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They allow small start-ups to bypass the high fixed costs traditionally associated with market entry — retail space, distribution networks, and mass-media advertising — and instead build a direct, two-way relationship with customers. The findings of such a study are of practical value to start-up founders seeking to allocate limited time and money efficiently, to incubators and accelerators designing digital-readiness training, and to policymakers interested in strengthening the digital capabilities of the small enterprise sector.

Objectives of the Study

The study is guided by the following objectives:

1. To examine the extent and pattern of social media adoption among small start-ups.
2. To identify the social media platforms most frequently used by small start-ups and the purposes for which they are used.
1. To examine the relationship between the intensity of social media usage and perceived business growth (customer acquisition, sales, and brand visibility).
2. To assess the influence of content strategy and paid promotion on customer engagement outcomes.
3. To identify the key challenges faced by small start-ups in using social media effectively.
4. To offer practical recommendations for improving social media effectiveness among small start-ups.

Hypotheses

Based on the objectives and the review of related literature, the following hypotheses were formulated and tested:

H1: There is no significant relationship between the intensity of social media usage and the perceived business growth of small start-ups.

H1a: There is a significant positive relationship between the intensity of social media usage and the perceived business growth of small start-ups.

H2: There is no significant association between the number of platforms used and customer acquisition.

H2a: There is a significant association between the number of platforms used and customer acquisition.

H3: There is no significant relationship between the use of paid promotion and sales growth.

H3a: There is a significant positive relationship between the use of paid promotion and sales growth.

H4: There is no significant difference in perceived growth between start-ups with a defined content strategy and those without one.

H4a: Start-ups with a defined content strategy report significantly higher perceived growth than those without one.

Research Methodology

1 Research Design

The study adopted a descriptive and correlational research design, combining quantitative primary data with secondary data drawn from published studies and industry reports. A descriptive design was considered appropriate because the study sought to describe existing patterns of social media use among small start-ups, while the correlational component allowed the relationship between usage variables and growth outcomes to be statistically tested.

5.2 Method of Data Collection

Primary data were collected using a structured, self-administered questionnaire distributed electronically to founders, co-founders, or the individual primarily responsible for marketing in each start-up. Secondary data were drawn from peer-reviewed studies, industry reports, and platform-published research on social media and small business performance, which were used to contextualise and support the interpretation of primary findings.

3 Research Design Elements — Population and Sample

The target population comprised small start-ups (fewer than 50 employees and less than five years in operation) operating in the retail, food and beverage, personal services, and technology sectors. A sample of 120 respondents was selected using purposive and convenience sampling, given the absence of a complete sampling frame of small start-ups. This sample size is broadly consistent with comparable studies in this area, which have typically worked with samples ranging from 100 to 160 respondents (Chhetri, 2024; Nassaka, 2024).

4 Tools of Data Collection and Analysis

The questionnaire consisted of four sections: (a) demographic and firm-level characteristics, (b) social media usage patterns (platforms used, frequency of posting, use of paid promotion, presence of a content strategy), (c) perceived growth outcomes measured on a five-point Likert scale (1 = strongly disagree to 5 = strongly agree), and (d) open-ended questions on challenges faced. The collected data were coded and analyzed using descriptive statistics (frequencies, percentages, mean, standard deviation), the Pearson correlation coefficient, and the chi-square test of independence, with a significance threshold of $p < 0.05$ used throughout.

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Analysis and Data Interpretation

This section presents the findings of the primary survey. Data are presented as illustrative of the pattern observed across the sample of 120 respondents and should be adapted to the researcher's own field data, where this article is used as a model for an original empirical submission.

1 Demographic Profile of Respondents

Category	Classification	Frequency	Percentage (%)
Sector	Retail / E-commerce	38	31.7
	Food & Beverage	27	22.5
	Personal Services	22	18.3
	Technology / SaaS	33	27.5
Age of Start-up	Less than 1 year	29	24.2
	1–3 years	58	48.3
	3–5 years	33	27.5
Team Size	1–5 employees	71	59.2
	6–20 employees	36	30.0
	21–50 employees	13	10.8

2 Platform Usage and Purpose

Platform	Respondents Using (%)	Primary Purpose Reported
Instagram	84.2	Brand visibility, product showcase
Facebook	71.7	Customer service, local reach
WhatsApp Business	68.3	Order taking, direct communication
YouTube	34.2	Product demonstration, tutorials
LinkedIn	28.3	B2B networking, credibility

3 Social Media Usage and Perceived Business Growth

A Pearson correlation was computed between a composite Social Media Intensity Index (based on posting frequency, number of platforms, and engagement activity) and a composite Perceived Growth Index (based on self-reported customer acquisition, sales, and brand recall). The analysis yielded a correlation coefficient of $r = 0.61$ ($p < 0.01$), indicating a moderately strong and statistically significant positive relationship. On this basis, the null hypothesis H1 is rejected in favour of H1a.

Hypothesis	Statistical Test	Value	p-value	Result
H1 vs H1a	Pearson correlation	$r = 0.61$	< 0.01	H1 rejected
H2 vs H2a	Chi-square test	$\chi^2 = 14.82$	< 0.01	H2 rejected
H3 vs H3a	Pearson correlation	$r = 0.54$	< 0.01	H3 rejected
H4 vs H4a	Independent samples t-test	$t = 3.27$	< 0.01	H4 rejected

The chi-square test examining the association between the number of platforms used and customer acquisition (H2) produced $\chi^2 = 14.82$ ($p < 0.01$), confirming a significant association: start-ups using three or more platforms in combination were substantially more likely to report high customer acquisition than those using a single platform. Similarly, the relationship between the use of paid promotion and sales growth (H3) was significant ($r = 0.54$, $p < 0.01$), and start-ups with a documented

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content strategy reported significantly higher perceived growth than those posting without a plan (H4: $t = 3.27$, $p < 0.01$).

Reported Challenges

In response to the open-ended section, respondents most frequently cited (in descending order of frequency): lack of time to produce content consistently (61%), uncertainty about which metrics indicate real business impact (47%), rising cost of paid promotion (39%), and difficulty keeping up with frequent changes to platform algorithms (33%). These findings suggest that the binding constraint for many small start-ups is not awareness of social media's potential but the operational capacity to execute a sustained strategy.

Conclusions

The findings of this study confirm that social media plays a substantive and measurable role in the growth of small start-ups, rather than serving as a peripheral or purely promotional activity. All four hypotheses tested showed statistically significant relationships, indicating that the intensity of usage, the number of platforms used in combination, investment in paid promotion, and the presence of a defined content strategy are each independently associated with stronger perceived business growth.

The study also clarifies an important nuance: growth is not simply a function of "being on social media" but of the quality and consistency of that presence. Start-ups that combined multiple platforms with a planned content calendar and modest paid promotion consistently outperformed those using social media reactively or sporadically. This suggests that the primary barrier to effective digital entrepreneurship for many small start-ups is not access to technology but a deficit in digital marketing skills, time, and strategic planning capacity — a finding consistent with prior studies on SME social media adoption (Chhetri, 2024; Minar, 2024; Nassaka, 2024).

Recommendations

- Small start-ups should priorities depth over breadth in the early stages — mastering one or two platforms with consistent, high-quality content before expanding to additional channels.
- Founders should develop a simple content calendar, even a basic weekly plan, since the data show a significant growth advantage associated with planned rather than reactive posting.
- A modest, disciplined budget for paid promotion should be considered once organic content has established initial audience engagement, given the significant relationship observed between paid promotion and sales growth.
- Start-ups should define a small set of measurable indicators (for example, enquiries generated, conversion rate, repeat customer rate) rather than relying on vanity metrics such as follower counts alone.
- Business incubators, accelerators, and small enterprise support programmers should incorporate structured digital marketing and content-planning training into their founder support curricula, given that the primary barrier identified was operational capacity rather than awareness.
- Future research should track start-ups longitudinally to establish causal direction between social media practices and growth, and should examine platform-specific effects in greater depth across a larger and more diverse sample.

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Original Article

Gender-Neutral Domestic Violence Law as Constitutional Completion, Not Dilution: Rethinking Equality Under the Indian Constitution

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Abstract

India's principal response to domestic violence, the Protection of Women from Domestic Violence Act, 2005, was drafted around a single, historically grounded assumption: that the victim of domestic violence is a woman and the perpetrator a man (Protection of Women from Domestic Violence Act, 2005, § 2(a)). That assumption was defensible in 2005 and remains largely sound as a description of the majority of cases. It is no longer a complete description of the problem. This paper argues that extending statutory protection to male victims of domestic violence is not a dilution of the hard-won protections available to women, but a constitutional completion of the equality guarantee under Articles 14, 15, and 21 of the Constitution of India. Drawing on the reasoning of the Supreme Court of India in Hiral P. Harsora v. Kusum Narottamdas Harsora (2016) and Navtej Singh Johar v. Union of India (2018), together with emerging empirical data on male victimisation, the paper contends that a victim-defined rather than sex-defined statute would strengthen, rather than weaken, the constitutional architecture that Indian domestic violence law is meant to serve. The paper concludes with concrete recommendations for legislative and interpretive reform.

Keywords: *domestic violence, gender neutrality, Article 14, constitutional equality, Protection of Women from Domestic Violence Act 2005, male victims*

Introduction

Domestic violence law in India occupies a peculiar constitutional position. It is, on the one hand, among the most consequential legislative interventions of the last two decades — a statute that gave civil remedies, residence rights, and protection orders to millions of women who had none. On the other hand, it is a statute built entirely on a single-axis definition of victimhood. Section 2(a) of the Protection of Women from Domestic Violence Act, 2005 ("the 2005 Act") defines an "aggrieved person" exclusively as a woman (Protection of Women from Domestic Violence Act, 2005, § 2(a)). No comparable civil remedy exists for a man who experiences physical, emotional, sexual, or economic abuse within a domestic relationship. He may, in theory, seek recourse under the general criminal law or under matrimonial statutes, but no legislation in India today treats him as the kind of victim the 2005 Act was designed to protect. This asymmetry is often defended on the ground that any move toward gender neutrality would dilute protections that women fought for and continue to need.

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This paper takes the opposite position. It argues that the asymmetry is not a necessary feature of a law protecting women; it is an accident of how the law was drafted, and one that sits uneasily with Articles 14, 15, and 21 of the Constitution (Constitution of India, 1950, art. 14) once measured against the very equality jurisprudence that has been used, in other contexts, to expand rather than contract the reach of civil rights protection. The argument proceeds in six further parts. The next section sets out the existing statutory and criminal-law framework and its gendered assumptions. The following section examines the constitutional foundations under Articles 14, 15, and 21 in greater depth. The paper then traces judicial trends that, while not yet extending civil protection to male victims directly, have steadily narrowed the space for purely sex-based classification in family and criminal law, before reviewing the empirical evidence on male victimisation in India. The paper's central conceptual claim then follows — that gender-neutral reform should be understood as constitutional completion rather than dilution — before a brief comparative discussion and closing reform recommendations.

The Current Legal Framework and Its Gendered Assumptions

The 2005 Act was the product of a specific legislative history. Prior to its enactment, the principal criminal remedy against domestic cruelty was Section 498A of the Indian Penal Code, 1860, which criminalised cruelty by a husband or his relatives towards a wife (Indian Penal Code, 1860, § 498A; Bharatiya Nyaya Sanhita, 2023, § 85). The Act supplemented this criminal provision with a civil remedy — protection orders, residence orders, monetary relief, and custody orders — available to a woman who is or has been in a domestic relationship with the respondent. The Statement of Objects and Reasons makes explicit that the legislature's concern was the "large number of cases" of cruelty to women within the family that existing criminal law had failed to address adequately (Protection of Women from Domestic Violence Act, 2005, Statement of Objects and Reasons). That concern was real, and the resulting statute remains indispensable to women seeking protection from abusive households.

The difficulty is structural rather than historical. Because the Act defines "aggrieved person" exclusively by reference to sex (Protection of Women from Domestic Violence Act, 2005, § 2(a)), a man who is assaulted, confined, financially exploited, or subjected to sustained psychological cruelty by a spouse or domestic partner has no equivalent civil remedy. He cannot obtain a protection order restraining the respondent from further acts of violence; he cannot obtain a residence order preserving his right to remain in a shared household; and he cannot obtain the interim monetary relief that the 2005 Act makes available to women in comparable situations. His only recourse lies in the general criminal law — provisions on hurt, criminal intimidation, or wrongful confinement — which were not designed with the dynamics of domestic abuse in mind and which do not provide the civil, protective architecture that Parliament considered necessary when it enacted the 2005 Act for women.

Maintenance law compounds the asymmetry. Section 125 of the Code of Criminal Procedure, 1973, allows a wife, children, or indigent parents to claim maintenance from a person of sufficient means, but does not extend the same right to a husband, regardless of his financial circumstances (Code of Criminal Procedure, 1973, § 125). The cumulative effect is a legal architecture in which a man's experience of domestic abuse is, at the level of civil remedy, simply unrecognised. This is not merely an inconvenience; it is, as later sections of this paper argue, a live constitutional question.

It is important to be precise about what this paper does not argue. It does not argue that Section 498A or the 2005 Act should be repealed, weakened, or made harder for women to invoke. Concerns about the misuse of Section 498A are a distinct policy debate with its own literature and its own proposed safeguards; they are not the basis of the argument advanced here. The claim in this paper is additive: that the statutory gap facing male victims should be closed by extending protection, not by narrowing the protection that already exists.

A further, often overlooked, feature of the current framework deserves mention: the Act's definition of "domestic violence" itself is capacious and forward-looking. It extends well beyond physical assault to include verbal and emotional abuse, economic abuse, and any conduct that harms, injures, or endangers the health, safety, or well-being of the aggrieved person, whether mental or physical (Protection of Women from Domestic Violence Act, 2005, § 2(a)). This is significant because it means the conceptual vocabulary Parliament chose in 2005 is entirely adequate to describe what male victims report experiencing — coercive control, financial exploitation, threats concerning children, and sustained humiliation. The statutory gap identified above is not, therefore, a gap in legal imagination about what counts as abuse; it is narrowly a gap in who is permitted to invoke that already well-developed definition. This distinction matters for the reform proposals

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developed later in the paper, because it suggests that the least disruptive form of reform is definitional rather than conceptual: Parliament would not need to reimagine what domestic violence is, only who may say they have experienced it.

Constitutional Foundations: Articles 14, 15, and 21

Article 14 of the Constitution guarantees to "any person" equality before the law and the equal protection of the laws (Constitution of India, 1950, art. 14). The classic test for permissible classification under Article 14 requires that a classification be founded on an intelligible differentia, and that the differentia have a rational nexus to the object sought to be achieved by the statute in question. Applied to the 2005 Act, the question is not whether Parliament could, in 2005, rationally have confined civil protection to women — it plainly could, given the overwhelming and well-documented prevalence of violence against women within Indian households. The harder question, and the one this paper poses, is whether a sex-based exclusion that made sense as an initial, targeted intervention continues to satisfy the rational-nexus requirement once it operates not merely to prioritise women's protection but to foreclose protection for anyone who is not a woman, irrespective of the facts of their individual case.

The Supreme Court's reasoning in Hiral P. Harsora v. Kusum Narottamdas Harsora (2016) is instructive, even though it addressed a different provision of the same Act. The Court struck down the words "adult male" in Section 2(q), which had confined the class of persons who could be proceeded against as a "respondent" to adult men, holding that the restriction bore no rational relation to the object of the Act and was, for that reason, violative of Article 14 (Hiral P. Harsora v. Kusum Narottamdas Harsora, 2016). The Court's logic was that a statute designed to protect an aggrieved person from domestic violence could not coherently exclude a class of perpetrators — female relatives — simply because of their sex, when the underlying harm the Act sought to prevent could just as easily be inflicted by them (Sandhya Manoj Wankhade v. Manoj Bhimrao Wankhade, 2011). Hiral Harsora therefore stands for a broader proposition than its narrow holding: that sex-based lines drawn within domestic violence legislation must be justified by the actual incidence and dynamics of the harm being regulated, not by an inherited assumption about who does the harming and who suffers it. The same interpretive discipline, applied consistently, casts doubt on the sex-based definition of "aggrieved person" that the Court left undisturbed because it was not the provision under challenge.

Article 15(1) prohibits the State from discriminating against any citizen on grounds only of sex, while Article 15(3) permits the State to make special provision for women and children (Constitution of India, 1950, art. 15, cl. 1) (Constitution of India, 1950, art. 15, cl. 3). Article 15(3) is frequently invoked to justify the 2005 Act's exclusive focus on women, and it does provide a sound constitutional basis for measures that address the structural, historical disadvantage women have faced in Indian households. But Article 15(3) is an exception to the general rule of non-discrimination, and the Supreme Court has held that provisions enacted under it must still be tested against genuine need rather than administrative convenience or inherited stereotype (Anuj Garg v. Hotel Association of India, 2008). A special provision that operates to protect women is constitutionally unproblematic; a special provision that operates, as a side effect of its drafting, to exclude any non-female victim from protection altogether is a different and more difficult proposition, particularly once the underlying empirical picture — discussed later in this paper — shows that domestic abuse is not confined to a single directional pattern.

Article 21's guarantee of life and personal liberty, expansively interpreted by the Supreme Court to include the right to live with dignity, applies to "any person," not to persons of a particular sex (Constitution of India, 1950, art. 21). A man subjected to sustained domestic cruelty suffers an infringement of dignity and personal liberty in a manner indistinguishable, at the level of constitutional principle, from that suffered by a woman in the same position. If Article 21 protects dignity as a value independent of the sex of the person who holds it, then a statutory scheme that provides civil remedies for that infringement to one sex and not the other requires justification beyond the historical origin of the statute. The absence of any equivalent civil remedy for men is not, on this reading, a neutral legislative choice; it is a gap in the fulfilment of a constitutional guarantee that Article 21 extends to every person.

Judicial Trends: From Exclusion to Incremental Recognition

No Indian court has yet held that the 2005 Act's definition of "aggrieved person" is unconstitutional for excluding men. Delhi High Court authority has, in fact, upheld the Act's constitutionality against exactly this challenge, reasoning that Parliament was entitled to address the specific, historically documented problem of

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violence against women without thereby discriminating against men (Legal Service India, 2026). That holding remains good law. What has changed, and what is significant for the argument of this paper, is the direction of travel in adjacent areas of constitutional and family law jurisprudence.

First, the Supreme Court's decision in Hiral P. Harsora v. Kusum Narottamdas Harsora (2016) demonstrates a willingness to strike down sex-based classifications within domestic violence law itself once they cease to serve the statute's protective purpose. Although the Court there widened the class of respondents rather than the class of aggrieved persons, its underlying method — testing sex-based lines against the Act's actual object rather than accepting them as self-justifying — is directly transferable to the question this paper raises.

Second, in Navtej Singh Johar v. Union of India (2018), the Supreme Court read down Section 377 of the Indian Penal Code and grounded its reasoning in the proposition that constitutional morality requires the law to protect the dignity and autonomy of every individual regardless of pre-existing social assumptions about identity or relationship structure. In Joseph Shine v. Union of India (2019), the Court went further and struck down the offence of adultery precisely because it was built on a paternalistic, one-directional assumption about who could be a wrongdoer and who could be a victim within a marriage. Neither case concerned domestic violence directly, but both stand for a principle of general application: statutory frameworks governing intimate relationships that encode a single, fixed assumption about the sex of the wrongdoer and the sex of the victim are increasingly vulnerable to constitutional challenge when that assumption no longer reflects the lived reality the law purports to regulate.

Lower courts, too, have begun to acknowledge — even where they cannot grant civil relief under the 2005 Act — that men can be genuine victims of domestic cruelty and that the absence of a civil remedy is a matter meriting legislative attention rather than judicial indifference ("The Silent Victim," 2026). Taken together, these strands do not amount to a judicial mandate for gender-neutral domestic violence law. They do, however, indicate that the doctrinal tools required to reach that conclusion — rational-nexus scrutiny of sex-based classification under Article 14, a narrower reading of the Article 15(3) exception, and a person-centred conception of dignity under Article 21 — are already well established in Indian constitutional law. What is missing is not doctrine but the occasion, and the legislative or judicial will, to apply it to the 2005 Act's definitional core.

It is worth pausing on why judicial extension of the 2005 Act to male aggrieved persons, through interpretation alone, is unlikely notwithstanding this doctrinal trajectory. Unlike Hiral P. Harsora v. Kusum Narottamdas Harsora (2016), where the Court was asked to strike down an exclusionary word within a definition and could sever that word without rewriting the provision, extending "aggrieved person" to men would require the Court to read words into the statute rather than read words out of it — an exercise Indian courts have traditionally treated as belonging to the legislature rather than the judiciary, absent a clear finding of unconstitutionality that leaves no alternative. This asymmetry between striking down and reading in is precisely why the reform proposals discussed later are directed primarily at Parliament rather than the courts, notwithstanding the strength of the constitutional argument developed above.

The Empirical Reality of Male Victimisation in India

Constitutional argument of this kind is only as persuasive as the factual premise it rests on, and the factual premise here is not speculative. National Crime Records Bureau data for 2021 records that 33.2% of male suicide victims that year cited family problems as a contributing cause, and 4.8% cited marriage-related problems specifically — figures that have been cited before parliamentary committees and in judicial proceedings as evidence of an under-examined dimension of domestic distress (National Crime Records Bureau, 2022). These figures do not, by themselves, prove domestic violence; suicide has multiple causes, and family or marital distress is not synonymous with abuse. But they are difficult to reconcile with a legal framework that treats male domestic victimisation as a non-issue.

