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Digital Transformation in the Age of FinTech and E-Commerce: Insights from Global Trends and Industry Reports

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Abstract

Purpose: The paper discusses how digital transformation (DT) is disrupting the FinTech and e-commerce ecosystems and how it is changing the management of customer experience, operational efficiency, and resiliency. The paper will (1) synthesise evidence on DT in the context of FinTech and e-commerce ecosystems, (2) conceptualise managerial implications of their convergence, and (3) suggest future research and practise agendas to support accelerating digital innovations.
Methodology: Secondary research design was chosen and a synthesis of peer-reviewed literature, global consulting reports, and publications by international organisations and regulatory bodies was carried out. A comparative and synthetic analytical approach was used to determine patterns of global adoption, technological innovation, and managerial performance.
Findings: The findings show the fast development of FinTech (digital payments, lending, Insurtech, blockchain) and e-commerce (cross-border trade, mobile-first purchasing, social commerce). Embedded finance, BNPL, and digital wallets enhance the customer experience and efficiency of operations, but create problems regarding compliance with regulation, credit risk, and consumer trust. Relative analysis reveals that developed economies are moving forward on a path of scale and infrastructure, whilst emerging economies are moving forward on a path of mobile-first inclusion models.
Conclusion: Digitalization of FinTech and e-commerce is no longer marginal; it is structural change of business on a global scale. Firms that find a balance between innovation, compliance and customer trust are best placed to experience long term benefits. More research is required to apply mixed methods and cross-national research to relate digital transformation more directly to agility, resilience, and sustainable growth theory.

Keywords: Digital transformation, FinTech, E-commerce, Embedded finance, Supply chain, Managerial implications

Introduction:

Digital transformation (DT) has become one of the most significant trends of the modern management that changes the approaches and methods of designing strategies, structuring work, and value creation on a functional level (Cioppi et al., 2023; Cosa and Carlucci, 2024). Strategy Digitalisation (DT) introduces data, platforms and smart technologies to business model and performance system reformulations that demand novel organisational agility and behaviours (Cosa & Carlucci, 2024). In the meantime, FinTech and e-commerce have added complexity to the restructuring of markets: digital payment, mobile wallets, embedded finance, and BNPL (buy-now-pay-later) options can no longer be distinguished as individual elements of an online shopping experience, and have transformed customer behaviour, firm capabilities, and competitive dynamics (Agarwal et al., 2025; Kumar et al., 2024; Yuan et al., 2025).

The simultaneous existence of FinTech and e-commerce to managers does not represent a channel change-a systems change. A fulfilment of scale, accelerated by e-commerce and informed by data supplied by a supply chain, can realise a winning distribution channel (Al Mashalah et al., 2022; Jing et al., 2024; Li et al., 2025). Embedded payment innovations on the platform, which lead to ticket size and conversion on the demand side (Kumar et al., 2024), also pose novel risk-regulation and financial-health challenges that managers need to address (Agarwal et al., 2025). The fact maybe that it is the amplified impact of the extension of the digital payment to the changes of higher orders in the macroeconomy that transforms the very concept of topicality of the policy and transforms the society (Birigozzi et al., 2025). This paper is a synthesis of global trends that have been documented in high-quality scholarly literature and sources within the industry to shed light on how the convergence of FinTech-e-commerce is re-wiring management practise. Although a number of reviews map DT in marketing and performance systems (Cioppi et al., 2023; Cosa and Carlucci, 2024), and empirical work quantifies the actual impact of FinTech in the real-economy or banking areas (Agarwal et al., 2025; Yuan et al., 2025), an integrated, management-focused synthesis across digital marketing, e-commerce, supply chain, and FinTech is relatively fragmented. To place the adoption trends and the market structure in context, we supplement peer-reviewed results with recent reports about the trends in the industry (World Economic Forum, 2024, 2025).

Objectives: Based on this positioning, the article attempts to:

(1) To bring together evidence on DT in FinTech and e-commerce ecosystems.

(2) To draw managerial conclusions across customer experience, operational efficiency, and resilience; and

(3) To map out research and practise agendas that can align firm strategy with rapid changing digital innovations.

Research Questions:

RQ1: To what degree has the digital transformation reshaped the FinTech/e-commerce ecosystem such that the adoption patterns, the innovation of new technologies, and the geographic aspects-based diffusion are believed to have occurred by 2020-2025?