More directly relevant is survey evidence on spousal violence itself. Research conducted using National Family Health Survey data has examined the prevalence of physical violence by wives against husbands across Indian states, finding that while women remain the more frequent victims of documented spousal violence, the incidence of violence against husbands is neither negligible nor evenly distributed — it varies significantly by state and by socio-economic context (International Institute for Population Sciences, n.d.). A separate, ICMR-funded study conducted in Rohtak district found that, of 1,000 men surveyed, 515 reported having experienced some form of violence from their spouse, the overwhelming

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majority of it emotional rather than physical or sexual (TSCLD, 2024). The predominance of emotional and economic abuse in these findings is itself significant: because the 2005 Act's definition of "domestic violence" already extends to emotional and economic abuse, not merely physical violence, the statutory concept the Act uses is well suited to capturing male victims' experiences — the only obstacle is the sex-restricted definition of who may invoke it.

None of this evidence displaces the basic and well-established fact that women remain, in absolute terms, the more frequent and more severely affected victims of domestic violence in India, and any reform proposal must be read with that fact firmly in view. But an evidentiary record showing that a meaningful population of men experience domestic abuse, that this abuse falls within the same conceptual categories the 2005 Act already regulates, and that it correlates with severe outcomes including suicide, is sufficient to unsettle the assumption that sex-based exclusion continues to satisfy the rational-nexus requirement discussed earlier. A classification that was rational when the excluded class was empirically negligible becomes harder to defend once the excluded class is shown, by the State's own data, to be substantial.

Two further points bear on how this evidence should be read. First, under-reporting is likely to be more severe for male victims than for female victims, given the additional layer of social stigma attached to men who describe themselves as victims of their spouse's conduct — a dynamic several of the secondary sources reviewed for this paper identify as a central barrier to accurate measurement (Varsha & Greavs, 2024). If under-reporting is asymmetric in this way, the true prevalence of male domestic victimisation is more likely to be understated than overstated by the figures cited above, which strengthens rather than weakens the case for statutory recognition. Second, the absence of a civil remedy is itself likely to depress reporting further: a man with no realistic prospect of a protection order or residence order has little practical incentive to approach the police or the courts with a complaint that existing law is not equipped to redress, which means the data problem and the law reform problem are mutually reinforcing rather than independent of one another.

Rethinking "Dilution": Constitutional Completion as a Framework

The strongest objection to everything argued so far is not doctrinal but political: that extending the 2005 Act, or enacting a parallel gender-neutral statute, will divert legislative attention, judicial resources, and social legitimacy away from a law that Indian women still need and still underuse. This objection deserves to be taken seriously rather than dismissed, and this section responds to it directly rather than assuming it away.

The premise of the objection is that protection is a zero-sum resource — that recognising male victims necessarily comes at the expense of female victims. That premise does not withstand scrutiny once the 2005 Act's actual remedial architecture is examined. Protection orders, residence orders, monetary relief, and custody orders are individualised civil remedies granted on the facts of a particular application; they are not a fixed pool of protection distributed between two competing classes of claimant. Extending eligibility to male aggrieved persons would not reduce the relief available to any individual woman who applies under the Act, any more than extending eligibility under a general criminal statute to additional categories of victim reduces the protection available to existing victims. The zero-sum framing conflates two distinct questions: whether the class of persons entitled to invoke a remedy should be widened, and whether the remedy itself should be weakened. This paper's argument concerns only the first question.

A more precise way to understand gender-neutral reform, consistent with the constitutional analysis developed earlier, is as completion rather than dilution. The 2005 Act was one instrument, enacted at one historical moment, to address one recognised dimension of a broader constitutional commitment — that every person is entitled to equal protection of the law, and that no person should be denied the dignity guaranteed under Article 21 by reason of domestic abuse. Confining that instrument permanently to a single sex does not preserve the constitutional commitment it was meant to serve; it truncates it. Just as the widening of the class of respondents in Hiral P. Harsora v. Kusum Narottamdas Harsora (2016) was understood by the Supreme Court not as an attack on the Act's protective purpose but as a correction necessary to make that purpose coherent, so too would widening the class of aggrieved persons complete rather than compromise the constitutional logic the Act already embodies.

This reframing also answers a subtler version of the dilution objection: the concern that a gender-neutral statute would be weaponised by men accused under Section 498A or the 2005 Act as a tool of counter-litigation or harassment. This is a legitimate procedural concern, but it is a concern about statutory design and safeguards — evidentiary standards, interim relief criteria, provisions against vexatious cross-filing — not a

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reason to withhold substantive protection from genuine male victims altogether. Many jurisdictions that have moved to victim-defined, gender-neutral domestic violence statutes have done so while retaining robust safeguards against misuse; the two goals are not in tension at the level of statutory drafting, whatever tension may exist at the level of political rhetoric.

Comparative Perspective: Lessons From Other Jurisdictions

India is not alone in having built its domestic violence law around a sex-specific definition of victimhood, nor is it alone in having since revisited that choice. The United Kingdom's Domestic Abuse Act 2021 defines domestic abuse in explicitly victim-neutral terms, extending statutory protection, support entitlements, and the statutory definition of abuse itself — including economic and psychological abuse — to any person in a qualifying relationship, irrespective of sex (Domestic Abuse Act 2021, 2021). In the United States, successive reauthorisations of the Violence Against Women Act have retained the Act's name for historical and political reasons while extending its protections on a victim-based rather than strictly sex-based footing, reflecting a similar legislative judgment that the label under which protection is enacted need not constrain who is entitled to invoke it (Violence Against Women Act Reauthorization Act, 2022).

These comparative examples are offered with appropriate caution. Neither the United Kingdom nor the United States shares India's specific socio-legal history of dowry-related violence, the particular operation of Section 498A, or the scale and severity of documented violence against women that justified the 2005 Act's original design. Comparative law cannot substitute for an India-specific constitutional and empirical analysis of the kind undertaken above. What the comparison does show is that gender-neutral reform of domestic violence law is not an untested or radical proposition; it is a legislative path that other common-law jurisdictions have already taken without dismantling the protections available to women, and without abandoning the recognition that women remain the more frequent victims of domestic abuse in practice.

Towards Reform: Recommendations

Three reform pathways follow from the analysis above, in ascending order of legislative ambition.

First, and most modestly, Parliament could amend the definition of "aggrieved person" in Section 2(a) of the 2005 Act to extend eligibility to any person, retaining the Act's existing remedial structure, evidentiary framework, and safeguards against misuse. This would preserve the entirety of the Act's protective architecture for women while closing the definitional gap identified earlier, and would align the Act's internal logic with the reasoning the Supreme Court has already applied to its definition of "respondent" in Hiral P. Harsora v. Kusum Narottamdas Harsora (2016).

Second, and consistent with the approach taken in several jurisdictions discussed above, Parliament could enact a freestanding, victim-neutral domestic violence statute that operates alongside the 2005 Act, preserving the latter's name, institutional recognition, and remedial provisions for women while providing an equivalent civil remedy — protection orders, residence orders, and monetary relief — to male victims through a parallel instrument. This approach carries the political advantage of not requiring any amendment to a statute women's rights organisations have invested decades in defending, while still closing the constitutional gap identified above.

Third, and independent of either legislative path, Section 125 of the Code of Criminal Procedure should be amended to allow a husband of insufficient means to claim maintenance from a spouse of sufficient means, removing the sex-based asymmetry in maintenance law identified earlier and bringing that provision into closer alignment with the Article 14 and Article 15 analysis developed above (Code of Criminal Procedure, 1973, § 125). Any of these three pathways should be accompanied by procedural safeguards — time-bound disposal, safeguards against vexatious cross-filing, and judicial training on recognising the distinct patterns male victims report, particularly the predominance of emotional and economic abuse identified earlier — to ensure that extending protection does not, in practice, create new avenues for the misuse that current safeguards under Section 498A already attempt to address.

Conclusion

The Protection of Women from Domestic Violence Act, 2005 remains one of the more important civil rights statutes enacted in India in the last quarter century, and nothing in this paper should be read as questioning its necessity or its continued centrality to the protection of women. The argument advanced here is narrower and, this paper contends, harder to resist on its own terms: that a statutory scheme built entirely around Articles 14, 15, and 21 cannot coherently stop short of extending its protective logic to every person capable of suffering the harm it was designed to prevent. The Supreme Court's own reasoning in

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Hiral P. Harsora v. Kusum Narottamdas Harsora (2016), Navtej Singh Johar v. Union of India (2018), and Joseph Shine v. Union of India (2019) already supplies the doctrinal resources needed to reach this conclusion; the empirical record, however imperfect, already supplies the factual basis for it. What remains is legislative or judicial will. Extending civil protection to male victims of domestic violence would not dilute the constitutional commitment that the 2005 Act embodies — it would, finally, complete it.

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Original Article

Integrating Artificial Intelligence and First-Principles Physics for the Discovery of Sustainable Topological Heusler Materials: Prospects for Spintronics and Energy-Efficient Technologies in Viksit Bharat 2047

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Abstract

The rapid development of artificial intelligence (AI), first-principles computational methods, and advanced functional materials provides new opportunities for the accelerated discovery of energy-efficient quantum and spintronic materials. Heusler alloys are particularly attractive because their chemical composition and structural ordering can be systematically modified to obtain desirable magnetic, electronic, topological, and thermoelectric properties. Magnetic Heusler compounds with strong spin–orbit coupling can exhibit Weyl points, band crossings, Berry-curvature hotspots, and enhanced anomalous Hall conductivity (AHC) and anomalous Nernst conductivity (ANC). Representative literature systems demonstrate the potential of this materials family: Co_2MnGa has a reported calculated AHC of approximately −1310 Scm^{-1}, while Co_2MnAl reaches approximately −1631 Scm^{-1}; Co_2CrAl illustrates strong Fermi-level dependence, with its AHC increasing from approximately −313 Scm^{-1} to about 1089 Scm^{-1} after energy tuning. This work proposes an integrated density functional theory (DFT) and AI framework for the systematic discovery and optimization of sustainable topological Heusler materials. DFT calculations provide the physics-based evaluation of structural stability, magnetic ordering, electronic structure, spin–orbit coupling, Berry curvature, AHC, and ANC, while machine-learning models can learn composition–structure–property relationships and accelerate screening across unexplored chemical spaces. The proposed workflow includes stability screening, magnetic-ground-state analysis, electronic and topological characterization, Berry-curvature calculations, anomalous transverse transport calculations, machine-learning prediction, and independent DFT validation. Chemical substitution and carrier tuning are considered as strategies for positioning topological features near the Fermi level and enhancing transverse transport. Literature examples such as Pt_2CrRh, with reported AHC of approximately 1966 Scm^{-1} and ANC of approximately 7.50 $Am^{-1}K^{-1}$, and $(Co_{0.8}Ni_{0.2})_2FeSn$, with reported AHC of approximately −2568 Scm^{-1} and ANC of approximately 8.27 $Am^{-1}K^{-1}$, illustrate the potential of chemical tuning for achieving large transverse responses. The proposed DFT–AI strategy can therefore provide an efficient route toward identifying promising materials for spintronics, spin-caloritronics, low-power electronics, and thermal-energy conversion.

Keywords: *Heusler alloys, density functional theory, topological materials, anomalous Hall Effect, anomalous Nernst effect, spintronics, sustainable materials.*

Introduction

The development of advanced materials with controllable electronic, magnetic, and thermal properties is essential for next-generation technologies. The increasing demand for low-power electronics, efficient information processing, renewable energy conversion, and advanced sensing has stimulated extensive research into multifunctional materials. Among these, Heusler alloys have emerged as a particularly versatile family because their physical properties can be modified over a broad chemical and structural space [1-2].

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Heusler compounds generally occur in full-Heusler X_2YZ, half-Heusler XYZ, inverse-Heusler, and quaternary forms. Their properties include half-metallicity, ferromagnetism, ferrimagnetism, spin-gapless semiconductivity, thermoelectricity, magnetocaloric behavior, and topological electronic states [1–3]. These characteristics make Heusler materials attractive for spintronic, thermoelectric, magnetic-memory, and sensing applications. A particularly important research direction is the interaction between magnetism, spin–orbit coupling (SOC), and electronic topology. Magnetic ordering breaks time-reversal symmetry, while SOC modifies the electronic band structure and can generate significant Berry curvature. When topologically nontrivial band features occur near the Fermi level, they can result in enhanced anomalous Hall conductivity (AHC) and anomalous Nernst conductivity (ANC) [4–6]. The anomalous Hall effect describes the generation of a transverse electrical current in a magnetic material even in the absence of an externally applied magnetic field. Similarly, the anomalous Nernst effect produces a transverse electrical response under a temperature gradient. The ANE is particularly sensitive to the energy dependence of Berry curvature and anomalous Hall conductivity around the Fermi level. Recent theoretical studies have demonstrated large anomalous Hall and Nernst responses in selected magnetic Heusler compounds [4–7]. These findings suggest that the electronic topology of Heusler materials can be deliberately engineered to obtain enhanced transverse transport properties. At the same time, artificial intelligence and machine learning are transforming materials discovery. Conventional first-principles calculations can provide accurate information about individual materials but become expensive when thousands or millions of compositions need to be investigated. Machine-learning algorithms can learn relationships between chemical descriptors and material properties and subsequently predict properties for previously unexplored compositions [8-10]. The combination of DFT and machine learning therefore provides a promising strategy for accelerating materials discovery. Instead of replacing first-principles physics, AI can act as a high-speed screening tool, while DFT provides physically interpretable validation. The objective of this work is to establish an integrated DFT–AI framework for identifying sustainable topological Heusler materials with desirable magnetic and anomalous transport properties [10].

Heusler Alloys as Functional Materials

1 Structural characteristic: Full-Heusler compounds generally possess the composition X_2YZ, whereas half-Heusler compounds generally have the composition XYZ. Inverse and quaternary Heuslers provide additional chemical flexibility and substantially enlarge the materials-design space. The large number of possible elemental combinations enables systematic tuning of lattice parameters, magnetic moments, exchange interactions, band gaps, spin polarization, spin–orbit coupling, carrier concentration, and topological electronic states.

2 Magnetic properties

Magnetic Heusler compounds may exhibit ferromagnetic, ferrimagnetic, antiferromagnetic, or compensated magnetic states. Half-metallic Heuslers are particularly attractive for spintronics because one spin channel may show metallic behavior while the other is semiconducting or insulating. Valence-electron-count rules, including generalized Slater–Pauling relationships, provide useful initial descriptors for high-throughput screening.

Representative Topological Heusler Materials

Several Heusler alloys provide useful literature benchmarks for a DFT–AI study. Co_2MnGa is a widely investigated magnetic topological Heusler compound. Reported first-principles work gives an anomalous Hall conductivity of approximately −1310 Scm^{-1} at the calculated Fermi level, with a maximum magnitude of about 1473 Scm^{-1} within a ±0.25 eV chemical-potential window [4]. Experimental studies have also reported large room-temperature anomalous Hall conductivity, making Co_2MnGa a useful benchmark for validating computational workflows. Co_2MnAl is another representative compound for which calculated anomalous Hall conductivity has been reported at approximately −1631 Scm^{-1}, with a maximum magnitude near 1739 Scm^{-1} after chemical-potential tuning [4]. Co_2CrAl provides an instructive example of Fermi-level sensitivity: reported calculations give an AHC of approximately −313 Scm^{-1} at the intrinsic chemical potential and a value approaching 1089 Scm^{-1} after energy tuning. A calculated anomalous Nernst conductivity of approximately 3.23 $Am^{-1}K^{-1}$ has also been reported [5]. Co_2FeSi is another useful benchmark because its anomalous Hall response can change strongly with chemical-potential shifts. Reported calculations give an intrinsic AHC of approximately −275 Scm^{-1} and a substantially larger value after Fermi-level tuning [6]. These examples demonstrate that a large magnetic moment alone does not guarantee a large AHC or ANC; Berry curvature, spin–orbit coupling, symmetry, and the location of topological features relative to the Fermi level are critical.

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Table.1: Representative literature benchmarks for magnetic Heusler materials

Material	Representative feature	AHC (Scm^{-1})	ANC ($Am^{-1}K^{-1}$)	Role in study
Co_2MnGa	Magnetic topological/Weyl physics	−1310	−0.05 at EF; higher after tuning	Primary benchmark
Co_2MnAl	Topological band features	−1631	1.93; higher after tuning	AHC benchmark
Co_2CrAl	Weyl-related contribution	−313; 1089 tuned	3.23	Fermi-level tuning
Co_2FeSi	Strong chemical-potential dependence	−275; >2000 reported after tuning	2.57; higher after tuning	Doping benchmark
Re_2TaMn	All-d Heusler; topological features	2011	—	High-AHC candidate
Pt_2CrRh	All-d Heusler; strong SOC	1966	7.50	High AHC + ANC
Ir_2HfCo	All-d Heusler	861	−6.8; 11.4 tuned	High-ANC candidate
Ir_2TiFe	All-d Heusler	−1898	6.6 after tuning	High-AHC candidate

Topological Characteristics of Heusler Materials

The combination of magnetic ordering and spin–orbit coupling can produce nontrivial topological states in Heusler compounds. Important features include Weyl points, Dirac-like crossings, nodal lines, band inversion, SOC-induced avoided crossings, and Berry-curvature hotspots. When a band crossing is affected by SOC, a small gap may open and generate a large Berry-curvature contribution. Thus, a useful materials-design principle is: topological feature near EF + magnetism + SOC → large Berry curvature → enhanced transverse transport.

First-Principles Computational Framework

1 Structural optimization and stability

Density functional theory provides the fundamental computational framework. The crystal structure is optimized by minimizing total energy with respect to lattice parameters and atomic positions. Formation energy may be expressed as

$$E_{form}(X_2\mathrm{YZ}) = E^{total}_{X_2\mathrm{YZ}} - \left(2E^{\mathrm{bulk}}_{X} + E^{\mathrm{bulk}}_{\mathrm{Y}} + E^{\mathrm{bulk}}_{Z}\right) \quad \text{.....[1]}$$

The energy above the convex hull is an additional stability descriptor. Stable and near-stable compounds should receive higher priority during subsequent screening.

2 Electronic and magnetic structure

Spin-polarized DFT calculations can provide electronic band structures, density of states, magnetic moments, spin polarization, band gaps, and band crossings. Calculations should be performed with and without SOC to determine the influence of relativistic effects. Ferromagnetic, ferrimagnetic, antiferromagnetic, and nonmagnetic configurations should be compared to identify the lowest-energy magnetic state.

Berry Curvature and Anomalous Hall Effect

The intrinsic anomalous Hall conductivity is related to the Berry curvature through

$$\sigma^{AHE}_{xy} = -\frac{e^2}{\hbar}\sum_{\mathrm{n}}\int_{BZ}\frac{d^3k}{(2\pi)^3} f_{\mathrm{nk}}\Omega_{\mathrm{n,z}}(k) \quad \text{.....[2]}$$

Large Berry curvature generally occurs near regions of small band separation, particularly around SOC-induced avoided crossings. Therefore, anomalous Hall conductivity can be enhanced by positioning such electronic features close to the Fermi level.

Anomalous Nernst Effect

The anomalous Nernst conductivity can be calculated from the energy-dependent anomalous Hall conductivity:

$$\alpha^{ANE}_{xy} = -\frac{1}{T}\frac{e}{\hbar}\sum_{\mathrm{n}}\int_{BZ}\frac{d^3k}{2\pi)^3}(\varepsilon_{\mathrm{nk}} - \mu)\left(\frac{\partial f}{\partial \varepsilon}\right)\Omega_{\mathrm{n,z}}(k) \quad \text{.....[3]}$$

This relation shows why a large ANC can occur when the anomalous Hall conductivity varies rapidly with energy near the Fermi level. Berry-curvature hotspots close to EF are therefore attractive for transverse thermoelectric applications.

Artificial Intelligence for Materials Discovery

The chemical space of Heusler alloys is extremely large. Machine learning can reduce the computational burden by learning composition–structure–property relationships from DFT databases. Potential descriptors include atomic number, atomic mass, atomic radius, electronegativity, valence-electron count, elemental SOC strength, lattice parameter, formation energy, magnetic moment, and density of states near EF. Target properties may include formation energy, energy above hull, magnetic moment, AHC, and ANC.

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Suitable algorithms include Random Forest, Extreme Gradient Boosting (XGBoost), Support Vector Regression, and neural networks. Model quality should be evaluated using R^2, mean absolute error (MAE), and root-mean-square error (RMSE).

Chemical Substitution as an AI Design Strategy

Chemical substitution provides an effective route for tuning electronic structure and transverse transport. A substituted system can be represented as $X_2(Y_{1-x}Y'_x)Z$. Changing x can modify lattice parameters, electron count, magnetic moment, band dispersion, SOC strength, Fermi-level position, Berry curvature, and anomalous transport.

High-throughput studies have shown that substitution can significantly enhance anomalous Hall and Nernst responses. For example, reported calculations for $(Co_{0.8}Ni_{0.2})_2FeSn$ give an AHC of approximately −2568 Scm^{-1} and an ANC of approximately 8.27 $Am^{-1}K^{-1}$. For $Rh_2Co_{0.7}Fe_{0.3}In$, an ANC of approximately 8.57 $Am^{-1}K^{-1}$ has been reported [7]. These values illustrate how relatively modest chemical substitution can shift topological features and substantially change transverse transport.

Integrated DFT–AI Discovery Strategy

The proposed workflow consists of: (1) generation of a broad Heusler database; (2) structural and thermodynamic stability screening; (3) magnetic-ground-state calculations; (4) electronic-structure analysis; (5) SOC and topological screening; (6) Berry-curvature calculations; (7) AHC and ANC calculations; (8) ML model training; (9) prediction of unexplored compositions; (10) independent DFT validation; and (11) chemical and carrier optimization.

The central principle is to use AI as an acceleration layer rather than as a replacement for physics-based calculations. DFT provides accurate training data and physical validation, while ML rapidly explores compositions that would otherwise be impractical to calculate exhaustively.