RQ2: In the digital era, what are the new customer experience, operational efficiency and supply chain resilience because of FinTech-e-commerce convergence with managerial implications?

RQ3: What can be the research and practise agendas to align firm strategies to accelerating payments, digital platform, and supply chain management innovations?

Structure.

The paper continues to provide a specific literature review, methods section describing data sources and

data analysis methodology, research results on FinTech and e-commerce trends and integration into supply chains, and a discussion of policy and managerial implications, and directions of future research.

Literature Review

What is meant by digital transformation in management?

Digital transformation (DT) is not just the use of technology: it refers to the intentional reorganisation of resources, processes, and value propositions via digital technologies to gain sustained competitive advantage. Recent systematic and meta-reviews (Plekhanov, 2023; Reis et al., 2023) have demonstrated that DT is a multi-level phenomenon that can reshape organisational structures, performance measurement, dynamic capabilities and demand integrative frameworks that serve as a nexus between technological change, organisational change and managerial change. These works demonstrate that successful DT programmes are dependent on how digital investments can be aligned with strategic objectives, governance, and employee competencies, and not on technology itself.

FinTech development: milestones, acceptance worldwide, innovations

Published FinTech literature has grown at a fast pace and tracks the shift towards the payments and mobile banking paradigm to embedded finance, AI-based credit scoring, and platformed financial services. In recent bibliometric and review articles, a proliferation of publications is reported and emphasises key thematic clusters payments, blockchain/crypto, robo-advisory, insurtech, and AI to detect credit and fraud but notes regulatory and inclusion barriers to scaling innovations (Jafri, 2025; Pandey, 2025). Empirical literature also connects FinTech diffusion to modifications in bank performance and financial intermediation, implying not only productivity proceeds but also novel systemic risks that managers and policymakers should trade off.

E-Commerce development: platforms, changes in customer behaviour, omnichannel strategies.

According to electronic commerce studies in recent years, there has been a fast-track maturation in platform ecosystems, mobile commerce and integration of the omnichannel. Research indicates that consumers are increasingly expecting more seamless cross-channel experiences with faster delivery, personalization and frictionless payments (Liu, 2024; Sharma, 2025), and companies are responding by investing in platform capabilities through innovative last-mile delivery and personalization analytics. Another trend noted in the literature is a shift to experience-based commerce (social commerce, super-apps), which closely envelops services, loyalty, and payments.

Digitisation of the economy: FinTech and E-Commerce

Researchers are starting to consider FinTech and e-commerce as co-ecosystems and not silos. Recent research indicates embedded finance (payments, lending, insurance embedded into platforms), BNPL plans, and digital wallets are demand-side facilitators of increased conversion and basket sizes, and that they also impose new operational and regulatory burdens on merchants and platforms (Vukovic, 2025; Hasselwander, 2025). The convergence literature identifies network effects, where reach increases the distribution of financial products on a platform, and managerial tradeoffs between growth (conversion, monetization) and risk (fraud, credit exposure, compliance).

Management Change of Direction concept.

Digital Transformation (DT) is an emerging strategic requirement. In their paper, Chen et al. (2025) provide a comprehensive systematic literature review of the project management issue and the impact of DT changes on governance, agility, and capability building-lessons that can be applied to any management discipline. Further, Global Journal of Flexible Systems Management includes, DT is specifically an

organizational resilient performance flexible system which has the digital literacy and ethics components embedded in the performance systems (Cosa & Carlucci, 2024; APA). These kinds of studies bring DT together as a strategic orchestration, not the usage of technology.

This study investigates the connexion between organisational competence and SMEs.

Gonzalez-Varona et al. (2024) refer to SMEs because they think that DT assumes the development of organisational competencies through the learning, knowledge, and capabilities cultivation. They find that under resource-constrained conditions, SMEs contribute to digital maturity through internalisation of common knowledge and management flexibility (priceless knowledge).

Resilience Customer and Supply Chain Value.

Alquraish (2025) revisits the concept of DT, supply chain resilience, and sustainability and concludes that a model of a digital approach to a resilient and sustainable supply chain can be developed specifically in the context of manufacturing industries in developing economies. Tavana et al. (2022) provide the text mining to demonstrate how Industry 4.0 technologies, big data, AI, IoT, analytics, blockchain, and so on, transform SCM and make it flexible, circular, and sustainable. Brandtner (2024) works empirically/practically in the interview mode and analyzes the experts in the area, attempting to reveal the key barriers to the SCM data analytics integration process, and propose possible solutions, including explainable AI and data governance, to find a balance between trust and adoption.

FinTech / E-Commerce Convergence.

Dai et al. (2024) consider the dynamics between digital financial inclusion (DFI) and the evolution of e-commerce in China as a synbiotic ecosystem that thrives with the emergence of entrepreneurship. Their paper draws attention to how DFI tools built into e-commerce platforms minimise friction in transactions and democratise access to SMEs and rural entrepreneurs-a clear demonstration of FinTech-e-commerce convergence as creating managerial opportunity and inclusion.

Technology Acceptance/Trust of E-Commerce.

A bibliometric survey (2024) of e-payments and technology acceptance constructs conducted by MDPI suggests that trust, perceived usefulness, and risk are closely connected in consumer uptake of e-commerce-and, by proxy, embedded payment solutions. As critical as the functionality of the technology in determining adoption and organisational strategy is trust-driven design and security.

Review of Knowledge Gaps for Combinative Cross Domain Research

The expansion of literature highlights a disjointed landscape: we do not have cross-domain, integrative empirical research that brings DT, FinTech, e-commerce and SCM together into a single managerial system. The majority of the works are still domain-specific (e.g., supply chain resilience, SME capabilities, or financial inclusion). We badly need integrative syntheses relating market-level trends (DFI, e-commerce expansion) to the firm-level management implications (capability-building, performance systems, resilience). Despite a significant amount of work on the domain (DT, FinTech, e-commerce, supply chain), recent reviews consistently report an inadequate evidence base: only a small number of studies have offered comprehensive cross-domain analyses that integrate managerial outcomes (customer experience, operational efficiency, resilience) with macro adoption patterns and regulatory dynamics. In addition to that, most of the empirical works are one country, one platform based, and generalisation is problematic; the weakness in the research methodology is small longitudinal experimental studies and insufficient multi-source data to compare performance at the company level to tendencies at the ecosystem level (Pandey, 2025; Plekhanov, 2023). Such gaps encourage an integrative, management-driven synthesis that is based on indexed research and quality industry evidence.

Methodology

The current research uses the analytical design, based on secondary sources, to investigate the changing dynamics of digital transformation in FinTech and e-commerce. Instead of gathering primary data, the analysis relies on previous knowledge bases that present the overall understanding of the global trends in digital form. In this way, the findings will have a sound basis in authoritative, diverse, and up-to-date sources. The research data were obtained using various types of secondary data. First, the managerial opinion and future-looking strategies towards the digital economy were embraced by consulting reports published by major companies including PwC, McKinsey, Deloitte, and BCG across the globe. Second, we utilised publications of international organisations, such as the World Bank, IMF, OECD, and UNCTAD to contextualise the macroeconomic, regulatory, and policy aspects of digital transformation. Third, we reviewed industry-specific reports, with a specific focus on annual reports of the Reserve Bank of India, publications of the bank of international settlement, and digital finance and e-commerce studies of the world economic forum. All these sources provide an abundant source of evidence that connects the academic to the practitioner and policy perspectives.

It has been a comparative and synthetic study of analysis. Systematic screening of reports and datasets was performed to obtain relevant indicators and thematic insights. The most recent trends were consolidated into 3 categories of customer experience, operational efficiency and resilience. This was then cross-referenced by geography and sector to enable shared success factors and regional directions to be identified. The synthesis of results provided the opportunity to build a compound image of the revolution of management in the Digital Era since the instrument of management practice of the world of FinTech and e-commerce is being changed within the frames of the digital revolution. Like any other secondary analysis, this paper is limited. Such findings rely on the quality and extent of the reports that have been accessed and can vary in approach and depth. Even a few insights are becoming obsolete in the very near future, due to the pace of digital innovation. Furthermore, no statistical validation and primary empirical testing are carried out in the study but also patterns and implications have been obtained. These weaknesses are what, in their turn, also signalise that further research may be done to build on the evidence synthesised through the primary data collection and quantification techniques.