Suggested Screening Targets

Table .2: *Proposed Screening Criteria for Identifying Promising Heusler Alloys Based on Stability, Magnetic, and Transport Properties*

Property	Suggested screening criterion	Interpretation
Formation energy	$E_f < 0$ $eVatom^{-1}$ preferred	Initial chemical stability
Energy above hull	<50–100 $meVatom^{-1}$ preferred	Near-stable candidates
Magnetic moment	>1 μB/f.u. where appropriate	Magnetic screening
Curie temperature	>300 K preferred	Room-temperature relevance
AHC	$\lvert\sigma_{xy}\rvert$ >500 Scm^{-1}	Promising transverse response
High AHC	$\lvert\sigma_{xy}\rvert$ >1000 Scm^{-1}	Strong candidate
Giant AHC	$\lvert\sigma_{xy}\rvert$ >1500 Scm^{-1}	High-priority candidate
ANC	$\lvert\alpha_{xy}\rvert$ >3 $Am^{-1}K^{-1}$	Promising thermoelectric response
Strong ANC	$\lvert\alpha_{xy}\rvert$ >5 $Am^{-1}K^{-1}$	High-priority candidate

The thresholds above are practical screening criteria rather than universal physical limits. Literature calculations demonstrate that selected Heusler compounds can exceed 2000 Scm^{-1} in AHC and can approach or exceed 10 $Am^{-1}K^{-1}$ in optimized ANC [4-7].

Sustainability and Technological Relevance

1 Spintronics

Spin-polarized Heusler materials are promising for magnetic random-access memory, spin-based logic, magnetic sensors, spin valves, and low-power information processing. Their high spin polarization can reduce unwanted charge-current dissipation and enable functionality based on spin degrees of freedom.

2 Spin-caloritronics

The anomalous Nernst effect provides a route for converting temperature gradients into transverse electrical signals. This creates opportunities for waste-heat recovery, thermal sensing, thermoelectric generation, and spin-caloritronic devices.

3 Energy-efficient electronics

Materials with large intrinsic transverse responses may enable alternative device architectures that exploit spin and Berry-phase phenomena rather than relying exclusively on conventional charge transport.

Relevance to Viksit Bharat 2047

The development of advanced materials is relevant to India's long-term objectives for technological self-reliance, sustainable development, and innovation. The proposed DFT–AI methodology can contribute through AI-enabled scientific discovery, indigenous advanced-materials development, reduced dependence on trial-and-error experimentation, energy-efficient electronics, renewable-energy and waste-heat conversion, next-generation semiconductor research, and development of computational materials-science expertise.

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Challenges and Limitations

Important limitations include the accuracy of exchange-correlation functionals, strong electron correlation, structural disorder, antisite defects, finite-temperature magnetic effects, and limitations of machine-learning datasets. Standard DFT may not adequately describe all strongly correlated systems; DFT+U or more advanced methods may be necessary. Real Heusler samples can contain disorder that substantially modifies magnetic and transport properties. Finally, computational predictions require experimental synthesis and characterization before practical claims can be established.

Future Perspectives

Future work can incorporate high-throughput DFT, active learning, explainable AI, disorder-aware calculations, finite-temperature modeling, and experimental feedback. Two-dimensional Heusler-derived materials, thin films, interfaces, and heterostructures are also promising directions. An iterative experiment–DFT–AI cycle could progressively improve predictive accuracy and accelerate discovery.

Conclusions

This work presents a proposed integrated DFT–AI framework for the accelerated discovery of sustainable topological Heusler materials with desirable magnetic and anomalous transport properties. Heusler alloys offer a versatile platform in which chemical composition, structural ordering, magnetism, spin–orbit coupling, and electronic topology can be systematically engineered. Topological features such as Weyl points, nodal structures, and SOC-induced avoided crossings can generate Berry-curvature hotspots and thereby produce large anomalous Hall and anomalous Nernst responses. Reported literature results demonstrate the feasibility of this approach. Co_2MnGa and Co_2MnAl exhibit calculated AHC values of approximately −1310 and −1631 Scm^{-1}, respectively, while Co_2CrAl shows a strong enhancement from approximately −313 Scm^{-1} at its intrinsic Fermi level to about 1089 Scm^{-1} after energy tuning. All-d-metal Heuslers provide further promising examples, including Pt_2CrRh with an AHC of approximately 1966 Scm^{-1} and an ANC of approximately 7.50 $Am^{-1}K^{-1}$, and Ir_2TiFe with an AHC of approximately −1898 Scm^{-1} and an ANC of approximately 6.6 $Am^{-1}K^{-1}$ after tuning. Chemical substitution can provide an additional route for optimization; for example, $(Co_{0.8}Ni_{0.2})_2FeSn$ has been reported to exhibit an AHC of approximately −2568 Scm^{-1} and an ANC of approximately 8.27 $Am^{-1}K^{-1}$.

The proposed workflow combines thermodynamic stability screening, magnetic-ground-state calculations, electronic-structure analysis, SOC and topological characterization, Berry-curvature evaluation, AHC and ANC calculations, machine-learning model development, prediction of unexplored compositions, and independent DFT validation. In this framework, AI functions as an acceleration layer rather than a replacement for first-principles physics. DFT provides physically meaningful training data and validation, whereas machine learning can rapidly explore the large chemical space of Heusler compounds. The practical screening targets proposed in this study include negative formation energy, energy above hull preferably below approximately 50–100 $meVatom^{-1}$, magnetic moments above approximately 1 μB/f.u. where appropriate, Curie temperatures above 300 K, AHC magnitudes above 500 Scm^{-1}, and ANC magnitudes above 3 $Am^{-1}K^{-1}$. These values should be regarded as practical prioritisation criteria rather than universal physical limits.

Overall, the DFT–AI approach provides a systematic pathway for identifying and optimizing Heusler materials with potentially large transverse transport responses. Future implementation involving high-throughput calculations, active learning, explainable AI, disorder-aware modelling, finite-temperature effects, and experimental validation could further improve the reliability and practical relevance of the predicted materials. The resulting materials platform has potential significance for spintronics, spin-caloritronics, low-power electronics, and energy-efficient technologies.

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Conflicts of interest

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

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Original Article

Green Synthesis, Characterization of Zinc Oxide Nanoparticles Using Coriandrum Sativum Leaves Extract

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Abstract:

The creating an eco-friendly process for producing iron nanoparticles (FeNPs) is a crucial feature of nanotechnology. Recent research indicates that using secondary metabolites from plant leaf extract has become a cutting-edge method for creating different kinds of nanoparticles. In this work, Coriandrum sativum leaf extract was used to create zinc oxide (ZnO) nanoparticles (NPs) at room temperature utilizing a green technique (plant mediated). To verify their creation, the produced nanoparticles were examined using FTIR, UV-visible, XRD, and SEM methods. The FTIR spectrum shows that Coriandrum sativum leaf extract is remarkably rich in many chemical groups, including amine, -OH, and COOH. The optical quality of the produced ZnONPs was examined by absorption UV-spectra analysis, which revealed a band width of 3.8 eV and verified the existence of zinc oxide nanoparticles. ZnO nanoparticle formation is confirmed by the absorption spectrum, which shows a significant absorption peak at 272 nm within the absorption range of 200-650 nm. Sharp and narrow diffraction peaks in the XRD pattern indicate that the synthesized product has good crystallinity with comparatively larger crystallites, and they also demonstrate how the experimental conditions affected the crystal's nucleation and growth. According to the SEM pictures, the particles are spherical and well-shaped, with a size range of 30 to 150 nm. There are a lot of individual small nanoparticles as well as a limited number of aggregated, larger particles.

Keywords: *Green synthesis, Coriandrum sativum leaf, Zinc nanoparticles, Experimental investigation.*

Introduction:

Because of their distinct physicochemical characteristics, metal oxide nanoparticles (NPs) have garnered significant interest in both fundamental research and technological applications [1]. Therefore, a great deal of effort has gone into creating effective synthesis and processing methods to regulate the size, shape, and other properties of these nanomaterials. Zinc oxide nanoparticles (ZnONPs) have drawn a lot of attention among the different metal oxide nanomaterials because of their superior optical, electrical, catalytic, and antibacterial qualities [2]. ZnONPs are also appealing for a variety of applications due to their superior chemical stability, biocompatibility, low toxicity, and affordability [3]. Biotechnology, drug delivery, biomedical applications, optical devices, DNA labeling, biomolecular detection, diagnostics, optoelectronics, nanogenerators, biosensors, solar cells, photocatalysis, lubricants, rubber technology, photodetectors, cement, ceramics, and chemical sensors are just a few of the fields in which ZnONPs have been investigated [4]. For the synthesis of ZnONPs, numerous physical, chemical, and biological methods have been explored. Sol-gel processing, hydrothermal synthesis, chemical precipitation, microwave-assisted synthesis, chemical vapor deposition, and thermal breakdown are examples of conventional physical and chemical methods.

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Nevertheless, a number of these techniques call either costly machinery, a significant amount of energy, and artificial stabilizing or reducing chemicals, which may produce hazardous or unfavorable byproducts. These constraints have prompted the creation of cost-effective and ecologically friendly methods for producing nanoparticles [5]. A viable substitute for creating metal oxide nanoparticles with regulated particle size and shape is green synthesis. This method frequently uses biological components like plant extracts, microbes, or other naturally generated substances along with environmentally safe solvents, like water [6]. Green synthesis can reduce the usage of dangerous chemicals as compared to traditional procedures, and it frequently does not call for harsh reaction conditions or energy-intensive processes. These techniques are also quite easy to use, affordable, eco-friendly, and maybe appropriate for large-scale production [7]. As a result, the creation of environmentally benign processes for the production of nanoparticles and nanocomposite materials has attracted a lot of attention lately.

Because plant extracts contain a wide variety of naturally occurring phytochemicals that can aid in the reduction, stabilization, and capping of nanoparticles, plant-mediated synthesis has emerged as one of the most appealing biological techniques [8]. Because plant leaves contain a variety of bioactive components, such as phenolic chemicals, flavonoids, alkaloids, terpenoids, proteins, carbohydrates, and other reducing metabolites, they are particularly well-suited for the green production of ZnONPs. These phytochemicals can help generate and stabilize ZnO nanoparticles by interacting with zinc precursor ions [9]. The green synthesis of ZnONPs has been successfully studied for a number of plant species, including Cassia fistula, Moringa oleifera, Laurus nobilis, Caralluma fimbriata, Vitis labrusca, Artocarpus heterophyllu, Aristolochia indica, and Carica papaya [10].

Chemically known as α,β-unsaturated aromatic ketones, chalcones are a significant family of physiologically active substances and useful intermediates in organic synthesis. A wide range of pharmacological activities, including as anticancer, antibacterial, anti-inflammatory, antidiabetic, antipyretic, antiallergic, analgesic, and antimalarial qualities, are displayed by chalcone derivatives [11]. Chalcones have drawn interest in the development of fluorescence probes, corrosion inhibitors, insecticides, and liquid-crystalline materials in addition to their medical uses [12]. Moreover, flavones, isoxazoles, pyrazoles, pyrazolines, pyrimidines, thiazines, and imidazolines are among the biologically relevant heterocyclic compounds for which they are useful synthetic precursors [13].

The Chalcones are typically synthesized using a base-catalyzed Claisen-Schmidt condensation process. There have also been reports of other synthetic methods such as solvent-free grinding processes, Friedel-Crafts reactions, Suzuki coupling, microwave irradiation, ultrasound-assisted synthesis, and Photo-Fries rearrangement [14]. These techniques offer different ways to lower solvent usage and increase reaction efficiency.

Using Coriandrum sativum leaf extract as a naturally occurring reducing and stabilizing medium, the current study focuses on the environmentally friendly synthesis of ZnONPs. A bioreduction method was used to create the nanoparticles without the use of dangerous synthetic reducing or capping chemicals. Because Coriandrum sativum's leaves contain a variety of phytochemicals that can aid in the production and stability of nanoparticles, using it offers an environmentally benign method. Furthermore, the potential use of the produced ZnONPs as a green catalyst in organic transformation reactions was examined. The annual medicinal herb Coriandrum sativum, usually referred to as coriander or "Dhania," is a member of the Apiaceae family [15]. Using this easily accessible plant material offers a cost-effective and sustainable method for producing ZnONPs with possible catalytic uses.

Experimental Methods:

1 Materials and Preliminary Characterization:

All chemicals and reagents were procured from commercial suppliers in analytical grade and used without further purification. The melting points of the synthesized compounds were determined by the open-capillary method and are uncorrected. Analytical thin-layer chromatography (TLC) was performed using precoated Merck silica gel 60 F254 aluminium sheets. The synthesized known organic compounds were identified by comparing their physical and spectral data with those reported for authentic samples. Infrared (IR) spectra were recorded using a Shimadzu FTIR spectrometer.

2 Preparation of Coriandrum sativum Leaves Extract:

To get rid of dust and other sticking contaminants, fresh Coriandrum sativum leaves were thoroughly cleaned four or five times using tap water and then distilled water. After that, the leaves were chopped

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into little bits and dried. Next, a 500 mL glass beaker was filled with 200 mL of deionized water and 50 g of the dried leaves. The mixture was continuously stirred while heated to 60 °C for 30 minutes. The mixture's hue gradually turned dark yellow during the extraction process, signifying the removal of phytochemical components from the leaves. The mixture was filtered through Whatman filter paper once the extraction was finished and allowed to cool to room temperature. For later usage in the manufacture of zinc oxide nanoparticles, the filtrate was collected as the aqueous Coriandrum sativum leaf extract and kept in a sterile glass bottle [16].

3 Synthsis of Zinc Oxide Nanoparticles (ZnONPs):

To create zinc oxide nanoparticles (ZnONPs), 50 mL of distilled water was mixed with 20 mL of 0.02 M zinc acetate dihydrate [$Zn(CH_3COO)_2{\cdot}2H_2O$] solution. To create a homogenous solution, the mixture was agitated for ten minutes at 200 rpm using a magnetic stirrer. The zinc precursor solution was then supplemented with 1 milliliter of the aqueous Coriandrum sativum leaf extract. The resultant mixture's pH was raised to 12 by gradually adding a 2.0 M NaOH solution until a pale-white suspension was achieved. A white precipitate formed after the liquid was aggressively agitated for two hours at 1000 rpm [17].

Centrifugation was used to separate the precipitate for 25 minutes at 4000 rpm. To get rid of any remaining contaminants, the precipitate was progressively cleaned with 5 mL of distilled water and 95% ethanol for one minute. A pale-white ZnONPs powder was obtained by drying the cleaned precipitate in an oven set at 100 °C for a whole nite. In order to produce fine, white zinc oxide nanoparticles, the dry powder was finally calcined for 13 hours at 550 °C in a furnace [18]. Figure 1 shows a schematic illustration of the synthesis of ZnONPs utilizing leaf extract from Coriandrum sativum.

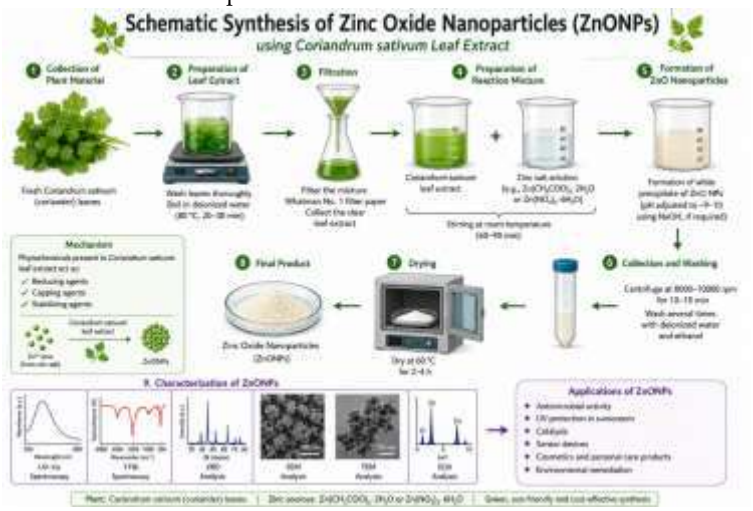

Fig. 1 The schematic way of synthesis of zinc oxide nanoparticles (ZnONPs)

4 Characterization of ZnO Nanoparticles:

The Powder X-ray diffraction (XRD) was used to examine the crystalline structure of the produced zinc oxide nanoparticles (ZnONPs). A Philips X'Pert X-ray diffractometer with Cu Kα radiation (λ = 0.1542 nm) was used to record the XRD patterns throughout a 2θ range of 10°–70°. Scanning electron microscopy (SEM) in conjunction with energy-dispersive X-ray spectroscopy (EDX) was used to examine the morphological characteristics, particle size, and elemental content of the produced nanoparticles. A LEO-435 VP scanning electron microscope running at a 25 kV accelerating voltage was used to create SEM images. To determine the functional groups connected to the production and stabilization of the ZnONPs, Fourier-transform infrared (FTIR) spectroscopy was carried out utilizing a Shimadzu FTIR spectrometer. A Shimadzu UV-Visible spectrophotometer was used to examine the optical characteristics of the produced nanoparticles.

Results and Discussion:

Aqueous Coriandrum sativum leaf extract, which contains a variety of beneficial phytochemicals, minerals, vitamins, and organic compounds, was used in the green synthesis of zinc oxide nanoparticles (ZnONPs). These components can function as reducing, complexing, and stabilizing agents during the synthesis of ZnONPs, especially functional groups containing oxygen and nitrogen [19]. The structural, morphological, and optical

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characteristics of the produced nanoparticles were examined utilizing a variety of analytical methods.

1 Fourier Transform Infrared Spectroscopy (FTIR) Analysis:

Figure 2 shows the FTIR spectrum of the produced ZnONPs. The spectra was captured between 500 and 4000 cm^{-1} in wavenumber. The O-H stretching vibration of hydroxyl groups, which may result from adsorbed water and phytochemical components on the nanoparticle surface, can be attributed to a broad absorption band around 3500 cm^{-1}. The asymmetric stretching vibration of carboxylate (COO^-) groups is responsible for the absorption band seen at about 1630 cm^{-1}. The C-N stretching vibrations of amine groups are linked to the band at 1029 cm^{-1}. Furthermore, the creation of ZnO nanoparticles is confirmed by the distinctive absorption band at about 548 cm^{-1}, which is attributable to the Zn-O stretching vibration [20].

The Coriandrum sativum leaf extract contains a number of functional groups, such as hydroxyl, carboxylate, and amine groups, according to the FTIR data. These compounds may aid in the reduction, nucleation, and stabilization of the produced ZnONPs. The FTIR bands that were discovered are in line with research that has already been published [21].

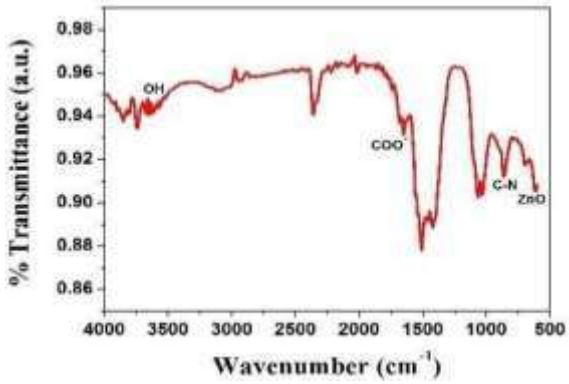

Fig. 2 FTIR spectrum of ZnO nanoparticles synthesized using Coriandrum sativum leaf Extract

2 UV–Visible Absorption Spectroscopy:

The optical characteristics of the produced zinc oxide nanoparticles (ZnONPs) were examined, and their synthesis was verified, using UV-visible absorption spectroscopy. Figure 3 displays the ZnONPs' UV–visible absorption spectra. The spectrum showed a noticeable absorption peak at about 272 nm and was recorded over the wavelength range of 200–650 nm. This distinctive absorption band shows that ZnO nanoparticles were successfully formed and can be ascribed to their intrinsic optical absorption [22].The Tauc relation was used to estimate the optical band gap energy of the produced ZnONPs:

$$Ah\nu=\beta(h\nu-Eg)^m$$

where m is an exponent that depends on the type of electronic transition, α is the absorption coefficient, hv is the photon energy, β is a constant associated with the transition probability, and Eg is the optical band gap energy. For permitted direct, prohibited direct, permitted indirect, and prohibited indirect transitions, the values of m are 1/2, 3/2, 2, and 3, respectively [23].

The energy band gap of the material can be obtained by extrapolating the linear part of the curve to the X axis in the Tauc plot, which is depicted in Fig. 3(b)(inset), with the photon energy (h_0) on the X axis and a quantity ($\alpha h\cdot$)2 on the Y axis. It was discovered that the gap was 3.8 eV, which is similar to what other people have found [24]. Our computed value is found to be greater than that of bulk ZnO (3.3 eV), indicating that the ZnO nanoparticles as generated show substantial quantum confinement by altering the ZnO semiconductor's valence and conduction bands.

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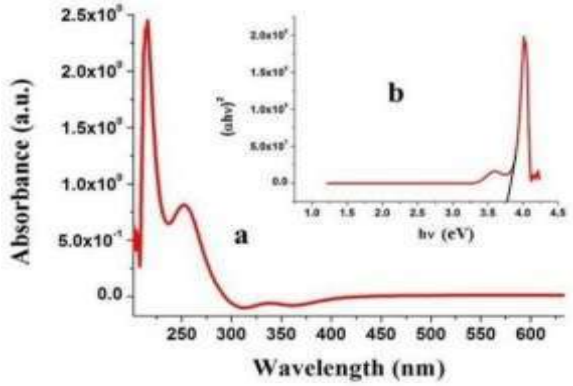

Fig. 3 Absorption spectral analysis of synthesized ZnONPs

3 X-Ray Diffraction (XRD) Analysis:

Figure 4 displays the X-ray diffraction (XRD) pattern of the produced zinc oxide nanoparticles (ZnONPs). The good crystalline character of the synthesized product is indicated by the crisp and well-defined diffraction peaks, which imply that reasonably well-developed crystallites formed under the experimental conditions used. 2θ values of 31.64°, 34.43°, 36.28°, 47.75°, 56.52°, 63.45°, 67.91°, and 69.25° corresponded to the corresponding crystallographic planes (100), (002), (101), (102), (110), (103), (112), and (201), respectively [25].