Findings and Analysis

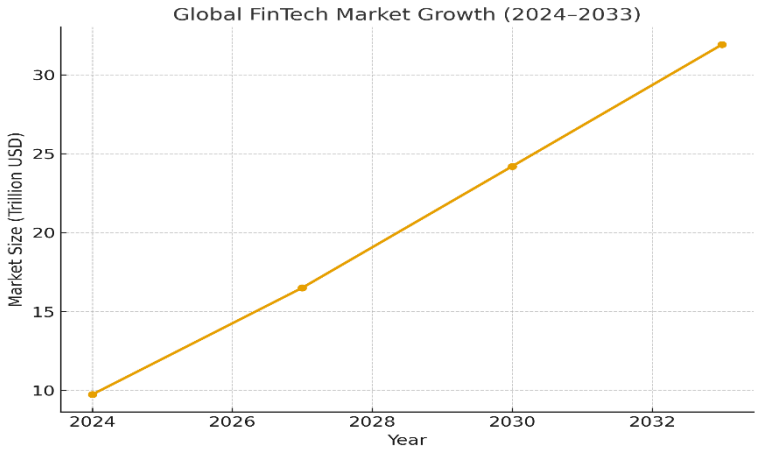
Global Trends in FinTech

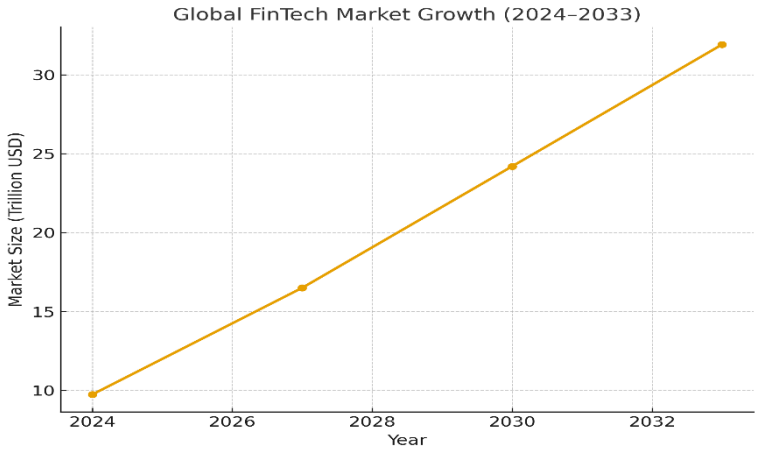
FinTech sector is growing at a fast. The global market is projected to hit USD 321 billion in 2025, and USD 653 billion in 2030, a growth rate of 15.3 percent on a compound annual basis (CAGR). Funding to FinTech reached a reset with USD 44.7 billion in H1 2025 -- the lowest on record since H1 2020 -- as investors retreat due to an uptick in interest rates and a chill on appetite. But the sector is showing its strength; major FinTech companies with a revenue over USD 500 million per year currently occupy 60 percent of all FinTech revenue and are expanding three times more rapidly than conventional banks. Regarding sub-sectors, digital payments are the leading FinTech use cases, then digital lending, Insurtech, and blockchain-based solutions such as neobanks. It is widely adopted by consumers and enterprises: 78 per cent of all users of the internet across the world currently use at least one FinTech product per month, with millennials taking the lead with 91 per cent adoption rate and the total digital payments are expected to reach USD 9.2 trillion by the year 2025. However, the FinTech industry is still expanding at a fast pace even though investments are going to slow down in early 2025. The market is dominated by digital payments, then lending, Insurtech, blockchain applications, and neobanks.

Table 1. Key Global FinTech Metrics

Indicator	Value/Projection	Source
Global FinTech market size (2024)	USD 9.74 trillion	Business Research Insights (2024)
Projected market size (2033)	USD 31.92 trillion (CAGR 13.9%)	Business Research Insights (2024)
Global FinTech funding (H1 2025)	USD 44.7 billion (2,216 deals)	KPMG (2025), *Pulse of FinTech*
Digital payments user base (2024)	> 3 billion users	Siege Media (2024), *FinTech Statistics*

Analysis: The market is growing or expanding at a fast pace with digital payment and lending acting as anchors. Whilst the rate of growth has decelerated from the peak of valuation growth, the big-box FinTech companies (revenue > USD 500m) are growing three times faster than traditional banks (BCG, 2025).





Graph 1: Global FinTech Market Growth (2024–2033)

Source: Statista (2024), PwC FinTech Report (2023), World Bank Digital Finance Report (2024).

This chart shows the estimated growth of the FinTech sector in the next 10 years. The trend is a positive

sign of advancements in payments, digital lending, blockchain, Insurtech, and neo banking. According to the data, Asia-Pacific is growing fastest due to the high rates of mobile adoption and enabling regulatory sandboxes, and Europe and North America are growing at steady, albeit stable, paces (driven by digital payments and embedded finance).

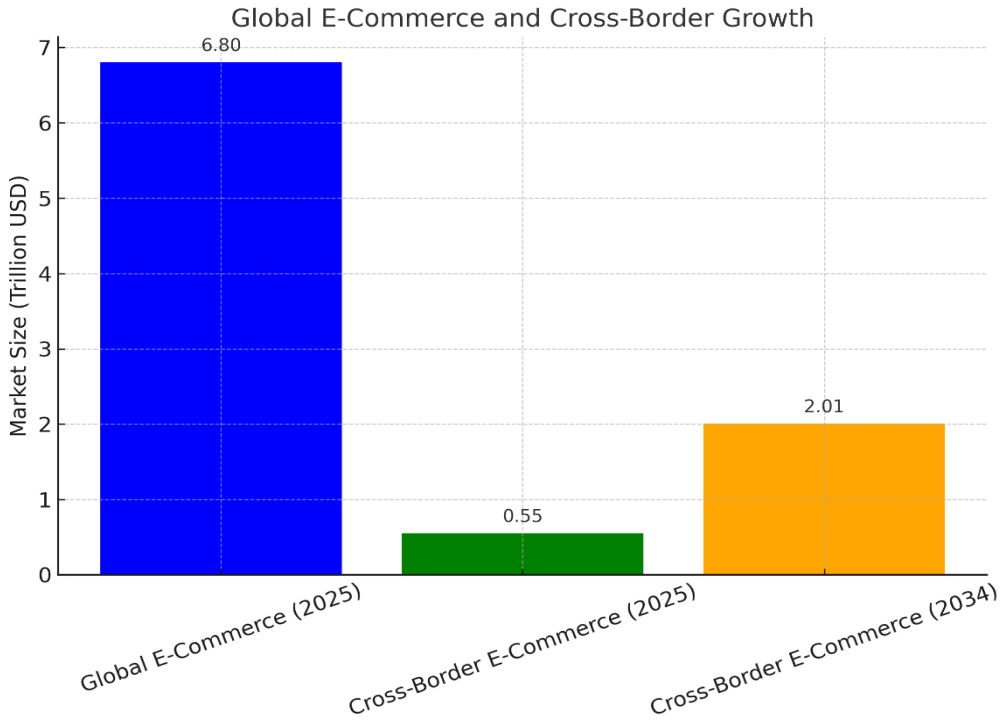
Global Trends in E-Commerce

E-commerce is rising steadily. It is estimated that the global market will exceed USD 4.8 trillion in 2025 (comprising 23% of all retail transactions by 2027). The e-commerce across the borders is booming and is expected to reach USD 1.47 trillion in the year 2025, USD 4.81 trillion in 2032, growing by a CAGR of 18.4. Logistics is changing accordingly: the cross-border e-commerce logistics market will increase to USD 102.55 billion in 2025 and continue to grow with the forecast CAGR of 18.3% up to 2029. In the meantime, last-mile delivery is tracking a strong growth-projected to USD 68.5 billion in 2024 and USD 165.1 billion in 2034 with a 9.2% CAGR. Consumer behaviour is also evolving: social commerce, mobile-first and personalization are becoming increasingly aggressive. Moreover, resale e-commerce is also sustainable and cost-effective: the resale market will surpass USD 100 billion by 2026, with 60% of Americans expected to participate in the second-hand sales between 2022-2023. E-commerce is still growing as a leading channel of retail. Consumer engagement is being transformed through mobile-first commerce, cross-border commerce and social commerce..

Table 2. Global E-Commerce Growth Trends

Indicator	Value/Projection	Source
Global e-commerce sales (2025)	USD 6.8 trillion	Sellers Commerce (2024)
Cross-border e-commerce market (2025)	USD 551.2 billion	Precedence Research (2025)
Cross-border projection (2034)	USD 2,006.9 billion (CAGR 15.4%)	Precedence Research (2025)
Global B2C e-commerce sales projection (2027)	USD 5.5 trillion (CAGR 14.4%)	U.S. International Trade Administration (2024)
Online retail share of total purchases (2025)	21%	Sellers Commerce (2024)

Analysis: The e-commerce will reach USD 7 trillion in 2025 and cross-border trade will explode. The next stage of growth is being determined by supply-chain digitisation and consumer behaviours that are driven by sustainability (resale commerce, personalisation)..