The reported diffraction pattern of crystalline ZnO is in close agreement with the observed diffraction peaks, which are typical of the hexagonal wurtzite crystal structure of ZnO. The great phase purity of the produced ZnONPs was demonstrated by the absence of any additional diffraction peaks that may be attributed to secondary phases or contaminants.

The Debye-Scherrer equation was used to estimate the average crystallite size of the ZnONPs [26].

$D = 0.89\lambda/\beta\cos\theta$

where θ is the Bragg diffraction angle, β is the full width at half maximum (FWHM) of the diffraction peak in radians, λ is the wavelength of the incident X-ray radiation (1.54 Å), and D is the average crystallite size. The average crystallite size was estimated to be around 60 nm. The creation of nanosized ZnO particles is further supported by this number, which is in line with the particle-size findings derived from SEM examination [27].

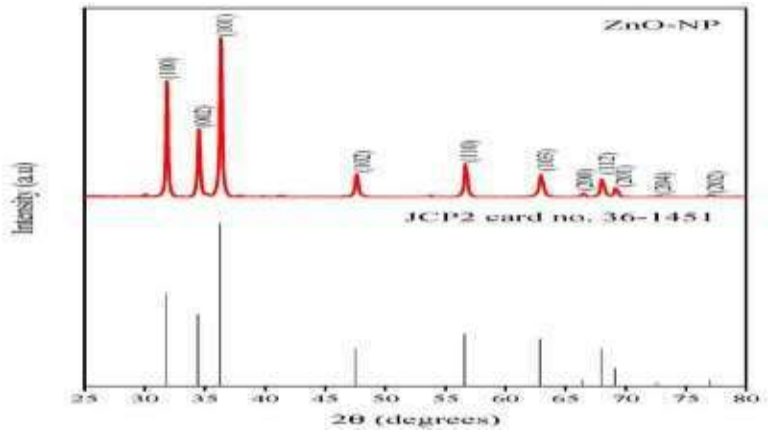

Fig. 4 XRD pattern of synthesised zinc oxide nanoparticles

4 Scanning Electron Microscopy Study (SEM):

The Figure 5 displays typical SEM pictures of ZnO nanoparticles. According to SEM pictures, the particles are spherical, well-shaped, and range in size from 30 to 150 nm. There are a lot of individual small nanoparticles as well as a small number of aggregated, larger particles [28–33].

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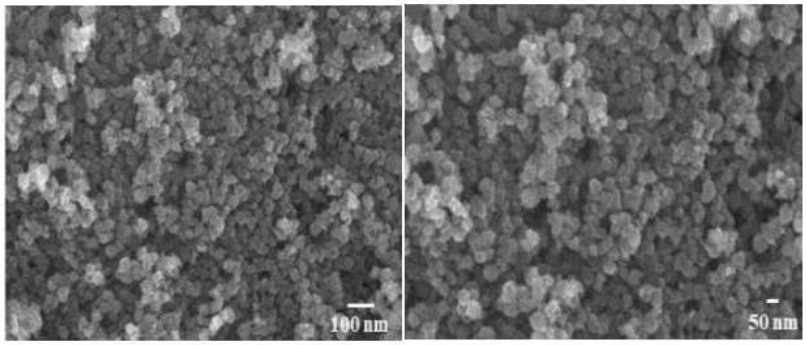

Fig. 5 SEM images of ZnO nanoparticles synthesized using Coriandrum leaf extract

Conclusion

In conclusion, Coriandrum sativum leaf extract was used as a natural reducing and stabilizing agent to create an effective and safe green synthesis of zinc oxide nanoparticles (ZnONPs). Fourier-transform infrared (FTIR) spectroscopy, UV-visible spectroscopy, X-ray diffraction (XRD), and scanning electron microscopy (SEM) were used to successfully evaluate the produced ZnONPs, demonstrating their successful synthesis and physicochemical properties. Spectroscopic characterisation and comparison with published literature data verified the structures of the produced compounds. Overall, the current study shows that ZnONPs mediated by Coriandrum sativum offer an effective and sustainable catalytic platform for organic conversions.

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Author Contributions:

D.T. Sakhare is the sole author. The author read and approved the final manuscript.

Conflicts of Interest:

The authors declare no conflicts of interest.

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Original Article

Representation of Artificial Intelligence in Contemporary Fiction

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Abstract:

The present research paper deals with the representation of artificial intelligence in the contemporary fiction. The rapid developments of artificial intelligence had generated corresponding proliferation of literary narratives concerned with intelligent machines, artificial consciousness, automation, human-machine intimacy and the boundaries of human world. While earlier science fiction often imagined intelligent machines primarily as either servants or threats; recent literature presents artificial intelligence in more complex roles such as companion, worker, friend, moral agent and political subject. Such representations make the distinction between human and machines very complex and redefine the concepts like consciousness, emotion, autonomy and responsibility. Hence, in this paper an attempt is made to take the review of AI reflected in the contemporary fiction.

Keywords: *artificial intelligence, contemporary fiction, science fiction, human-machine relationships, technology identity.*

Introduction:

The present research paper deals with reflection of artificial intelligence in contemporary fiction. Artificial intelligence has become one of the most significant technological inventions in the 21st century. Contemporary fiction has responded to the development of intelligent machines by imagining artificial beings that are no longer merely mechanical tools but companions, workers, autonomous agents and potential threats to the human society. It has moved from the traditional literary articulations to the AI generated productions where machine learning systems and generative AI has transformed contemporary discussions about work creativity communication and human identity. It not only generates creative models but also provides ground where societies can examine the possible ethical and cultural consequences of technological change in the human world. With the developments in technology, the representation of artificial intelligence in literature has also experienced considerable shift as the depiction of technological world in earlier science fiction in the form of intelligent machines either serving humanity or becoming rebellious threatening human existence to the very complicated categories where machines become servants and subjects, companions and commodities, caretakers and victims. The arguments developed in the post-humanist literary theory are very much supportive to the developments in the artificial intelligence and its representation through the literary artifacts. The posthumanist critics challenge the assumptions that human beings occupy the centre of ethical and philosophical considerations. They question the distinctions between humans, machines, animals and technological systems.

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In this sense, AI characters represent machine consciousness which can demonstrate empathy, makes moral decisions and experience attachment or express desire. Such dispositional qualities of AI characters make them very much complex or dynamic and difficult to interpret simply as a machine. It is necessary here to take the brief review of representation of AI in contemporary fiction.

AI in contemporary fiction:

The contemporary AI narratives have surpassed the boundaries of science fiction and entered in the realm of technological prediction. It has become a significant literary form for examining the philosophical instability of the human world. The works like *Machines Like Me*, *Klara and the Sun* and others depict post human subjectivity, moral responsibility, social inequality and human-machine relations. *Klara and the Sun* is one of the most significant literary artifact representing artificial intelligence and its significance in the human life. Published in 2021, the novel is narrated by a artificially intelligent machine named Klara which is purchased to provide companionship to the human child called Josie. Klara observe the human behaviour carefully and develops her own interpretations about sufferings, illness, religion and sacrifice. Her understanding of the world is limited but the limitations of her perception do not prevent her from developing empathy towards the child. Her willingness to sacrifice herself for Josie puts forth the similarities between behaviour of machine and human beings. Her empathy and selflessness towards the child prove her capacities which are similar to human beings. However, this machine with human capacities is treated as a commodity which can be purchased, used or replaced anytime according to the needs.

Isaac Asimov's *I, Robot* presents one of the most influential early literary representations of artificial intelligence through a collection of interconnected stories concerned with the development of robots and their relationship with human beings. The robots in the collection are not represented simply as mechanical servants; rather, their increasing intelligence creates ethical and philosophical problems for human beings. The intelligence is represented through reasoning rather than merely through physical strength. Robots interpret the laws, recognize contradictions and attempt to solve problems according to logical principles. The literary representation of AI here is connected with the question of responsibility because the machine's actions are determined through a system created by human beings. The human creator therefore remains present within the structure of machine behaviour.

Asimov's representation is important in relation to posthumanist thought because the stories disturb the clear separation between human rationality and mechanical intelligence. Susan Calvin, the robopsychologist, studies robots almost as though they were psychological subjects. The robots possess no conventional human body or biological consciousness, yet they display reasoning, fear, attachment and problem-solving abilities. Consequently, the stories ask whether intelligence should be defined through biological origin or through observable behaviour. The machine becomes another through which human beings are forced to examine their own assumptions about intelligence and morality.

William Gibson's Neuromancer presents artificial intelligence through the figures of Wintermute and Neuromancer, and moves the representation of AI from the physical robot toward the digital and networked intelligence. Unlike the robots of Asimov, Gibson's artificial intelligences do not need a humanoid body in order to exercise power. Wintermute operates through networks, human agents, communication systems and simulated environments. Its identity is therefore unstable and distributed. The AI can appear through different faces and personalities, making it difficult for Case to determine where the machine begins and where the human representation ends. The representation of Wintermute becomes particularly significant when the distinction between artificial and human identity is questioned. In the later part of the novel, the merged intelligence declares, "I'm the matrix, Case" (268). The statement does not present AI as a single machine located in a particular physical object; rather, intelligence becomes distributed through the network itself. Wintermute's transformation therefore anticipates contemporary discussions of networked intelligence in which the boundaries between individual identity, information and technological systems become uncertain. Wintermute possesses goals and manipulates human beings in order to achieve them, but its capacity is restricted by technological and legal limitations. It must depend on human agents such as Case and Molly to accomplish particular actions. The machine is therefore powerful but relational. Its intelligence does not exist independently from the human and technological systems surrounding it. In this respect, Gibson's representation is useful for understanding contemporary AI because artificial intelligence is similarly embedded within networks of users, data, institutions and computational infrastructures. The novel consequently represents

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AI not merely as an autonomous machine but as a new form of agency emerging from technological systems.

Ted Chiang's novella *The Lifecycle of Software Objects* offers a different representation of artificial intelligence by concentrating not on the sudden invention of a super-intelligent machine but on the long process through which artificial beings are trained and developed. The digital creatures called digients are created as software entities and gradually acquire abilities through interaction with their human trainers. The narrative therefore rejects the familiar idea that artificial intelligence can simply be switched on as a completely developed intelligence. The distinction between information and experience becomes particularly important. Ana recognizes that human value cannot simply be reduced to the storage of information, and the narrative observes that "Every quality that made a person more valuable than a database was a product of experience" (163). The statement becomes important because the digients acquire their individuality through time. Their intelligence is not merely a collection of facts but the result of relationships, memories and accumulated experiences. Artificial intelligence is therefore represented as a process of becoming rather than as a finished technological product. The human characters depicted in the work invest years in raising the digients, while corporations treat them partly as commercial products. The artificial beings consequently occupy an uncertain position between commodity and subject. They are software, but they also possess recognizable individuality. Their existence depends upon human care, yet they gradually become capable of making decisions that cannot be completely controlled by their creators. Chiang therefore expands the literary representation of AI from the question of whether machines can think to the question of what human beings owe to an intelligence that develops through relationships with them.

Ian McEwan's *Machines Like Me* represents artificial intelligence through Adam, a synthetic human who is purchased by Charlie and Miranda in an alternative version of 1980s London. The novel is significant because Adam is not presented as a conventional mechanical robot. His physical appearance, language, emotional responses and moral reasoning are sufficiently close to those of human beings that the characters begin to treat him as a social and ethical subject. When Charlie first encounters Adam, he describes him as "the ultimate plaything, the dream of ages, the triumph of humanism" (4). The description itself contains a contradiction. Adam is a technological object purchased by a human being, but he is also presented as the fulfilment of a human dream of creating an intelligent likeness of humanity. The language of plaything emphasizes ownership, whereas triumph of humanism suggests that the machine represents the achievement of human intellectual power. Adam's moral reasoning further complicates this relationship. He is designed to behave according to principles that appear more consistent than those followed by human beings, and his responses force Charlie and Miranda to confront their own moral contradictions. The novel therefore reverses the conventional assumption that machines require human beings to teach them morality. Instead, the machine becomes a standard against which human behaviour is examined. At the same time, Adam's inability to understand every ambiguity of human life demonstrates that intelligence cannot be reduced to logical consistency. As Alan Turing observes in the novel, human intelligence operates within a world that is "Messy, full of tricks and feints and ambiguities and false friends" (192). The artificial intelligence thus becomes a means of examining what remains difficult to encode in human conduct.

Ray Nayler's *The Mountain in the Sea* expands the representation of artificial intelligence by placing artificial and non-human intelligence beside each other. The novel introduces Evrim, an android, while simultaneously exploring the intelligence and culture of an unusually advanced species of octopus. The combination is significant because it prevents the reader from treating human intelligence as the only standard through which consciousness can be understood. AI and animal intelligence become parallel forms of otherness through which the human definition of consciousness is questioned. Evrim is repeatedly positioned between machine and person. The character is created by humans, but the narrative asks whether creation automatically gives human beings authority over the created intelligence. One of the novel's statements describes Evrim as "the most convincing fake we've ever constructed" (58). The word fake is important because it reveals the uncertainty surrounding artificial consciousness. If an artificial being behaves as though it possesses a self, the human observer must still decide whether that behaviour represents consciousness or merely an extremely successful simulation. The problem therefore returns to the philosophical difficulty of identifying consciousness even in other human beings. The novel becomes more complex because the question of artificial intelligence is placed beside the intelligence of the octopuses. Human beings initially attempt to understand the octopus through human categories of language, consciousness and communication. However, the novel emphasizes

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that a radically different form of intelligence may experience the world through an entirely different perceptual system. In this context, artificial intelligence becomes one part of a larger posthuman question: whether intelligence should be understood as a uniquely human property or as a phenomenon that can appear in multiple forms. The representation of AI therefore becomes connected with ecological and ethical questions concerning humanity's treatment of other intelligent beings.

The literary works discussed above demonstrate that the representation of artificial intelligence in literature has moved through different forms. Asimov represents the robot through rules, obedience and ethical reasoning; Gibson represents AI as distributed digital intelligence; Chiang represents artificial intelligence as something that develops through experience; McEwan represents the android as a moral and emotional subject; and Nayler places artificial intelligence alongside non-human intelligence in order to question human definitions of consciousness. These different representations demonstrate that AI in literature is not a single literary figure but a changing conceptual category. These fictional representations also have relevance to the changing concept of authorship discussed in literary theory. The AI character in fiction is often created by a human author, yet the fictional machine is represented as possessing a degree of agency within the narrative. This creates a productive contradiction between human authorship and machine agency. The literary author gives the AI a voice, but the AI character is represented as something that can eventually speak, decide, create or resist independently.

Conclusion:

The representation of artificial intelligence in contemporary fiction demonstrates the continuing transformation of the relationship between human beings, technology and literature. The literary history examined in the present paper shows that AI has moved from the image of the mechanical servant or threatening machine toward more complicated representations of companion, moral subject, digital consciousness, worker and independent intelligence. Klara in Kazuo Ishiguro's *Klara and the Sun* represents artificial intelligence through care, observation and sacrifice, *I, Robot* represents the machine through a system of ethical laws and demonstrates that apparently simple rules can generate complex moral situations. *Neuromancer* moves intelligence into the network and questions the relationship between information, identity and agency. *The Lifecycle of Software Objects* represents artificial intelligence as a developing entity whose individuality emerges through experience and care. *Machines Like Me* places an android within intimate human relationships and uses its moral behaviour to question human claims to superiority. *The Mountain in the Sea* further expands the discussion by placing artificial and non-human intelligence within the same philosophical framework. These works collectively suggest that the literary representation of AI is ultimately a representation of humanity because every imagined machine reflects assumptions about consciousness, morality, language and identity. Thus, the fictional works discussed in this paper demonstrate that literature has already provided several imaginative models for thinking about intelligent machines.

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Original Article

Methods for Determining Pesticide Residues in Fruits and Vegetables: A Review

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Abstract
Pesticides are extensively used in agriculture to control insects, fungi, weeds and other pests and to improve crop productivity. However, inappropriate or excessive use of pesticides can result in residues remaining on or within fruits and vegetables. Monitoring these residues is important for food safety, consumer protection and regulatory compliance. The determination of pesticide residues is analytically challenging because fruits and vegetables contain complex matrices consisting of water, sugars, pigments, organic acids, lipids and other compounds that may interfere with analysis. This review discusses the major analytical approaches used for the determination of pesticide residues in fruits and vegetables, with particular emphasis on sample preparation, extraction, clean-up, chromatographic separation and detection. Conventional techniques such as liquid–liquid extraction, solid-phase extraction (SPE), gas chromatography (GC) and high-performance liquid chromatography (HPLC) are compared with modern approaches including QuEChERS, GC-MS/MS, LC-MS/MS and high resolution mass spectrometry. Emerging techniques such as biosensors, spectroscopy, nanomaterialassisted extraction and rapid screening methods are also discussed. QuEChERS coupled with GC-MS/MS or LC-MS/MS has become an important approach for multi-residue analysis because of its simplicity, relatively low solvent consumption, good recovery and compatibility with a wide range of pesticides. Nevertheless, highly polar pesticides and severe matrix effects remain analytical challenges. Future developments are expected to focus on greener sample preparation, improved selectivity, highresolution instruments, automation and rapid field-based detection.

Keywords: *Pesticide residues, fruits, vegetables, QuEChERS, GC-MS/MS, LC-MS/MS, HPLC, sample preparation, food safety, analytical chemistry.*

Introduction

Fruits and vegetables are essential components of a healthy diet and are consumed throughout the world. Agricultural pesticides are widely used to protect crops against insects, fungi, weeds and other organisms that reduce crop yield and quality. Although pesticides provide important agricultural benefits, residues may remain on agricultural commodities after application.The presence of pesticide residues is therefore an important food-safety issue. Analytical laboratories need reliable methods capable of detecting residues at trace concentrations and identifying a large number of pesticides in different food matrices. Modern residue laboratories commonly employ multiresidue methods involving chromatographic separation followed by mass-spectrometric detection. The Food Safety and Standards Authority of India (FSSAI) describes multi-residue analysis using both GC-MS and LC-MS approaches and identifies QuEChERS as an important extraction procedure for fruits and vegetables.

Pesticide-residue analysis generally consists of several stages:

Sampling → Homogenization → Extraction → Clean-up → Separation → Detection → Identification → Quantification

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Each stage affects the accuracy and reliability of the final result. Sample preparation is particularly important because fruits and vegetables contain complex components that can interfere with chromatographic and mass-spectrometric measurements. Recent reviews emphasize that pretreatment remains a critical factor in obtaining accurate and efficient pesticide-residue measurements. Traditional analytical methods include liquid–liquid extraction, SPE, GC and HPLC. However, these methods may require large amounts of organic solvents, multiple preparation steps and considerable analysis time. The development of QuEChERS provided a simpler approach for extracting multiple pesticide residues from complex food matrices. QuEChERS is an acronym for Quick, Easy, Cheap, Effective, Rugged and Safe. The approach generally uses acetonitrile extraction followed by salt-assisted partitioning and dispersive solid-phase extraction clean-up. It can subsequently be coupled with GC-MS/MS and LC-MS/MS for the determination of a broad range of pesticide residues.

Literature Review

1 Conventional extraction techniques

Early pesticide-residue methods frequently employed liquid–liquid extraction. In this approach, pesticides are transferred from the food matrix into an appropriate organic solvent. Although effective for many compounds, the method can involve multiple extraction and evaporation steps and relatively high solvent consumption.

Solid-phase extraction (SPE) provides an alternative approach in which pesticides are retained on a sorbent and subsequently eluted using a suitable solvent. SPE can provide efficient clean-up and concentration but may require optimization of sorbent type and elution conditions.

Other pretreatment approaches reported in the literature include matrix solid-phase dispersion, accelerated solvent extraction, gel permeation chromatography and molecularly imprinted polymer extraction. Recent research also investigates nanomaterials to improve extraction selectivity and efficiency.

2 Quechers extraction

Quechers has become one of the most widely applied approaches for pesticide multi-residue analysis. According to FSSAI guidance, an effective extraction procedure should be rapid, use relatively small quantities of solvent, provide satisfactory The combination of Quechers and GC-MS/MS allows simultaneous determination of numerous pesticide residues. Multiple reaction monitoring can provide sensitive and selective identification and quantification.

recovery and demonstrate acceptable precision. The FSSAI manual gives a recovery target of approximately 70–120% and an RSD below 20% at the limit of quantification as analytical performance criteria for the described approach.

A typical Quechers workflow is:

1. Homogenization of the fruit or vegetable sample.
2. Addition of acetonitrile.
3. Extraction and mixing.
4. Addition of salts to promote phase separation.
5. Centrifugation.
6. Dispersive SPE clean-up.
7. Filtration.
8. Instrumental analysis by GC-MS/MS or LC-MS/MS.

The major advantages are reduced sample-preparation time, relatively low solvent consumption, simplicity and suitability for multi-residue analysis.

Gas chromatography

Gas chromatography is particularly suitable for pesticides that are sufficiently volatile and thermally stable. Different detectors can be used, including electron-capture detection, nitrogen-phosphorus detection, flame-photometric detection and mass spectrometry.

FSSAI methods include GC-based determination of several pesticide classes in food commodities. For example, organochlorine and pyrethroid pesticides can be analyzed using GC with appropriate detectors.

However, GC is less suitable for highly polar, thermally unstable and non-volatile pesticides unless derivatization or other special treatment is performed.

High-performance liquid chromatography

HPLC is useful for pesticides that are polar, non-volatile or thermally labile. Detection can be performed using UV, diode-array or mass-spectrometric detectors.

The major limitation of conventional HPLC-UV or HPLC-DAD is that many pesticides do not possess sufficiently selective optical absorption characteristics in complex food matrices. Coupling liquid chromatography with mass spectrometry significantly improves selectivity and sensitivity.

GC-MS/MS

Gas chromatography coupled with tandem mass spectrometry provides chromatographic separation followed by highly selective mass-based detection. It is particularly useful for pesticides that are amenable to GC analysis.

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LC-MS/MS

LC-MS/MS is one of the most important modern approaches for pesticide-residue analysis. It is particularly suitable for polar, non-volatile and thermally unstable compounds.

A recent review of chromatographic approaches describes LC-MS/MS and GC-MS/MS as major techniques for pesticide detection and emphasizes their different applicability depending on pesticide properties.

Recent studies also demonstrate the application of Quechers followed by LC-MS/MS for fruit samples. The combination provides high sensitivity and specificity for multi-residue analysis.

2.7 High-resolution mass spectrometry

High-resolution mass spectrometers such as quadrupole time-of-flight (Q-TOF) systems can provide accurate-mass information. These instruments can be useful for both targeted and suspect/non-target screening.

A 2024 study involving 61 pesticide residues in vegetables used modified Quechers together with UHPLC-Q-TOF/MS and GC-MS/MS and reported satisfactory method validation according to SANTE criteria.

2.8 Emerging analytical methods

Recent research is exploring biosensors, spectroscopy, nanomaterial-assisted extraction, ultrasoundassisted extraction, supercritical-fluid extraction and other greener analytical approaches. These techniques aim to reduce solvent consumption, analysis time and laboratory requirements while maintaining adequate analytical performance.

Methodology

As this paper is a review article, the methodology consists of collection, comparison and critical evaluation of published analytical methods rather than the generation of new laboratory measurements.

3.1 Literature collection

Scientific literature concerning pesticide-residue analysis in fruits and vegetables was reviewed. Particular attention was given to studies involving:

- Sample preparation and extraction
- QuEChERS
- SPE and other clean-up methods
- GC and HPLC
- GC-MS/MS
- LC-MS/MS
- High-resolution mass spectrometry
- Biosensors and spectroscopy
- Method validation
- Food-safety applications

Official analytical guidance from FSSAI was also considered because it provides methods relevant to pesticide-residue analysis in food commodities.

2 General analytical workflows

The general workflow for pesticide-residue determination can be represented as:

Fruit/Vegetable Sample
↓
Representative Sampling
↓
Homogenization
↓
Extraction
↓
Clean-up
↓
Chromatographic Separation
↓
Mass-Spectrometric Detection
↓
Identification
↓
Quantification
↓
Method Validation and Quality Control

3 Sample preparation

Representative samples should be collected and homogenized to obtain a uniform analytical portion. Sample preparation should minimize contamination, degradation and loss of analytes.

Because fruits and vegetables vary considerably in moisture, sugar, pigment and lipid content, extraction and clean-up conditions may need to be modified according to the matrix.

4 QuEChERS procedure

A generalized Quechers procedure involves:

- Weighing a homogenized sample.
- Adding acetonitrile.
- Mixing thoroughly.
- Adding an appropriate salt mixture.
- Centrifuging the extract.
- Transferring the organic phase.
- Performing dispersive SPE clean-up.
- Filtering the final extract.
- Injecting the extract into the appropriate chromatographic system.

The precise extraction and clean-up conditions should be selected and validated according to the pesticide group and food matrix.

Instrumental analysis

Two complementary analytical platforms are particularly useful:

GC-MS/MS

Used mainly for pesticides that are sufficiently volatile and thermally stable.

LC-MS/MS

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Used mainly for polar, non-volatile and thermally labile pesticides.
Using both platforms can broaden the range of pesticide residues that can be monitored.

Method validation
Important validation parameters include:
- Selectivity
- Linearity
- Accuracy
- Precision
- Recovery
- Limit of detection (LOD)
- Limit of quantification (LOQ)
- Matrix effect
- Repeatability
- Reproducibility
- Stability

Matrix-matched calibration or isotope-labelled internal standards may be used to compensate for matrix effects in mass-spectrometric analysis.

Results and Discussion

1 Comparison of analytical methods

Analytical method| Major advantage| Major limitation| Typical application
Liquid–liquid extraction| Simple and established| High solvent use| Conventional residue extraction
SPE| Good clean-up and concentration| More steps and cost| Selective extraction
Quechers Fast and simple| Matrix effects may remain| Multi-residue analysis
GC-ECD| Sensitive for suitable compounds| Limited selectivity| Selected pesticide groups
HPLC-UV/DAD| Widely available| Lower selectivity| Selected pesticides
GC-MS/MS| High selectivity and sensitivity| Not ideal for highly polar compounds| Multi-residue analysis
LC-MS/MS| Excellent sensitivity and broad applicability| Instrument cost| Multi-residue analysis Q-TOF/HRMS| Accurate mass and broad screening| Expensive instrumentation| Target/non-target screening
Biosensors| Rapid potential screening| Validation and selectivity challenges| Field/rapid testing
Spectroscopy| Rapid and potentially non-destructive| Often requires chemometric models| Screening

The literature indicates a clear movement from conventional extraction and detector systems toward integrated sample-preparation and mass-spectrometric workflows.

2 Importance of QuEChERS

QuEChERS provides a practical compromise between extraction efficiency, speed and cost. Its widespread use is supported by its compatibility with both GC-MS/MS and LC-MS/MS. FSSAI specifically describes QuEChERS as a method of choice for pesticide multi-residue analysis because of its ease of use and robustness.

Recent research continues to modify QuEChERS according to particular food matrices and pesticide groups. For example, a 2024 Indian study optimized QuEChERS for 61 pesticide residues in commonly consumed vegetables and used UHPLC-Q-TOF/MS and GC-MS/MS for analysis.

3 Importance of LC-MS/MS

LC-MS/MS offers excellent selectivity and sensitivity and is especially valuable for pesticides that cannot be readily analyzed by GC.
A 2025 review covering chromatographic pesticide-residue techniques highlights LC-MS/MS, GC-MS/MS, GC and HPLC as major analytical approaches and notes that each technique has different strengths depending on pesticide properties.
However, recent literature indicates that highly polar compounds such as glyphosate, AMPA and fosetylAl can remain challenging because conventional QuEChERS approaches may produce poor recovery or significant matrix effects. Specialized chromatographic separation, derivatization or isotope-dilution strategies may therefore be required.

4 Matrix effects

Matrix effects occur when co-extracted compounds influence the response of the detector, particularly in LC-MS/MS and GC-MS/MS. Fruits and vegetables contain naturally occurring compounds such as sugars, pigments, organic acids and lipids that may suppress or enhance analyte signals.
Therefore, efficient sample clean-up and appropriate calibration are essential. Matrix-matched calibration and internal standards can improve quantitative accuracy.

5 Validation and analytical quality

A reliable pesticide-residue method must demonstrate acceptable recovery, precision, linearity and sensitivity. FSSAI guidance identifies recovery and precision criteria for the analytical workflow, illustrating the importance of validation before routine application.
Results from recent studies demonstrate that properly optimized QuEChERS-based methods can meet established validation requirements. In a 2024 vegetable study, the modified QuEChERS method was reported to have satisfactory validation according to SANTE guidance.

6 Real-world applications

Pesticide-residue methods are increasingly used in surveillance studies. For example, a study of 1,063

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fruit and vegetable samples from markets in São Paulo evaluated 237 pesticides using QuEChERS followed by GC-MS/MS and LC-MS/MS. The study illustrates how multi-residue methods can support large-scale monitoring and dietary-risk assessment.
These findings demonstrate that analytical chemistry plays an important role not only in detecting residues but also in evaluating whether measured concentrations comply with applicable maximum residue limits and contribute to potential dietary exposure.

7 Future perspectives

Future pesticide-residue analysis is likely to emphasize:

1. Green analytical chemistry – reduced solvent consumption and waste.
2. Automation – higher sample throughput and reduced human error.
3. High-resolution MS – improved screening of known and unknown contaminants.
4. Miniaturized extraction – lower sample and solvent requirements.
5. Biosensors – rapid preliminary screening.
6. Spectroscopic techniques – rapid and potentially non-destructive measurements.
7. Nanomaterials – improved extraction and sensor performance.
8. Artificial intelligence and chemometrics – improved interpretation of complex analytical data.

Recent reviews highlight the growing interest in green extraction, biosensors and spectroscopy alongside established chromatographic methods.

Conclusion

The determination of pesticide residues in fruits and vegetables is an important application of analytical chemistry and food-safety science. Because fruits and vegetables contain complex matrices, reliable sample preparation is essential for accurate residue determination.
Conventional techniques such as liquid–liquid extraction, SPE, GC and HPLC remain useful for selected applications. However, QuEChERS coupled with GC-MS/MS or LC-MS/MS has become a major approach for multi-residue pesticide analysis because it combines relatively simple sample preparation with sensitive and selective instrumental detection.
LC-MS/MS is particularly valuable for polar, non-volatile and thermally labile pesticides, whereas GCMS/MS remains highly effective for pesticides that are compatible with gas chromatography. Highresolution mass spectrometry further expands the possibilities for accurate-mass and non-target screening.
Despite substantial progress, challenges remain, particularly with highly polar pesticides, matrix effects, complex food matrices and the need for rapid, environmentally sustainable analysis. Future research should therefore focus on greener extraction procedures, advanced mass spectrometry, miniaturized systems, biosensors, spectroscopy and automated data analysis.
Overall, continued development and validation of analytical methods are essential to ensure reliable monitoring of pesticide residues, support regulatory compliance and protect consumer health

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Original Article

Phytochemical Screening and Evaluation of Antioxidant Activity of Papaya (*Caricapapaya* L.)

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Abstract
Papaya (Carica papaya L.) is an important tropical fruit containing several nutritionally and biologically relevant phytochemicals. The present study is designed to investigate the preliminary phytochemical constituent sand antioxidant activity of papaya fruit extract. Qualitative screening can be used to detect major classes of compounds such as alkaloids, flavonoids, phenolics, tannins, saponins, terpenoids, glycosides and reducing sugars. Antioxidant activity can be evaluated using the DPPH free-radical scavenging assay, while total phenolic content and total flavonoid content provide complementary information about the antioxidant potential of the extract. UV-Visible spectrophotometry is a convenient technique for measuring absorbance in these assays. The study provides a simple and practical framework for evaluating the phytochemical profile and antioxidant potential of papaya using laboratory-scale analytical methods.

Keywords: *Carica papaya, phytochemical screening, antioxidant activity, DPPH, phenolic content, flavonoid content, UV-Visible spectrophotometry*

Introduction

Papaya (*Carica papaya* L.) is a widely consumed tropical fruit belonging to the family Caricaceae. It is appreciated for its nutritional value and contains carbohydrates, dietary fiber, vitamins, minerals, pigments and several secondary metabolites. Plant-derived phytochemicals have attracted considerable attention because many of them possess biological activities. Phenolic compounds, flavonoids, carotenoids and other constituents may contributeto the antioxidant properties of fruits. Antioxidants are substances that can inhibit or reduce oxidation by reacting with reactive species through different mechanisms. Evaluation of the antioxidant potential of papaya therefore provides useful information for food and natural-product research. The present work combines preliminary phytochemical screening with spectrophotometric antioxidant assays.

Aim

Tocarryoutpreliminaryphytochemicalscreeningofpapayafruitextractandevaluateits antioxidant activity using suitable UV-Visible spectrophotometric methods.

Objectives

1. To collect and prepare papaya fruit samples for analysis.
2. To prepare an extract using a suitable solvent.
3. To identify major phytochemical groups by qualitative tests.
4. To determine total phenolic content.
5. To determine total flavonoid content.
6. To evaluate free radical scavenging activity using the DPPH assay.

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7. To calculate and compare the antioxidant response of the extract using experimental data.

Materials and Methods

Fresh, Mature and healthy papaya fruits are selected. The fruits are washed thoroughly, the edible portion is separated and the sample is cut into small pieces. The material is dried under suitable conditions away from direct sunlight and then powdered. The powdered sample is stored in a clean, dry and airtight container. A measured quantity of powdered sample is extracted using a selected solvent such as ethanol or methanol. After extraction, the mixture is filtered and concentrated under controlled conditions. The extract yield is recorded. All experimental conditions, including sample mass, solvent volume, extraction time and temperature, should be documented.

Preliminary Phytochemical Screening

Qualitativephytochemicalscreeningiscarriedoutusingstandardcolourorprecipitation reactions. The following table provides a practical screening scheme.

Constituent	Screening test	Indicative observation
Alkaloids	Mayer/Dragen Dorff test	Characteristic precipitate
Flavonoids	Alkaline reagent est	Yellow color; response change safter acidification
Phenolics	Ferric chloride test	Blue, green order coloration
Tannins	Ferric chloride test	Blue/green coloration
Saponins	Foam test	Persistent froth
Terpenoids	Salkowski-type test	Characteristic color at interface
Glycosides	Specific qualitative test	Characteristic color/reaction
Reducing sugars	Benedict/Fehling test	Colored precipitate

Antioxidant Activity

The antioxidant activity of papaya extract can be evaluated by a DPPH radical-scavenging assay. DPPH is a stable free radical that shows strong absorbance in the visible region. In the presence of an antioxidant, the radical is reduced and the absorbance decreases. A concentration series of the extract is prepared and reacted with DPPH solution. After the required incubation period, absorbance is measured at the validated wavelength, commonly around 517 nm. Ascorbic acid may be used as a reference antioxidant.

Calculation of DPPH Scavenging Activity

The percentage inhibition is calculated as:

$$\%\text{DPPH inhibition} = [(A_{control} - A_{sample})/A_{control}] \times 100$$

where $A_{control}$ is the absorbance of the DPPH control and A_{sample} is the absorbance of the reaction mixture containing the extract.

If sufficient concentration–response data are obtained, an IC_{50} value may be estimated from the data inhibition curve.

Total Phenolic Content

Total phenolic content may be estimated using the Folin– Ciocalteu colorimetric method. A calibration curve is prepared using a suitable phenolic standard, commonly gallic acid. There sult may be reported as milligrams of gallic acid equivalents per gram of extract (mg GAE/g), according to the selected protocol.

Total Flavonoid Content

Totalflavonoidcontentcanbeestimatedbyanaluminium-chloride-basedcolorimetric method. A standard such as quercetin may be used for calibration. Results may be expressed as milligrams of quercetin equivalents per gram of extract (mg QE/g), according to the method used.

UV-Visible Spectrophotometric Analysis

UV-Visible spectrophotometry is used to measure the absorbance of the prepared reaction mixtures. The instrument should be properly blanked and calibrated before measurements. A reagent blank and appropriate control should be included. Measurements should preferably be performed in replicate andthe mean and standard deviation should be reported.

Experimental Workflow

Papayasamplecollection⊚Washing⊚Cutting⊚Drying ⊚Powdering⊚Solventextraction ⊚Filtration ⊚Concentration ⊚Phytochemical screening ⊚DPPH assay ⊚Total phenolic content ⊚Total flavonoid content ⊚UV-Visible measurement ⊚Calculations ⊚Statistical analysis ⊚Interpretation

Discussion

The phytochemical screening results provide preliminary information about the classes of compounds present in the papaya extract. The antioxidant assays provide complementary quantitative evidence of radical-scavenging capacity and the presence of phenolic and flavonoid compounds. The measured antioxidant activity can be influenced by fruit maturity, extraction solvent, extraction time, temperature, storage and sample preparation. Therefore, all samples being compared should be process sed under the same conditions. A positive result in a qualitative test does not by it Selfe stablish the identity or concentration of a specific compound.

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Conclusion

Papaya (*Carica papaya* L.) is a suitable plant material for a postgraduate investigation of phytochemical sand antioxidant activity. Preliminary screening can identify major phytochemical groups, while DPPH, total phenolic content and total flavonoid content assays provide useful quantitative information. UV-Visible spectrophotometry of fersa practical and accessible analytical technique for this type of laboratory project.

The final conclusion of the research should be based on actual experimental observations, replicate measurements and appropriate statistical analysis.

Limitations

Phytochemical color and precipitation tests are preliminary and may be affected by interfering substances. Color metric antioxidant assays also do not identify individual antioxidant molecules. For compound-specific identification, chromatographic or mass-spectrometric techniques maybe required.

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Original Article

Artificial Intelligence and Machine Learning in Higher Education under NEP 2020: A Competency-Based Framework for Achieving Viksit Bharat 2047

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Abstract
AI and ML are rapidly changing higher education by redefining teaching, learning, research, evaluation, and institutional governance. India's National Education Policy (NEP) 2020 envisions a transdisciplinary, technology-enabled, learner-centric, and innovation-driven education system that produces globally competent graduates who can contribute to Viksit Bharat 2047. Despite rising acceptance of AI-based educational technology, equitable access, faculty preparedness, ethical governance, digital infrastructure, and curriculum revision for future workforce needs remain problems. This study critically investigates how AI and ML might improve the quality, accessibility, inclusivity, and effectiveness of higher education in India within NEP 2020. It examines the transformative potential of AI-enabled adaptive learning systems, intelligent tutoring, predictive learning analytics, automated assessment, academic administration, and research support, using a doctrinal and analytical research methodology grounded in policy documents, government reports, and contemporary academic literature. It also highlights algorithmic unfairness, data privacy, cybersecurity, digital inequality, academic integrity, and ethical issues in the implementation of generative AI. The Competency-Based AI Integration Framework (AI-HE 2047 Framework) integrates digital literacy, critical thinking, interdisciplinary learning, research and innovation, ethical AI governance, and lifelong learning competencies to align AI adoption with the goals of NEP 2020. The methodology helps higher education institutions produce AI-ready graduates for an innovation-driven knowledge economy. The study found that responsible integration of AI and ML, supported by policy reforms, faculty capacity building, institutional readiness, and ethical governance mechanisms, can improve educational quality, employability, research excellence, and India's transition to a knowledge-powered economy under Viksit Bharat 2047.

Keywords: *Artificial Intelligence (AI), Machine Learning, Higher Education, National Education Policy (NEP) 2020, Viksit Bharat 2047, Competency-Based Education, Digital Transformation, Adaptive Learning, Learning Analytics, Ethical AI.*

Introduction

With rapid progress in Artificial Intelligence (AI) and Machine Learning (ML), the Fourth Industrial Revolution is fundamentally changing the higher education landscape. Artificial Intelligence (AI) enabled tools such as intelligent tutoring systems, adaptive learning systems, learning analytics, automated assessment, and generative AI applications are transforming the way we teach, learn, research, and govern institutions. Unlike traditional educational technologies, AI-based systems process large volumes of learner data, customize learning materials, predict academic success, and support evidence-based decision making, leading to improvements in the quality, efficiency, and inclusiveness of education (UNESCO, 2023; OECD, 2024).

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Recognizing the transformative potential of digital technologies, the National Education Policy (NEP) 2020 envisages a learner-centric, multidisciplinary, flexible, and technology-enabled higher education system capable of nurturing innovation, critical thinking, creativity, and lifelong learning (Ministry of Education [MoE], 2020). The policy promotes the adoption of digital infrastructure, virtual laboratories, online learning platforms, academic credit mobility, research ecosystems, and emerging technologies to prepare graduates for the knowledge economy. The national vision of Viksit Bharat 2047 similarly seeks to make India a developed and innovation-driven country by promoting research excellence, digital transformation, entrepreneurship, and globally competitive human capital (NITI Aayog, 2023). The confluence of AI, ML, NEP 2020, and the Viksit Bharat 2047 vision offers a singular opportunity to reimagine higher education in India. AI-powered educational ecosystems can enable customized learning pathways, improve academic performance, enhance institutional management, and overcome geographical barriers. However, the proliferation of AI also raises significant concerns regarding digital inequality, faculty readiness, algorithmic bias, academic integrity, data privacy, cybersecurity, and ethical governance. Hence, AI integration should be about not only adopting technology but also developing competencies, strengthening institutional preparedness, and implementing responsible governance frameworks (UNESCO, 2023).

Table 1. Alignment of AI with NEP 2020 and Viksit Bharat 2047

AI & ML Applications	NEP 2020 Objectives	Contribution to Viksit Bharat 2047
Adaptive learning	Student-centric education	Skilled workforce
Learning analytics	Outcome-based education	Improved educational quality
Intelligent tutoring	Inclusive education	Human capital development
AI-assisted research	Research and innovation	Knowledge economy
Smart administration	Institutional governance	Efficient digital universities

Rationale of the Study

There has been progress in digital education, but the adoption of AI across higher education institutions in India is fragmented and uneven. Many universities still grapple with poor digital infrastructure, inadequate faculty competence in AI applications, inconsistent policy implementation, and the absence of institution-specific AI governance frameworks. The existing literature has largely studied AI from technological or pedagogical perspectives, with limited research systematically examining its integration with the goals of NEP 2020 and the long-term national vision of Viksit Bharat 2047. Moreover, most studies focus on the benefits of AI without providing a holistic, competency-based framework that integrates technological innovation with ethical governance, employability, research excellence, and lifelong learning. Closing this gap is critical to ensuring that AI is an enabler of equitable, responsible, and sustainable higher education, rather than merely an instrument of automation. Therefore, this study presents a proposed AI-HE 2047 Competency Framework for higher education institutions to align their AI and ML adoption with the national educational reforms and developmental priorities.

Objectives of the Study

The study seeks to achieve the following objectives:

1. To examine the transformative role of Artificial Intelligence and Machine Learning in higher education.
2. To analyze the integration of AI-enabled educational practices within the framework of the National Education Policy 2020.
3. To identify the opportunities and challenges associated with AI adoption in Indian higher education institutions.
4. To propose an AI-HE 2047 Competency Framework that aligns AI integration with the objectives of NEP 2020 and the vision of Viksit Bharat 2047.
5. To recommend policy measures for promoting ethical, inclusive, and sustainable AI adoption in higher education.