Graph 2: Global E-Commerce and Cross-Border Growth

Source: UNCTAD E-Commerce Index (2024), eMarketer Global E-Commerce Outlook (2024), OECD Digital Trade Report (2023).

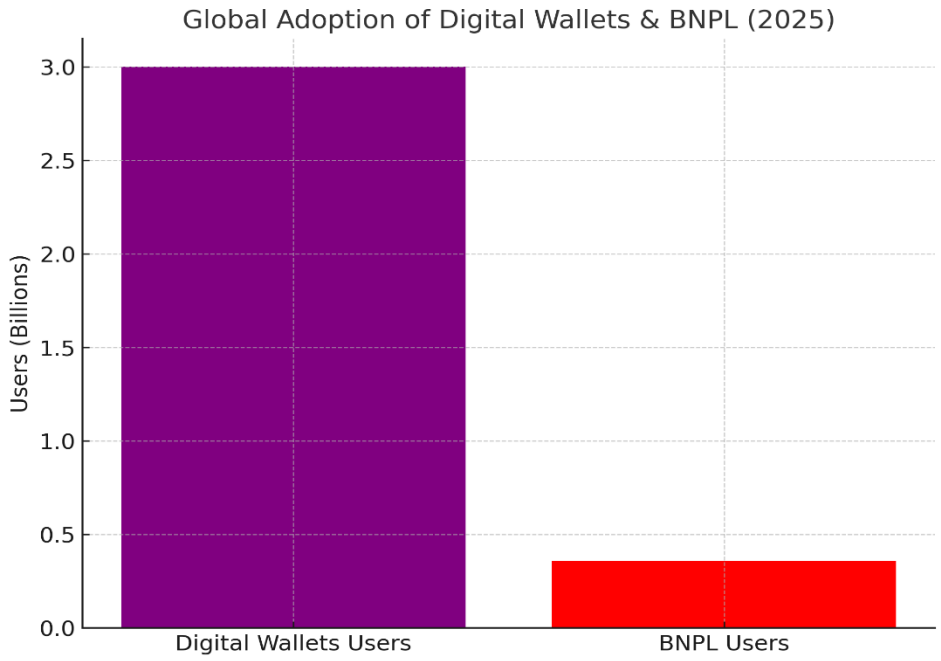
This chart shows how e-commerce sales have been growing exponentially around the world with a robust increase in cross-border trade. The information indicates the growing influence of mobile commerce, social commerce, and AI-based personalization on consumer behaviour. Interestingly, some of the most promising markets today are in emerging economies like India, Southeast Asia, and Africa and they are being supported by mobile-first platforms and better logistics. Instead, developed economies prioritise customer experience improvement via omnichannel policy and sustainability.