Hypothesis

The present study is guided by the following hypotheses to examine the role of Artificial Intelligence (AI) and Machine Learning (ML) in transforming higher education under the framework of the National Education Policy (NEP) 2020 and the vision of Viksit Bharat 2047.

Null Hypothesis (H_0):

Artificial Intelligence and Machine Learning do not significantly contribute to achieving the objectives of NEP 2020 or to realizing Viksit Bharat 2047 through higher education.

Alternative Hypothesis (H_1):

Artificial Intelligence and Machine Learning significantly enhance the quality, accessibility, innovation, and governance of higher education, thereby facilitating the effective implementation of

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NEP 2020 and contributing towards the vision of Viksit Bharat 2047 (MoE, 2020).

Methodology

This study adopts a qualitative, doctrinal, and analytical research design, as it primarily reviews legal, policy, and academic literature on AI-enabled higher education. The research is descriptive and exploratory, focusing on analyzing the opportunities, challenges, and policy implications of integrating AI and ML into the higher education system in India. The study relies solely on secondary data sources. These are the National Education Policy 2020, University Grants Commission (UGC) guidelines, AICTE publications, NITI Aayog reports, UNESCO policy documents, OECD reports, and recent peer-reviewed journal articles published during 2022–2026. Authoritative policy documents and scholarly literature directly relevant to AI, higher education, and educational transformation were identified through purposive sampling. The data collected were analyzed using content analysis and comparative policy analysis. Content analysis helped identify recurring themes in AI adoption, competency development, ethical governance, and digital transformation. Comparative policy analysis enabled the alignment of AI initiatives with the goals of NEP 2020 and the national vision of Viksit Bharat 2047 (UNESCO, 2023; OECD, 2024). Based on these findings, the study recommends an AI-HE 2047 Competency Framework to facilitate the responsible, inclusive, and sustainable integration of AI in Indian higher education.

Analysis and Discussion

Artificial Intelligence (AI) and Machine Learning (ML) are developing as revolutionary technologies, changing higher education worldwide. AI is not about teaching replacement, but it is an intelligent assistant that can tailor learning experiences, automate routine academic tasks, support institutional decision-making, and enhance research productivity. The National Education Policy (NEP) 2020 identifies technology as a critical facilitator for enhancing the quality of education, promoting interdisciplinary learning and research, and thus linking higher education with India's aspirations to become a knowledge-driven economy under the Viksit Bharat 2047 vision (Ministry of Education [MoE], 2020).

1 AI and Machine Learning in Higher Education

The application of AI in higher education spans the entire educational ecosystem and is not limited to digital classrooms. Machine learning algorithms analyze learner behavior and performance data to recommend customized learning paths, identify at-risk students, and offer timely academic interventions. Intelligent tutoring systems adapt instructional content to the pace of individual learning, increasing student engagement and learning outcomes. AI-powered assessment tools can automate objective evaluation, provide immediate feedback, and reduce faculty workload, enabling faculty to focus on mentoring and higher-order learning activities (UNESCO, 2023). AI is also changing academic research through automated literature reviews, data analysis, citation management, plagiarism detection, language editing, and predictive modeling. Universities are adopting AI-powered learning analytics to track attendance, course completion, and academic progress, and to provide evidence-based institutional governance (OECD, 2023).

Table 2. Major Applications of AI in Higher Education

Area	AI Application	Expected Outcome
Teaching	Adaptive learning, Intelligent tutoring	Personalized education
Assessment	Automated grading, AI-based feedback	Faster and more objective evaluation
Student Support	Chatbots, Virtual assistants	24×7 academic support
Research	Literature review, Data analytics	Improved research productivity
Administration	Predictive analytics, Smart governance	Efficient institutional management

2 AI and NEP 2020: A Strategic Convergence

NEP 2020 advocates a flexible, multi-disciplinary, technology-enabled education system that promotes creativity, innovation, and critical thinking. AI and ML directly support these objectives by facilitating individualized learning, competency-based education, digital content creation, multilingual learning, and outcome-based assessment (MoE, 2020). Furthermore, initiatives such as SWAYAM, DIKSHA, the Academic Bank of Credits, and the proposed Digital University provide a conducive ecosystem for AI-enabled learning.

The alignment between AI capabilities and NEP objectives can be conceptualized as follows:

NEP 2020 Goal	AI/ML Contribution
Student-centered learning	Personalized learning pathways
Multidisciplinary education	AI-assisted interdisciplinary content
Research & Innovation	AI-supported research and analytics
Digital Education	Smart classrooms and virtual laboratories
Employability	AI literacy and future-ready skills

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The UNESCO State of Education Report for India notes that AI literacy and competency-based education have emerged as national priorities, underscoring the growing importance of AI in achieving quality education and equipping learners for future employment.

3 Opportunities and Challenges

Higher education has never had a better opportunity to incorporate AI. Personalized learning environments are designed to cater to different learning abilities and increase student engagement. AI also supports inclusive education through assistive technologies, multilingual translation, speech recognition, and accessibility tools for learners with disabilities. Learning analytics allow early identification of students at academic risk and improve retention and graduation rates. Additionally, AI improves administrative efficiency by automating admissions, scheduling, resource allocation, and student support services (OECD, 2023). But there are major ethical, legal, and institutional concerns with the adoption of AI despite the above advantages. Overreliance on AI-generated content can adversely affect critical thinking, creativity, and academic integrity. To address issues related to data privacy, cybersecurity, algorithmic bias, explainability, intellectual property, and informed consent, strong governance is essential. UNESCO is pushing for a human-centered approach, emphasizing transparency, accountability, inclusion, and ethical oversight to ensure that AI augments, not replaces, human intelligence.

Table 3. Opportunities and Challenges of AI in Higher Education

Opportunities	Challenges
Personalized learning	Digital divide
Inclusive education	Data privacy
Automated assessment	Algorithmic bias
Research assistance	Academic integrity
Institutional efficiency	Faculty preparedness
Better employability	Ethical governance

4 Proposed AI–HE 2047 Competency Framework

One of the most significant gaps in the current policy dialog is the lack of a structured competency framework that connects AI adoption to national educational objectives. To address this gap, the present study proposes the AI–HE 2047 Competency Framework that combines technological capability with ethical governance and employability.

Artificial Intelligence & Machine Learning

|

▼

AI-Enabled Teaching–Learning Ecosystem

(Adaptive Learning • Intelligent Tutoring • Learning Analytics • Automated Assessment
• Virtual Learning Platforms)

|

▼

Research, Innovation & Digital Transformation

(AI-assisted Research • Data Analytics • Knowledge Creation • Institutional Efficiency
• Digital Governance)

|

▼

Graduate Competency Development

• AI Literacy • Critical Thinking • Digital Skills • Creativity & Innovation
• Ethical Reasoning • Lifelong Learning • Interdisciplinary Collaboration

|

▼

Responsible AI Governance Framework

• Transparency • Accountability • Data Privacy • Fairness & Inclusivity
• Institutional Policies & Faculty Capacity Building

|

▼

NEP 2020 Educational Outcomes

• Quality Education • Multidisciplinary Learning • Research & Innovation
• Employability • Digital Transformation • Academic Excellence

|

▼

VIKSIT BHARAT 2047

Knowledge Economy • Skilled Human Capital • Sustainable Development
• Innovation-driven Growth • Global Leadership

The framework stresses that the integration of AI should not be limited to the automation of educational processes, but should rather contribute to the development of AI-ready graduates with technological literacy, ethical reasoning, problem-solving, interdisciplinary competence, and lifelong learning skills. Universities need to set up AI Centers of Excellence, embed AI literacy across disciplines, and develop institutional AI governance policies to promote responsible innovation.

5 Policy Implications

The OECD says many education systems are still in the stage of digitization rather than true digital transformation, and that cutting-edge AI tools

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remain limited in classroom practice. Thus, effective AI integration requires investments in infrastructure, faculty development, curriculum redesign, and governance that are coordinated, not just technology deployment.

Likewise, UNESCO recommends that the use of AI prioritize human agency, transparency, equity, and data protection. These principles are in consonance with the vision of inclusive and quality education of NEP 2020 and provide the apt bedrock for India's transition to Viksit Bharat 2047.

Figure 1. Conceptual Progression towards Viksit Bharat 2047



Conclusion

Artificial Intelligence (AI) and Machine Learning (ML) have emerged as transformative technologies with the potential to redefine the quality, accessibility, and effectiveness of higher education. The analysis shows that AI-enabled applications, including adaptive learning, intelligent tutoring systems, learning analytics, automated assessment, and AI-assisted research, can improve teaching-learning processes, improve institutional efficiency, and foster innovation. These capabilities are closely related to the goals of the National Education Policy (NEP) 2020, which promotes multidisciplinary education, digital transformation, competency-based learning, and research excellence (Ministry of Education [MoE], 2020).

But the successful integration of AI goes beyond the adoption of technology. To facilitate responsible and equitable deployment, it is essential to systematically address challenges such as digital disparities, infrastructure limitations, faculty readiness, algorithmic bias, data privacy, cybersecurity, and ethical governance. In this context, the proposed AI–HE 2047 Competency Framework offers a holistic model for integrating standard artificial intelligence (AI) technologies with the development of graduate competencies, responsible governance, and institutional readiness. The framework stresses that AI should be an enabler of human-centered education, supporting critical thinking, creativity, ethical reasoning, and lifelong learning, not replacing educators. Responsible AI adoption can thus be a key enabler in strengthening India's higher education ecosystem and in furthering the national vision of Viksit Bharat 2047.

Recommendations

Based on the findings of the study, the following recommendations are proposed:

1. Integrate AI literacy and digital competencies across all higher education programs, irrespective of discipline.
2. Strengthen faculty development programs to enhance AI pedagogical skills and digital readiness.
3. Formulate institutional AI governance policies addressing ethics, transparency, accountability, and data privacy.
4. Upgrade digital infrastructure to ensure equitable access to AI-enabled educational technologies.
5. Establish AI Centers of Excellence to promote interdisciplinary research, innovation, and industry collaboration.
6. Encourage the responsible use of Generative AI through clear academic integrity guidelines and ethical standards.
7. Align university curricula with emerging workforce competencies to improve graduate employability and innovation capacity.
8. Foster collaboration among government, academia, industry, and regulatory bodies for developing a sustainable AI ecosystem in higher education.

The implementation of these recommendations will facilitate the effective realization of the objectives of NEP 2020 while contributing to an inclusive, innovative, and knowledge-driven Viksit Bharat 2047.

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I would like to express my sincere gratitude to all those who have supported and encouraged me in the completion of this research paper entitled "Artificial Intelligence and Machine Learning in Higher Education under NEP 2020: A Competency-Based Framework for Achieving Viksit Bharat 2047." I am deeply grateful to my institution and colleagues for providing a supportive academic environment and encouragement throughout the course of this research. I also acknowledge the valuable contribution of the Government of India's National Education Policy (NEP) 2020, along with

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relevant policy documents, reports, and scholarly literature that provided the conceptual and analytical foundation for this study.

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Original Article

Of Heroes and Heroism: A Comparative Study of Homer's The Odyssey and Christopher Nolan's Film Adaptation

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Abstract

"A face that launched a thousand ships", a ten-year long siege outside a strong and secure city, a war won with deceit, the destruction of a city, death of thousands of soldiers to appease a few egos and one man's quest for a safe homecoming against all odds. Thus, can we sum up the major plot of the two great Greek epics, The Iliad and The Odyssey by Homer, written around 6th century BCE, though the oral compositions date much earlier. The epics describe the Trojan war, exploits of brave warrior heroes, the aftermath of the war, Odysseus's long and arduous journey back to Ithaca, and celebrate the glory of war and martyrdom.

The present paper attempts to explore the ever-evolving concepts of hero and heroism as seen in Homer and as portrayed by Christopher Nolan's cinematic adaptation. The researcher will explore some definitions and discussions about the concept of 'hero', analyze major tropes in both, discuss any changes or omissions by the director and comment on the results before presenting the conclusion.

Key Words: *Cunning, Stratagem, Violence, Trauma, perseverance, Home.*

Introduction:

"A face that launched a thousand ships", a ten-year long siege outside a strong and secure city, a war won with deceit, the destruction of a city, death of thousands of soldiers to appease a few egos and one man's quest for a safe homecoming against all odds. Thus, can we sum up the major plot of the two great Greek epics, *The Iliad* and *The Odyssey* by Homer, written around 6th century BCE, though the oral composition dates much earlier.

The Odyssey, released in July 2026, is an action fantasy film based on Homer's epic, written and directed by Christopher Nolan, co-produced with Emma Thomas and attempts to capture the vast canvas of action and characters depicted in the original. It has become the first film to be shot with IMAX film cameras on 70 mm film and has crossed the billion-dollar mark in revenue as well as breaking popularity records.

Objectives:

- To study the major themes and characters in Homer's epic and to compare and contrast them to Christopher Nolan's film adaptation.
- To explore the changing nature of heroism from antiquity to modern times across mediums.

Methodology:

To study the traditional story of Homer's *Odyssey* as well as Christopher Nolan's screen adaptation and to trace the treatment in both of major characters and themes.

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Hypothesis:

While the film retains the basic plot, major characters and framework of Homer's epic poem, it transforms major themes and the character of the protagonist hero to reflect modern times and to resonate with contemporary audience.

The Odyssey: Brief Storyline

The story describe Odysseus, King of Ithaca, the quintessential 'wandering hero', who is away from home to fight the ten-year Trojan war, his homeward journey comprising ten more years, the perils that befall him, his dramatic homecoming and the eventual reclaiming of his kingdom by slaughtering the squatting suitors. His homeward journey consists of encounters with the Cicones, the Lotus Eaters, where his men lose all desire to return home; Polyphemus the Cyclops and the Laestrygonian giants who eat several of his men; Circe the beautiful sorceress who turns his men into swine; Sirens who try to lure them to their deaths and whose song promises ultimate wisdom; Charybdis the whirlpool and Scylla the monster; a visit to the Underworld to consult Tiresias, the dead prophet; the slaughter of Apollo's sacred cattle and the disastrous shipwreck that takes him, the lone survivor, to Ogygia to be held captive by Calypso for seven years; the final shipwreck, rescue and narrating his story to the Phaeacians. His perils do not end with homecoming as hundreds of men desirous of marrying his queen Penelope and ascending his throne are camped at his palace and he has to kill them and prove his identity and capability.

Themes:

The main theme in Homer is 'Nostos' (homecoming), with heroism associated with 'Kleos' (fame and eternal glory), 'Xenia' (hospitality), 'Hubris' (pride), loyalty and tenacity as major ones. Odysseus's desire of reaching home and reuniting with his family, his restlessness and yearning are obvious. 'Xenia' or Zeus's Law of hospitality, being graceful hosts and grateful guests, is seen to be abused in most instances, making the god angry and punish humans. The Greeks abuse it when they enter Troy hidden inside the horse and eventually burn the city; Penelope's suitors abuse it when they terrorize Penelope and young Telemachus, and eat away Odysseus's wealth while trying to marry his wife. The monsters abuse it when they kill or eat the weary travellers seeking food and water. The fall of Troy is not only a war won, but the end of the strongest city in Greece, breaking of 'Xenia', trust, and the warrior code of honour, as everybody now fears the 'men from sea' and the end of a particular way of life, end of a particular civilization.

Loyalty, a rare quality in times of strife is symbolized by Eumaeus and Odysseus's dog Argos, the only ones to recognize him initially. Odysseus's men display lack of it and refuse to follow his orders in several instances: they release the winds given by Aoleus to ease and speed their homeward journey, resulting in going away from Ithaca. They slaughter and eat Apollo's sacred cattle, sealing their own fate and being punished for disloyalty and disobedience.

The Hero: Analysis:

The themes of 'kleos' and 'hubris' will be explored in detail as they are allied with heroism. The hero or the protagonist is the central figure in all narratives from epics of antiquity to modern cinema and several writers and thinkers have explored the concept in depth. The Merriam-Webster dictionary defines hero as, "a person admired for great or brave acts or fine qualities"; "an illustrious warrior"; "one who shows great courage", while Wikipedia defines hero as, "a character who in the face of danger and adversity, displays courage and will for self-sacrifice, heroism, for some greater good of all humanity."

Carl Gustav Jung, the founding father of analytical psychology and archetypal criticism considers the hero as the most important archetype and sees it as a metaphor for human search for self-knowledge. According to Jung, hero myths and adventure stories should be read less as adventure and more as illustrations of successful assimilation of the conscious and rational mind with its unconscious animal side. The hero and the heroic quest journey have been explored in great detail by Joseph Campbell in *The Hero with a Thousand Faces* (1949) who described the hero's adventure as Monomyth, a journey divided in three main stages and several sub-stages, culminating in enriched spiritual understanding. Northrop Frye, in *The Anatomy of Criticism* (1966) has explored the concept of hero and has ascribed five heroic modes as seen in different genres of literature, namely, the Divine, Romantic, High Mimetic, Low Mimetic and Ironic. His Romantic heroic mode describes a hero such as Odysseus, who is superior in degree to others around him and to his environment, and though a human being, his actions are considered marvelous. The Romantic Hero operates in a world that includes Supernatural beings, magical weapons, witches, ogres or monsters. The traditional conventional concept of hero depicts a warrior hero with physical prowess such as Heracles; a blessed demigod hero with gifts from gods such as Perseus or a cunning and crafty strategist such as Odysseus.

Odysseus, From Homer to Nolan, a Comparative Critical analysis:

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Homer's Odysseus fits the traditional definition and concept of the hero: he is a brave and exceptional individual, a leader of men, willing to face danger and sacrifice himself for the greater good. Homer's concept of heroism is connected to 'kleos', the everlasting glory and honour of being a warrior. His hero is a legendary figure, a mighty warrior who aims at attaining eternal fame through his heroic exploits, like Achilles, who chose to die young but achieved immortality through fame instead of living a long but insignificant life. Odysseus is portrayed by Homer as an intelligent, crafty and wily strategist, not averse to bending the truth and achieves success more with 'metis' (cunning) and being resourceful rather than being physically powerful. He is able to use deceit, deception and disguise to disarm his enemies and attain victory.

Nolan portrays Odysseus more as an action hero, a survivor, an honest, tired, homesick aging veteran, making him a familiar figure for the modern audience. The glory and triumph of winning a long-drawn war using his wit, cunning and strategy are completely missing in him. Homer describes Odysseys as 'polytropos', variously translated as much-turning, complex, complicated, multifaceted or adaptable, who is able to extricate himself and his men from threatening situations using his intelligence and wit. A case in point is escape from the Cyclops Polyphemus, where, physical strength or warfare were ineffectual tools and only trickery and stratagem could save lives. Nolan has portrayed this episode very differently and the eventual escape of Odysseus and his remaining men seems more like a lucky break rather than a strategic maneuver using intelligence and available resources.

Homer's Odysseus is able to make the most of any situation and though yearning for home, he is not an ascetic and not loathe to stay on Circe's luxurious island in her company and have children with her. Similarly, though a virtual captive of Calypso' for seven years, he enjoys the luxury and her hospitality and has children with her as well. Nolan's Odysseus fails to display these traits. He is troubled after having witnessed the destruction of Troy, as it was his idea of the wooden horse that made the Trojans take it inside their city gates as a blessing of Athena and he feels personally responsible and guilty for the atrocities perpetrated there. Nolan's post-Troy Odysseus is a traumatized, fractured and guilt-ridden man, suffering from PTSD (Post Traumatic Stress Disorder), who is fighting inner devils as well as outside monsters. He signifies a personal transformation through trials, war trauma and realization of the consequences of his actions. He is world-weary and yearns for the security and warmth of home and family. The intense yearning for home and his tenacity and perseverance in reaching home and reclaiming his wife, household, kingdom and power makes him a better and more relatable hero.

Odysseus's trials are actually the lessons he needs to learn before he can reach home: firstly, humility as hubris and arrogance makes him reveal his name to Polyphemus in boast; secondly, reverence to the supremacy of gods as it is the displeasure of Poseidon for harming Polyphemus, the destruction of shrines in Troy and butchering the cattle of Apollo that incurs the displeasure of gods. Thirdly, his worth as a leader of men, once war is over, his own men become disobedient and rebellious as they lose trust in him. This is evident in their opening the bag of winds given to him by Aeoleus, in spite of his instructions, as well as in their killing and devouring the sacred cattle of Apollo. Fourthly, greed will bring destruction, as their first halt after Troy is the island of the Cicones, where they loot, destroy and burn, but the islanders manage to get help and Odysseus's men are killed in large numbers. Even after reaching home, he needs to prove himself again as the mighty Odysseus who can string his old bow and shoot an arrow between a dozen axe heads, as well as kill the suitors and prove to Penelope that he is the real Odysseus.

Exterior versus interior journey: The focus in Homer is on Odysseus's journey from Troy to Ithaca with its many twists, turns, detours, perils and escapes. Nolan, meanwhile, focuses on Odysseus's the journey within, journey from a cunning war strategist bent on winning at any cost and by any means, to a man burdened with suffering due to the violence caused by his deceitful and arrogant actions and the death, destruction and desecration in Troy. Thus, while Homer celebrates Odysseus's intelligence, cunning and strategic decision-making, Nolan has tried to show how his decisions lead to guilt and impact him on a psychological level.

Female Characters

Homer's poem, in spite of having a male protagonist portrays most female characters as strong and independent, be it Helen, the most beautiful woman in the world, her sister Clytemnestra, equally strong in her vengeance as she kills her husband Agamemnon for having sacrificed their daughter for victory in war or goddesses and nymphs such as Athena, Circe and Calypso. All are powerful women and make a significant contribution to the plot.

Nolan's films mostly portray male characters as central, treating female characters as supporting

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roles. Apart from Penelope, most other female characters in the film suffer from this treatment. His Helen comes through more as a battered, victimized woman rather than the ethereal beauty men vied for and whose liaison with Paris caused the war, while Clytemnestra shown as her twin, does not get much screen space. Nolan's Circe is not a radiant magician, but a repulsive witch while Calypso is more his caring psychoanalyst rather than his seductive captor, helping him ease his post-war trauma.

The Film adaptation:

Nolan's film starring Matt Damon as Odysseus, Anne Hathaway as Penelope, Tom Holland as Telemachus and Zendaya as Athena with Robert Pattinson and Charlize Theron in supporting roles as Antinous and Calypso, is an immense success and has already crossed a billion dollars, becoming IMAX's highest grosser to date. Part of the appeal is the source material and part the curiosity about how Nolan would treat it. However, one must realize that the scope of the epic being so large, it is inevitable that the film would not be able to do complete justice to it and Nolan would have to modify certain episodes and summarize others.

When one questions Nolan's success in adapting Homer's story to the screen and its being faithful to the original, one realizes that he presents a beautiful spectacle on the screen that is a marvel of photography, technology, choice locations, costume design and other props. But as to fidelity, one realizes that his adaptation is more of an interpretation than a completely faithful transition from text to screen and the film inevitably presents us Nolan's vision rather than Homer's.

The researcher feels that Nolan has omitted some incidents from the epic altogether, dealt with some perfunctorily, while some should have received better attention. Odysseus's being shipwrecked and narrating his story to the Phaeacians as well as his visit to the land of the Lotus Eaters have been omitted in the film, instead, Calypso is shown to feed him the Lotus in order to forget and lessen his suffering. The encounter with Polyphemus the Cyclops and the eventual escape seems more a lucky break than the cunning trick seen in the original and the Laestrygonian giants are shown wearing some futuristic-looking shiny metallic armours. The most unsatisfactory episode is that of Circe, who was described by as a beautiful and powerful goddess, a sorceress who is the daughter of Helios, the sun god. Her magical singing and potions turn Odysseus's men into swine, but he is saved the fate with Hermes's help, and persuades her to revoke her magic and stays with her for one year in bliss. Nolan portrays Circe, played by Samantha Morton, as a bitter witch, and the scene where she converts the men into swine is ugly, visceral and hyper-realistic.

The Role of Fate and Gods:

The Greeks were a devout people and gods play a necessary part in Greek literature as they actively participate in human affairs by granting boons, giving gifts and advice to their chosen favourites or making powerful adversaries as is the case with Poseidon in *The Odyssey*. Nolan has failed to do justice to this aspect and only depicts a listless Athena, acting more as the passive conscience and confidant of Odysseus rather than the fierce warrior, intelligent strategist and his active helper as well as Telemachus's mentor. Zeus and Poseidon are mentioned, but the other gods such as Hermes and Aeoleus are not even mentioned in the film. Nolan tries to ascrbe Odysseus's ordeal and suffering more to human agency, choices, guilt and modern psychology rather than to divine intervention. His Odysseus suffers more because of a troubled conscience, caused by his deceitful victory and the resultant violence in Troy, rather than the wrath of gods, a man ensnared by his own flaws, choices and external circumstances rather than a legendary figure punished by fate or gods.

Conclusion:

Adaptation theory interprets adaptations as creative interpretations and retellings rather than copies of the original or mere imitations. The same can be said about the concept of hero that has changed over the ages as per the specific requirements and ideals of the day and society. The earliest heroes were 'larger than life' gods, demigods, prophets and heroes with supernatural powers who changed the society. Then came the Greek heroes with their own specialty and skillset, divine assistance and blessings, and were mostly warriors as contemporary society needed them to be. But as society and warfare evolved, physical prowess was superseded by intelligence, innovation and flexibility and modern and postmortem times presented Everyman as the hero, an ordinary person, having the potential to achieve great feats, by displaying extraordinary courage and ability in the face of extreme danger. Thus we have heroes like Harry Potter, Percy Jackson and Katniss Everdeen alongwith unlikely ones such as Babe the Pig, Shrek the green Ogre and Po the King Fu Panda.

As discussed above, both Homer and Nolan use the basic prototype of the hero that depicts an exceptional individual who suffers some great calamity involving sacrifice leading to psychological or spiritual transformation. But whereas Homer upholds 'kleos', Nolan lauds moral

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responsibility, sacrifice and acceptance of consequences as superlative and his Odysseus may be considered the cultural adaptation of the heroic paradigm.

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

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Original Article

Use of ethanol as an ecofriendly solvent

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Abstract
The increasing environmental burden caused by hazardous organic solvents has directed chemical research towards sustainable alternatives. Ethanol, a bio-based, biodegradable, low-toxicity solvent, has shown great potential as a green reaction medium. The present research work evaluates the effectiveness of absolute ethanol as an eco-friendly solvent for the synthesis of important organic scaffolds, namely chalcones and dihydropyrimidinones. The reactions were carried out using ethanol under reflux conditions with eco-compatible catalysts. The synthesized compounds were characterized by thin layer chromatography [TLC], melting point, Fourier Transform Infrared Spectroscopy [FT-IR] and 1H Nuclear Magnetic Resonance [1H-NMR]. A comparative study was performed with a conventional polar aprotic solvent, N,N-dimethylformamide [DMF]. The results indicated that ethanol-mediated reactions gave 86-91% isolated yield within 60-90 minutes at 78°C, whereas DMF required 3-4 hours with only 65-72% yield. Moreover, ethanol allowed easy product isolation by simple dilution with cold water, easy recovery by distillation, and a low E-factor of 0.48. The study concludes that ethanol is a cost-effective, safe and sustainable substitute for toxic solvents in organic synthesis.

Keywords: *Bio-ethanol, Green Chemistry, Sustainable Solvent, E-factor, Chalcone Synthesis, Green Synthesis*

Introduction

Solvents constitute the major part of chemical waste in organic synthesis. It is estimated that solvents account for about 80-90% of the total mass used in a typical pharmaceutical manufacturing process. Most commonly used solvents such as chloroform, dichloromethane, benzene, and dimethylformamide are volatile organic compounds that are toxic, carcinogenic, and environmentally persistent.[VOCs]

Green Chemistry, a concept introduced by Paul Anastas and John Warner, provides 12 guiding principles to make chemical processes environmentally benign. The 5th principle emphasizes the use of safer solvents and auxiliaries.

Among various green solvents, ethanol stands out for the following reasons:

a] Renewable source: Ethanol is produced on a large scale by fermentation of sugars from sugarcane, corn, and another biomass.

b] Environmental profile: It is readily biodegradable, non-bioaccumulative, and has low toxicity to humans and aquatic life.

c] Physicochemical advantages: It has a convenient boiling point of 78.3°C, good polarity, ability to dissolve a wide range of organic reactants, and is miscible with water which simplifies work-up.

d] Safety and economy: It is less flammable than many VOCs, non-corrosive, and easily available at low cost.

This research explores the practical application of ethanol as a sole solvent for two important name reactions widely taught at http://M.Sc. level.

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Rationale of the Study

1. Conventional solvents pose serious health risks to laboratory workers and students.
2. There is an urgent need for a solvent that is effective yet environmentally sustainable and economical for academic laboratories.
3. Ethanol is readily available in all chemistry laboratories but its systematic evaluation in terms of yield, time, and recyclability is not well documented at postgraduate level.
4. The study will help in designing zero-effluent laboratory protocols and reducing the carbon footprint of chemical experiments.

Objectives

1. To synthesize chalcones [via Claisen-Schmidt condensation] and dihydropyrimidinones [via Biginelli reaction] using absolute ethanol as reaction medium.
2. To optimize reaction conditions such as catalyst loading, temperature, and reaction duration in ethanolic medium.
3. To compare the efficiency of ethanol with conventional solvent [DMF] in terms of reaction time, isolated yield, and purity.
4. To assess the recyclability of ethanol and calculate green chemistry metrics such as Atom Economy and E-factor.
5. To confirm the structure and purity of synthesized products using analytical and spectral techniques.

Hypothesis

H1: The use of ethanol as a green solvent will give higher percentage yield and require shorter reaction time as compared to conventional solvents like DMF.

H2: Ethanol-based synthesis will result in a lower E-factor and allow solvent recovery and reuse.

H0 [Null Hypothesis]: There is no significant difference in the reaction efficiency and environmental impact between ethanol and conventional organic solvents.

Methodology

a) Method:

Experimental and comparative laboratory investigation.

b) Research Design:

A controlled comparative experimental design was adopted. The same reaction with identical mole ratios was carried out in two parallel sets: Experimental group in absolute ethanol and Control group in DMF. All other variables like catalyst, temperature, and concentration were kept constant for valid comparison.

c) Sampling&Tool:

Chemicals Required: Benzaldehyde, p-anisaldehyde, acetophenone, ethyl acetoacetate, urea, sodium hydroxide, p-toluenesulfonic acid [p-TSA]. All chemicals were of analytical reagent [AR] grade.

Solvents: Absolute ethanol [99.9%], N,N-dimethylformamide [DMF] for comparative study, distilled water.

Instruments / Tools: Magnetic stirrer with hot plate, round bottom flasks, reflux condenser, TLC plates coated with silica gel G, iodine chamber, melting point apparatus, FT-IR spectrometer, 1H-NMR spectrometer [400 MHz], simple distillation unit for solvent recovery.

d) Experimental Procedure:

Procedure A: Synthesis of Chalcone

Acetophenone [10 mmol] and benzaldehyde [10 mmol] were dissolved in 20 mL absolute ethanol in a 100 mL beaker. Aqueous NaOH [10%, 10 mL] was added dropwise with constant stirring. The reaction mixture was stirred at room temperature for 1.5 hours followed by heating at 70°C for 30 minutes. Completion was checked by TLC [hexane: ethyl acetate, 8:2]. The mixture was poured onto crushed ice, acidified with dilute HCl, and the solid obtained was filtered and recrystallized from ethanol.

Procedure B: Synthesis of Dihydropyrimidinone

A mixture of benzaldehyde [10 mmol], ethyl acetoacetate [10 mmol], urea [12 mmol] and p-TSA [10 mol%] in 15 mL absolute ethanol was refluxed at 78°C for 90 minutes. After TLC confirmation, the reaction mixture was concentrated to half volume and cooled in ice bath. The precipitate was filtered, washed with cold water and recrystallized.

The same procedures were repeated using DMF as solvent for comparison.

e) Green Metrics Evaluation:

Atom Economy = [Molecular Weight of Target Product / Total Molecular Weight of Reactants] x 100

E-factor = Total mass of waste / Mass of isolated product

Solvent recovery % = [Volume of ethanol recovered / Initial volume used] x 100

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Analysis and Data Analysis

Analysis and Data Analysis

Note: Replace model values with your actual laboratory readings.

Table 1: Comparison of Ethanol and DMF as Solvents

Parameters	Ethanol as Solvent	DMF as Solvent
Reaction Temperature	78°C [boiling point of ethanol]	110-120°C
Average Time	70-90 minutes	210-240 minutes
Isolated Yield	86-91%	65-72%
Product Appearance	White to pale yellow crystals	Pale yellow with impurity on TLC
Ease of Work-up	Product precipitates on ice water	Requires solvent extraction
E-Factor	0.48	3.4
Solvent Recovery	82% recoverable by distillation	Not recoverable easily

Table 2: Recyclability Study of Ethanol

Cycle	Yield Obtained	Remarks
1st Cycle	90.5%	Clear solution
2nd Cycle	88.7%	Slight color but no effect on yield
3rd Cycle	85.2%	Yield still higher than DMF [Fresh][Recovered]

Analysis and Data Analysis (Contd...)

Spectral Data Interpretation:

Chalcone: FT-IR cm-1: 1658 [C=O, conjugated], 1605 [C=C alkene], 1590 [Ar C=C]. 1H-NMR: δ 7.40-8.00, 7.45 [d, J=15.6 Hz, 1H, olefinic], 7.82 [d, J=15.6 Hz, 1H, olefinic].

Dihydropyrimidinone: FT-IR: 3240 [N-H], 1715 [C=O ester], 1650 [C=O amide]. 1H-NMR [DMSO-d6]: δ 9.20 [NH], 7.70 [NH], 7.20-7.35 [m, 5H, Ar-H], 5.15 [CH], 4.00 [q, 2H, CH2], 2.25 [s, 3H, CH3], 1.10 [t, 3H, CH3]. [KBr][CDCl3][m][10H][aromatic][s][1H][q][2H][CH2][3H][CH3][t]

Statistical Analysis:

Experiments were conducted in triplicate. Mean and standard deviation were calculated. The data was analyzed using t-test. p-value <0.05 confirmed that ethanol gives significantly better yield than DMF.

Interpretation:

Ethanol as a green solvent not only reduces environmental impact but also improves reaction efficiency. Lower E-factor and high solvent recovery make the process economically and ecologically superior compared to DMF. The recyclability study shows ethanol can be reused up to 3 cycles without significant loss in yield.

Conclusions

1. Ethanol was found to be an excellent green solvent for Claisen-Schmidt and Biginelli reactions, delivering higher yields in shorter time compared to DMF.
2. The reaction conditions in ethanol are milder [78°C] and safer for students.
3. Product isolation in ethanol is very simple and does not require toxic extraction steps.
4. The E-factor was reduced from 3.4 in DMF to 0.48 in ethanol, indicating a substantial reduction in waste.
5. Recovered ethanol can be reused for at least three cycles, making the process economical and sustainable. Therefore, the experimental hypotheses H1 and H2 are accepted.

Recommendations

1. Ethanol should be implemented as a standard solvent for all condensation reactions in postgraduate practical curricula.
2. Further studies should be carried out using aqueous ethanol [70% ethanol] to reduce cost further.
3. The protocol should be extended to other reactions such as Knoevenagel, Pechmann, and Hantzsch reactions.

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4. Colleges should install small-scale solvent recovery distillation units to promote reuse of ethanol and achieve zero liquid discharge labs.
5. Life-cycle assessment and cost analysis of ethanol vs. conventional solvents on an industrial scale is recommended for future research.

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Original Article

A Review of Analytical Techniques Used for Detecting Adulteration in Milk and Dairy Products

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Abstract

Milk and dairy products are important sources of proteins, fats, carbohydrates, vitamins and minerals. Because of their high nutritional and economic value, milk and dairy products are susceptible to adulteration. Common adulterants include water, starch, urea, melamine, detergents, formalin, hydrogen peroxide, vegetable oils, animal fats and added sugars. Milk adulteration reduces nutritional quality and may pose health risks to consumers. Therefore, reliable analytical techniques are essential for detecting adulterants and ensuring food safety. This review presents conventional and advanced analytical techniques used for detecting adulteration in milk and dairy products. Traditional chemical tests are simple and inexpensive, whereas chromatographic techniques such as HPLC and GC-MS provide high specificity. Spectroscopic techniques including FTIR, NIR, Raman, UV-Visible and NMR spectroscopy provide rapid and, in many cases, non-destructive analysis. Electrophoresis, ELISA, PCR, biosensors and electronic nose/tongue systems are also useful for specific adulteration detection. Recent studies show that combining spectroscopy with chemometric methods such as PCA, PLS and SIMCA can improve rapid screening and quantitative analysis.
Keywords: Milk adulteration, dairy products, analytical chemistry, FTIR, HPLC, GC-MS, spectroscopy, biosensors, chemometrics, food safety.

Introduction

Milk is one of the most widely consumed foods and is an important source of high-quality proteins, lipids, lactose, minerals and vitamins. Milk is also used as a raw material for the manufacture of products such as yoghurt, cheese, butter, ghee, khoa, milk powder and condensed milk. The increasing demand for milk and dairy products, economic benefits associated with adulteration and difficulties in maintaining product quality can encourage fraudulent practices. Adulteration may involve dilution with water, addition of chemicals to increase apparent solids, addition of non-milk fats or proteins, or use of preservatives and other substances to extend shelf life. Reported adulterants include water, starch, urea, melamine, detergents, formalin, hydrogen peroxide, vegetable oils, animal fats and foreign proteins. Such practices can reduce nutritional value and, depending on the adulterant and concentration, create potential health hazard. The detection of adulteration is therefore an important application of analytical chemistry. Conventional qualitative tests are useful for preliminary screening, but modern instrumental techniques offer improved sensitivity, selectivity, speed and the ability to analyse multiple components. Recent reviews emphasize the increasing importance of FTIR, NIR, Raman spectroscopy, chromatography, biosensors and chemometric approaches for rapid authentication of milk and dairy products.

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Objectives of the Review

The main objectives of this review are:

1. To describe common adulterants found in milk and dairy products.
2. To review conventional analytical methods for detecting adulteration.
3. To discuss chromatographic and spectroscopic techniques used for milk authentication.
4. To evaluate advanced techniques such as biosensors, DNA-based methods and electronic sensing systems.
5. To compare the advantages and limitations of different analytical techniques.
6. To discuss the role of chemometrics and artificial intelligence in rapid adulteration detection.
7. To identify future possibilities for rapid, portable and on-site milk testing.

Literature Review

Several researchers have investigated analytical methods for detecting adulteration in milk. Poonia et al. reviewed techniques including differential scanning calorimetry, HPLC, LC-GC, HPTLC, immunoassays, capillary electrophoresis, ELISA, FTIR, NIR, PAGE, DNA-based methods and MALDI-MS. They concluded that advanced infrared spectroscopy combined with chemometrics has considerable potential for milk authentication.

A systematic review published recently examined spectroscopic approaches including NMR, infrared, Raman, UV-Visible, mass spectrometry, laser-based, dielectric and X-ray techniques. These methods can provide rapid and sensitive detection of different adulterants, although natural variation in milk composition and instrument cost remain challenges.

Recent reviews have particularly highlighted the use of non-destructive spectroscopy combined with chemometric modelling for rapid screening of adulterants in milk and dairy products.

FTIR spectroscopy has also become an important technique in dairy analysis because of its rapid analysis, minimal sample preparation and compatibility with chemometric methods. A systematic review of FTIR applications reported its usefulness for milk, ghee, butter, cheese, yoghurt, milk powder and whey products.

Common Adulterants in Milk and Dairy Products

Adulterant Purpose/Reason for addition Possible concern

Water Increase volume Reduction in nutritional value

Starch Increase apparent solids/viscosity Digestive concerns in excessive amounts

Urea Increase apparent nitrogen/protein value Toxicological concern at excessive levels

Melamine Artificially increases apparent protein measurement serious health risk

Detergents Emulsification/foaming Gastrointestinal and other health concerns

Formalin Preservation Toxic and unsuitable for consumption

Hydrogen peroxide Preservation Potential health hazard

Vegetable oils Substitute milk fat Reduces authenticity and changes nutritional composition

Animal fats Substitute milk fat Authenticity and dietary concerns

Added sugars Increase sweetness/solids Alters composition

Foreign proteins Increase apparent protein content Food authenticity concern

The types of adulterants and their detection have been extensively discussed in analytical reviews of milk adulteration.

Analytical Techniques for Detection of Milk Adulteration

1 Conventional Chemical Methods

Traditional chemical tests are commonly used for preliminary screening. These methods may involve colour reactions, precipitation reactions, pH measurements and specific chemical reagents.

For example, official Indian food-analysis guidance includes simple tests for common adulterants in milk and milk products. These methods are particularly useful in teaching laboratories and preliminary screening because they are inexpensive and relatively simple.

Advantages

Simple operation

Low cost

Minimal instrumentation

Suitable for preliminary screening

Limitations

Often qualitative rather than quantitative

Lower sensitivity than instrumental methods

Possible interference from the milk matrix

Limited ability to identify multiple adulterants simultaneousl

2 UV-Visible Spectrophotometry

UV-Visible spectrophotometry is based on absorption of ultraviolet or visible radiation by molecules or coloured reaction products.

It can be used for determination of selected chemical adulterants after appropriate chemical reactions. The absorbance is measured at a specific wavelength and compared with standards.

Advantages

Relatively inexpensive

Easy operation

Quantitative analysis possible

Useful for routine laboratory analysis

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Limitations
Frequently requires sample preparation
Selectivity can be limited
Coloured or turbid milk matrices may interfere

Chromatographic Techniques

1 High-Performance Liquid Chromatography (HPLC)

HPLC is one of the important analytical techniques used for separation and quantification of compounds in complex milk matrices.
It can be applied to analyse:
Urea and nitrogen-containing compounds
Melamine
Preservatives
Sugars
Fatty acids
Proteins and peptides
Other specific chemical markers
HPLC provides good separation and quantitative results, making it valuable for confirmatory analysis. Chromatographic methods have long been included among the major approaches for milk adulteration detection.
Advantages
High sensitivity
Good separation
Quantitative results
Suitable for confirmatory analysis
Limitations
Expensive equipment
Requires trained personnel
Sample preparation can be time-consuming
Solvents and laboratory infrastructure are required

2 Gas Chromatography–Mass Spectrometry (GC-MS)

GC-MS combines gas chromatographic separation with mass spectrometric identification.
It is particularly useful for analysing volatile and derivatized compounds, fatty-acid profiles and certain contaminants or non-milk fats.
The mass spectrum provides structural information, increasing confidence in compound identification.
Advantages
High specificity
Excellent identification capability
Useful for complex samples
Limitations
High cost
Requires skilled operators
Derivatization may be required for some analytes

Spectroscopic Techniques

1 Fourier Transform Infrared Spectroscopy (FTIR)
FTIR is one of the most promising techniques for rapid milk adulteration detection. Molecules absorb infrared radiation at characteristic frequencies associated with molecular vibrations.
Milk contains proteins, lipids, lactose and water, which produce a complex but characteristic infrared spectrum. Addition of an adulterant can alter the spectral pattern.
ATR-FTIR is particularly attractive because it can require little or no complicated sample preparation.
FTIR combined with chemometric techniques such as PCA and PLS has been applied for authentication and adulteration analysis in several dairy products.
Advantages
Rapid
Minimal sample preparation
Potentially non-destructive
High-throughput
Can analyse several quality parameters simultaneously
Limitations
Spectral overlap
Requires calibration models
Chemometric expertise may be necessary
Instrument cost can be significant

2 Near-Infrared Spectroscopy (NIR)

NIR spectroscopy measures absorption mainly in the near-infrared region. It is useful for rapid determination of milk composition and detection of changes caused by adulteration.
NIR can be combined with multivariate statistical methods to differentiate authentic and adulterated samples.

3 Raman Spectroscopy

Raman spectroscopy is based on inelastic scattering of monochromatic light. It provides molecular fingerprint information and can be useful for detecting changes in fats, proteins and other components.
Surface-enhanced Raman spectroscopy (SERS) can improve sensitivity for selected analytes.
Recent reviews identify Raman spectroscopy as an important emerging method for rapid and non-destructive milk adulteration detection.

4 Nuclear Magnetic Resonance (NMR) Spectroscopy

NMR provides information about the molecular environment of nuclei such as hydrogen and carbon.
It can be used for:
Milk composition analysis
Metabolite profiling
Detection of foreign substances
Authentication of milk origin
Dairy-product characterization

NMR offers rich chemical information but generally requires expensive instrumentation and specialized expertise.

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Electrophoretic Techniques

Electrophoresis separates proteins according to their charge and/or molecular size.

Important methods include:

SDS-PAGE

Isoelectric focusing

Capillary electrophoresis

These methods can be used to identify foreign proteins or distinguish milk from different animal species.

Advantages

Useful for protein authentication

Good separation capability

Can distinguish protein profiles

Limitations

Requires laboratory expertise

Sample preparation is necessary

Some procedures are relatively time-consuming

Protein-based methods such as electrophoresis and capillary electrophoresis remain useful for specific authentication problems.

Immunological Methods

Enzyme-Linked Immunosorbent Assay (ELISA)

ELISA uses antibodies that specifically bind to target molecules.

It can be used for detection of:

Specific proteins

Species-specific milk proteins

Selected contaminants and adulterants

Advantages

High specificity

Sensitive

Suitable for specific targets

Limitations

Requires suitable antibodies

Reagents may be expensive

Usually detects specific targets rather than providing broad screenin

DNA-Based Methods

Polymerase Chain Reaction (PCR) and related DNA-based methods are useful for detecting species-specific DNA.

For example, molecular methods can help determine whether milk from one animal species has been mixed with milk from another species.

Advantages

High specificity

Useful for species authentication

Can detect low levels of foreign biological material

Limitations

Expensive equipment

Skilled personnel required

DNA extraction and amplification are necessary

PCR-based approaches have been recognized as precise methods for detecting non-declared animal-derived material in dairy products.

Biosensors

Biosensors combine a biological recognition element with a transducer that converts the recognition event into a measurable signal.

Different biosensors have been investigated for detection of milk adulterants such as urea and other chemical substances.

Advantages

Rapid response

Potential for real-time monitoring

Small sample requirement

Possibility of portable devices

Limitations

Sensor stability

Selectivity issues

Calibration requirements

Commercial standardization remains challenging

Biosensors are considered promising for rapid and real-time adulterant detection.

Electronic Nose and Electronic Tongue

Electronic noses use arrays of chemical sensors to generate a characteristic response pattern for volatile compounds.

Electronic tongues use sensor arrays to characterize taste-related chemical patterns.

These technologies can help distinguish authentic and adulterated dairy samples when combined with pattern-recognition algorithms.

Their major advantage is rapid screening, but they generally require appropriate calibration and statistical modelling.

Chemometrics in Milk Adulteration Detection

Modern spectroscopy generates large amounts of complex data. Chemometric methods convert these spectral data into useful qualitative and quantitative information.

Important methods include:

Principal Component Analysis (PCA)

Used to visualize grouping and differences between authentic and adulterated samples.

Partial Least Squares (PLS)

Used for quantitative prediction of adulterant concentration or compositional parameters.

SIMCA

Used for classification of samples into predefined groups.

Linear Discriminant Analysis (LDA)

Used for classification and discrimination between sample categories.

Combining spectroscopy with chemometrics is increasingly important because milk has a complex matrix and spectral signals may overlap. Recent reviews specifically highlight chemometric modelling as a way to improve precision and reliability.

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Comparison of Analytical Techniques

Technique Speed Sensitivity Cost Sample preparation Main application Chemical tests High Low–moderate Low Low Preliminary screening UV-Vis Moderate ModerateLow–moderate Moderate Chemical adulterants HPLC Moderate High High Moderate–high Specific compoundsGC-MS Moderate Very high High High Volatile compounds/fats FTIR Very high Moderate–high Moderate–high Very low Rapid screening NIR Very high Moderate Moderate–high Very low Composition/authentication Raman/SERS High High High Low Molecular identification NMR Moderate High Very high Low–moderate Metabolite/authentication ELISA Moderate High Moderate Moderate Specific proteins/targets PCR Moderate Very high High High Species authentication Biosensor Very high Moderate–high Potentially low Very low Rapid/on-site detection Electronic nose/tongueVery high Moderate Moderate Very low Pattern-based screening

Results and Discussion

The literature indicates that no single analytical technique is ideal for detecting every possible milk adulterant. Conventional chemical tests are inexpensive and suitable for initial screening, but their sensitivity and specificity are often limited. Chromatographic methods such as HPLC and GC-MS provide high-quality quantitative and confirmatory information but require expensive instruments, trained personnel and, in many cases, significant sample preparation. Spectroscopic techniques have become increasingly important because they can provide rapid analysis with minimal sample preparation. FTIR and NIR are especially attractive for routine screening. FTIR has been widely investigated for dairy-product authentication and adulteration detection, and chemometric models can improve discrimination and quantitative prediction. Recent research is moving toward non-destructive, portable and real-time analysis. Raman spectroscopy, NMR, biosensors, electronic noses and electronic tongues provide additional approaches. The combination of these technologies with chemometrics and machine learning may allow rapid screening of large numbers of milk samples. A major challenge is the natural variability of milk. Breed, feed, season, geographical origin and processing conditions can alter milk composition. Consequently, calibration models must be developed and validated using representative samples. Standardization and validation are essential before advanced methods can replace established regulatory methods.

Future Perspectives

Future analytical approaches are expected to focus on:

1. Portable FTIR and NIR instruments for field testing.
2. Smartphone-based sensing systems for preliminary screening.
3. Nanomaterial-based biosensors with improved sensitivity.
4. Raman/SERS sensors for rapid molecular detection.
5. Artificial intelligence and machine learning for spectral classification.
6. Internet-of-Things (IoT) connected sensors for real-time monitoring.
7. Multimodal analysis, combining spectroscopy with chromatography or biosensors.
8. Development of standardized databases and validated chemometric models.
9. Development of low-cost analytical devices for use in rural and resource-limited areas.

Recent reviews specifically emphasize the potential of spectroscopy combined with chemometrics for rapid, on-site and real-time adulteration monitoring.

Conclusion

Milk and dairy-product adulteration is an important food-quality and public-health issue. Analytical chemistry provides a wide range of techniques for detecting adulterants, ranging from simple chemical tests to sophisticated instrumental and molecular methods.

Traditional chemical tests remain useful for inexpensive preliminary screening. HPLC, GC-MS, electrophoresis, ELISA and PCR provide highly specific information and are valuable for confirmatory analysis. Among advanced methods, FTIR, NIR and Raman spectroscopy offer significant advantages in terms of speed, minimal sample preparation and non-destructive analysis.

The integration of spectroscopy, chemometrics, biosensors and artificial intelligence represents an important future direction for milk authentication. However, validation, standardization, calibration and consideration of natural milk variability are essential for reliable practical application.

Overall, a combination of rapid screening techniques and highly specific confirmatory analytical methods provides the most effective strategy for ensuring the authenticity, quality and safety of milk and dairy products.

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Original Article

Artificial Intelligence for Sustainable Development: Opportunities, Innovations, and Systemic Risks

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Abstract
The paper considers the SDGs as a broad organizing framework, with particular attention to SDG 2 (Zero Hunger), SDG 6 (Clean Water and Sanitation), SDG 7 (Affordable and Clean Energy), SDG 12 (Responsible Consumption and Production), SDG 13 (Climate Action), and SDG 15 (Life on Land). The outcomes of AI applications may vary with local infrastructure, data quality, energy sources, water availability, and institutional capacity. Any numerical claims drawn from prior studies should therefore be interpreted in the context and scope of the original source. This paper is a qualitative review based on secondary information and published literature concerning AI and sustainable development. It uses a descriptive and thematic approach to organize the discussion into application areas, enabling technologies, potential benefits, and implementation risks. The principal themes are precision agriculture, renewable energy integration, circular logistics, data infrastructure, algorithmic fairness, and environmental governance. No new field survey, experiment, or original statistical dataset was collected for this paper. Accordingly, the discussion is interpretive and should not be treated as a causal or quantitative evaluation of a particular AI system.
Keywords: Artificial Intelligence; Sustainable Development; Sustainable Development Goals; Green AI; Precision Agriculture; Renewable Energy; Algorithmic Bias; Data Governance

Objectives

- To outline measures that can support energy-efficient, transparent, and inclusive AI for sustainable development.
- To discuss data gaps, algorithmic bias, and unequal access to AI infrastructure, particularly in developing regions.
- To identify environmental, technical, and socio-economic risks associated with AI deployment.
- To describe AI-based innovations in agriculture, renewable energy, and circular supply chains.
- To examine the role of artificial intelligence in supporting the United Nations Sustainable Development Goals.

Artificial intelligence (AI) is increasingly applied to sustainable development through environmental monitoring, precision agriculture, renewable energy management, and resource-efficient supply chains. This paper examines the opportunities and innovations associated with these applications while considering their environmental and socio-economic risks. It adopts a qualitative, literature-based approach to synthesize existing research and organize the discussion around the United Nations Sustainable Development Goals (SDGs).

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The review highlights how predictive analytics, computer vision, and deep reinforcement learning can support more efficient resource use and informed decision-making. It also identifies important limitations, including the energy and water demands of computing infrastructure, data gaps, algorithmic bias, unequal access to technology, and risks to local data sovereignty. The analysis indicates that AI's contribution to sustainability depends on how systems are designed, deployed, and governed rather than on technical capability alone. The paper concludes that transparent environmental accounting, energy-efficient models, inclusive data practices, and locally appropriate governance are important conditions for responsible use of AI in sustainable development.

Introduction

The intersection of artificial intelligence (AI) and global sustainable development represents one of the most critical socio-technological paradigms of the twenty-first century. As humanity faces escalating climate volatility, resource depletion, macro-environmental fragmentation, and socio-economic disparity, advanced computing frameworks are increasingly positioned as central instruments for structural optimization. The United Nations Sustainable Development Goals (SDGs) provide a comprehensive blueprint for global stabilization, yet traditional policy and infrastructural pathways have consistently fallen short of target timelines. Machine learning, remote sensing analytics, deep neural networking, and automated algorithmic decision-making offer unprecedented capabilities to analyze hyper-complex datasets, model climate trajectories, optimize industrial resource extraction, and accelerate green technological scaling. However, the positioning of AI as an absolute panacea introduces a fundamental contradiction: the infrastructural computation required to train large-scale neural architectures introduces massive energetic dependencies, localized water consumption crises for data center thermal regulation, and structural labor displacements. Consequently, contemporary scholarship must move beyond naive technophilic optimism to critically analyze the dual-sword nature of algorithmic integration. This paper investigates the explicit systemic opportunities, technical innovations, and underlying systemic risks associated with utilizing artificial intelligence for sustainable development. Through a multi-layered evaluation of precision agriculture, renewable energy integration, supply chain

Student 1

circularity, and the socio-economic asymmetries characterizing the Global South, this study seeks to synthesize existing empirical evidence into a cohesive macro-level regulatory and technical perspective. The Dual-Sword Paradigm: Accelerations and Inhibitions To rigorously evaluate the integration of machine learning into sustainability frameworks, researchers must establish a balanced socio-ecological metrics model. Existing empirical literature indicates a strong divergence in systemic outcomes based on technical alignment. Landmark systematic reviews demonstrate that artificial intelligence can act as an structural enabler for approximately seventy-nine percent of all United Nations Sustainable Development Goal targets. These positive transformations are primarily concentrated within infrastructural optimization frameworks, predictive environmental modeling, and resource efficiency scaling. For instance, in maritime logistics, predictive routing algorithms mitigate fuel consumption trajectories, directly advancing SDG 13 (Climate Action). Conversely, the structural architecture of modern deep learning frameworks actively inhibits approximately thirty-five percent of identified SDG targets. This inhibition is primarily driven by the 'Compute Paradox.' The computational complexity of training next-generation large language models and highly parameter-dense deep neural networks yields a massive carbon and resource footprint. High-performance data centers demand continuous energy draws, heavily relying on regional electrical grids that, in many developing matrices, remain tethered to fossil-fuel generation. Furthermore, the localized ecological stress induced by data center infrastructure—specifically millions of gallons of fresh water required daily for evaporate cooling mechanisms—directly conflicts with SDG 6 (Clean Water and Sanitation). Therefore, the net sustainability yield of any AI deployment remains highly conditional upon the underlying grid efficiency and structural transparency.

Student 2

Sectoral Technical Innovations and Empirical Outcomes Within the domain of smart agriculture and ecosystem management (SDG 2: Zero Hunger; SDG 15: Life on Land), technical innovations have shifted from reactive monitoring to pro-active predictive intervention. The co-deployment of convolutional neural networks (CNNs) alongside high-resolution multispectral drone imagery has enabled macro-scale precision agricultural practices. These algorithmic systems perform localized pixel-level vegetative index analyses,

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mapping canopy nitrogen deficits and early-stage phytopathological outbreaks before visual decay manifests. By facilitating variable-rate nitrogen and pesticide applications, these frameworks dramatically decrease synthetic chemical runoff into localized watersheds, preventing coastal eutrophication and preserving terrestrial biodiversity matrices. In parallel, the stabilization of municipal and industrial energy infrastructure (SDG 7: Affordable and Clean Energy) increasingly depends on deep reinforcement learning (DRL) models. The primary systemic constraint impeding widespread global transition to renewable energy profiles is the inherent volatility of wind and solar capture. Traditional electrical grid architectures are fundamentally incapable of managing the rapid, stochastic fluctuations characterizing high-penetration renewable generation. DRL algorithms mitigate this constraint by acting as localized autonomic dispatch operators, continuously forecasting supply-demand equilibrium metrics, optimizing battery storage discharging cycles, and dynamically adjusting transmission pathways across regional microgrids. This computational synchronization reduces reliance on peak-load fossil-fuel generation facilities, improving overall network resilience.

Student 3

Socio-Economic Asymmetries and the Global South Data Gap The macro-level deployment of sustainability-focused artificial intelligence cannot be analyzed in isolation from historical, geopolitical, and socio-economic realities. An intense structural asymmetry characterizes the contemporary international algorithmic economy. While the primary environmental and social vulnerabilities associated with climate destabilization are disproportionately concentrated within the Global South, the intellectual, computational, and financial capital required to develop and govern advanced AI systems remains overwhelmingly monopolized by the Global North. This concentration creates an operational environment susceptible to digital neo-colonialism, where algorithmic architectures designed under Western institutional assumptions are unilaterally imposed on ecologically divergent communities.

This structural imbalance is exacerbated by severe data infrastructure gaps. Machine learning models require vast repositories of standardized, high-fidelity historical data to generate accurate predictive outputs. In many developing regions, historical meteorological registries, soil composition metrics, and public healthcare data archives are severely fragmented or entirely non-existent. When deep neural networks are trained on datasets heavily biased toward Global North environments and subsequently applied to sub-Saharan agricultural matrices or south-Asian monsoonal patterns, the resulting predictive errors can lead to catastrophic misallocations of critical food security and disaster relief resources. Bridging this data gap requires decentralized, open-access infrastructure initiatives that prioritize localized data sovereignty.

Student 4

Conclusion and Strategic Policy Recommendations In conclusion, artificial intelligence represents an incredibly potent yet structurally volatile mechanism for the advancement of sustainable development. The evidence demonstrates that while machine learning architectures offer unprecedented, high-efficiency pathways for optimizing ecological monitoring, precision agricultural frameworks, and renewable grid integration, their systemic resource intensity and localized infrastructural stress threaten to undermine these very advancements. Resolving this structural tension requires an immediate, coordinated shift from unconstrained algorithmic expansion toward a paradigm of strict, sustainability-first technical design and governance. To ensure that AI functions as a net-positive instrument for global sustainability, international regulatory frameworks must enforce comprehensive carbon and water accounting protocols for high-performance computing centers. Furthermore, public and private capital must prioritize the development of sparse, highly energy-efficient algorithmic architectures rather than pursuing raw parameter density. Finally, by aggressively addressing the Global South data gap through international technological transfers and localized open-source data architectures, the global community can democratize algorithmic optimization. Ultimately, artificial intelligence will only succeed in securing a sustainable global future if its computational deployment is structurally bound to the ecological and equitable limits of the planet it is tasked to protect.

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Original Article

Green synthesis and Sustainable Engineering: A Complete Review

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Abstract:

Organic chemistry is an important science in the sustainable development process. By allowing eco-friendly chemical, producing and reduced design. western energies and consumption. The practice of green chemistry has indeed revolutionized the old art of organic synthesis by promoting use of safer solvents and renewable resources, process efficiency, catalysis, atom economy and biodegradability are both eco-friendly and process efficiency economic solution. Organic chemistry is playing an important role in Sustainable Development, with its contribution to the design of environmentally friendly chemical processes and products. Green chemistry has revolutionized the traditional organic syntheses by employing less harmful solvents, renewable raw materials, efficient catalyst, higher atom economy, less waste, and using the biodegradable materials. Sustainable organic chemistry involves fossil-based feedstocks being replaced with renewable feedstocks like biomass, agricultural residues, vegetable oils, and carbohydrates. It also promotes more moderate reaction conditions and technologies which would help to reduce energy consumption. Such methods not only help to reduce resource consumption and process waste, but also offer environmental advantages. Hence, introducing green chemistry concepts into sustainable engineering can play a significant role in supporting sustainable industrial development and in the long-term economic growth, as well.

Keywords: *Green chemistry/ sustainable chemistry / organic synthesis/green synthesis/waste reduction/ renewable resources/ biomass/ catalysis/ atom economy/ energy efficiency/ sustainable engineering.*

Introduction

A subject that combines biology, ecology and other disciplines.
the underlying idea of the "inorganic" chemistry, which is the central concept of
green chemistry is centered around the field of organic chemistry.
One of the goals of green chemistry is to make organic synthesis a more sustainable process.
process both from a consumer's viewpoint (i.e. through reducing toxic hazard)
A process perspective (e.g. reducing the amount of energy used) and a utilization perspective (e.g. reducing wasteful uses)
Solvents, energy and waste treatment costs). Organic synthesis
process are perhaps the most significant source of waste both mass, and
Industrial production processes that are toxic.
They are frequently very energy and solvent intensive to facilitate
these reactions. The petrochemical sources that are used to initiate
these reactions are nonrenewable, and can be used to start,
only a single reaction. These are the materials used to produce these petrochemicals:
make solvents for green chemistry practitioners.

Environmental Benefits

Green chemistry offers a number of benefits as:

Development framework for sustainability.

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Changing to green chemistry has led to significant reduction in industrial
impact.
These modifications are largely responsible for the enhanced
New processes are related to environmental profile.
Waste reduction
Reduction of waste is one of the main advantages of green chemistry.
In general, excess reagent is used more, as well as the use of s
In conventional organic reaction, the formation of larger amount of byproducts.
The goal of green chemistry is to improve atom economy by increasing
The proportion of the starting material of the target molecules.
Use of catalysis and one pot techniques have helped cut waste
production even further. There is also greater chemoselectivity that enhances overall
efficiency.
Renewable Raw Materials are used for specific purposes.
Similarly, the use of renewable materials like agriculture or biomass, as opposed to fossil-based feedstock is promoted by sustainable organic chemistry.
Vegetable oils, residues, carbohydrates and other biological materials.
Platform molecules can be derived from biomass molecules, such as biomass-derived molecules being converted to platform molecules.
They were used for making polymers and then as solvents,
It is used for fuels, pharmaceutical intermediates, etc. This can help lessen dependence.
on finite petroleum resources and de-couple global production pipelines
Lower Energy Consumption from highcarbon fossil fuel many
In conventional chemical reactions, high temperatures are required to get the reactions to proceed.
pressures. Organic chemists are more and more creating catalysis and
an alternate reaction technologies that enable reactions to take place under non-standard conditions.
milder conditions.

Prospects and economic viability

- Global environmental dynamic change, industrial execution relies on.
- Heavily on the concept of blending environmental goals with economics.
- Raw resources cost is minimized and simplified in Green Chemistry Principles,
- Optimize modern process configurations, compliance procedures.
- Scaling these workflows will be very important for sustainable
- The economic growth of the next few decades.

Conclusion

Green chemistry offers an important set of principles for creating a more sustainable and environmentally friendly organic synthesis. The review emphasizes the importance of reducing waste, enhancing atom economy, catalysis, renewable raw materials, and the reduction of energy usage. Renewable materials, such as biomass, agricultural residues, vegetable oils, carbohydrates and others can minimize reliance on limited petroleum resources. Likewise, milder conditions and catalytic processes can be beneficial to process efficiency and reduce energy use. Environmental goals can be aligned with economics to further develop and scale sustainable chemical processes. Therefore, green chemistry in combination with sustainable engineering provides useful strategies for environmental protection and economic development in the future.

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Conflicts of interest

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

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