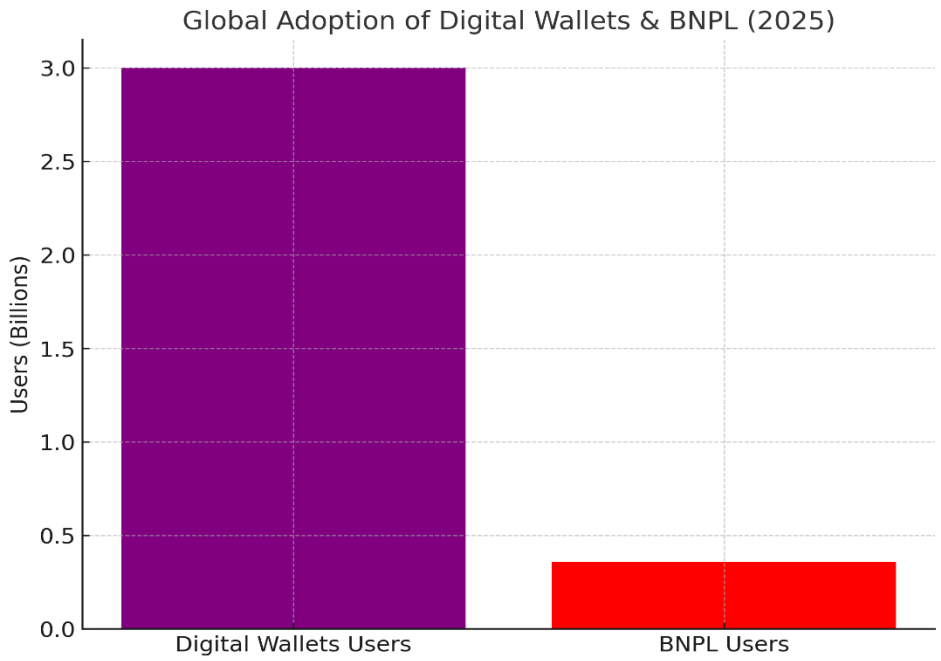
Convergence of FinTech and E-Commerce

The merging of FinTech and e-commerce are changing the digital business model. Embedded payments, BNPL, digital wallets, and platform financing streams (e.g. Amazon Pay, Alipay)- although platform-specific data was not provided in the latest reports are also common drivers of conversion and consumer retention. The spread of FinTech to the industry is also evident in payments infrastructure worldwide, such as RTPs (real-time payments), blockchain, and key open banking facilitators of frictionless cross-border trade and platform-based financial services. E-commerce is becoming more integrated with payments and financing. The convergence front runners are digital wallets, Buy Now, Pay Later (BNPL), and embedded finance.

Case Examples:

- With Alipay (Alibaba) and Amazon Pay, the gateway for hassle-free checkout has become an integral part of the equation.
- An example of local ecosystems building on embedded payments is Paytm and Flipkart (UPI integration in India).
- Global FinTech infrastructures will facilitate cross-border e-commerce (real time payments, RTP, blockchain) (Convera, 2025).





Graph 3: Adoption of Digital Wallets & BNPL (2025)

Source: BIS Payments Report (2024), McKinsey Global Payments Report (2024), IMF Digital Finance Insights (2023).

This graph shows the adoption within the digital wallets and Buy Now, Pay Later (BNPL) in each area in terms of percentages. Asia is at the forefront in terms of wallet adoption, with apps such as Alipay, WeChat Pay, Paytm; and the BNPL would have better chances to expand in Europe and North America, where people are more receptive to flexible credit. These results show that there was convergence between payment innovation and consumer demand in the dimensions of affordability, and convenience. This presents an opportunity to businesses to attract new customers and a risk of rising credit defaults.

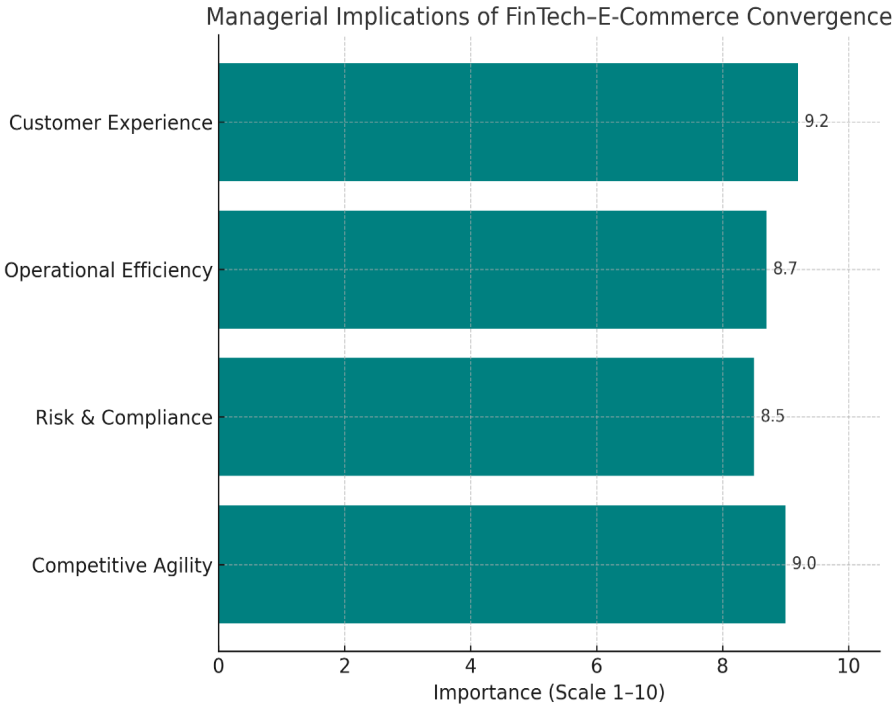
Implications for Management in the Digital Age

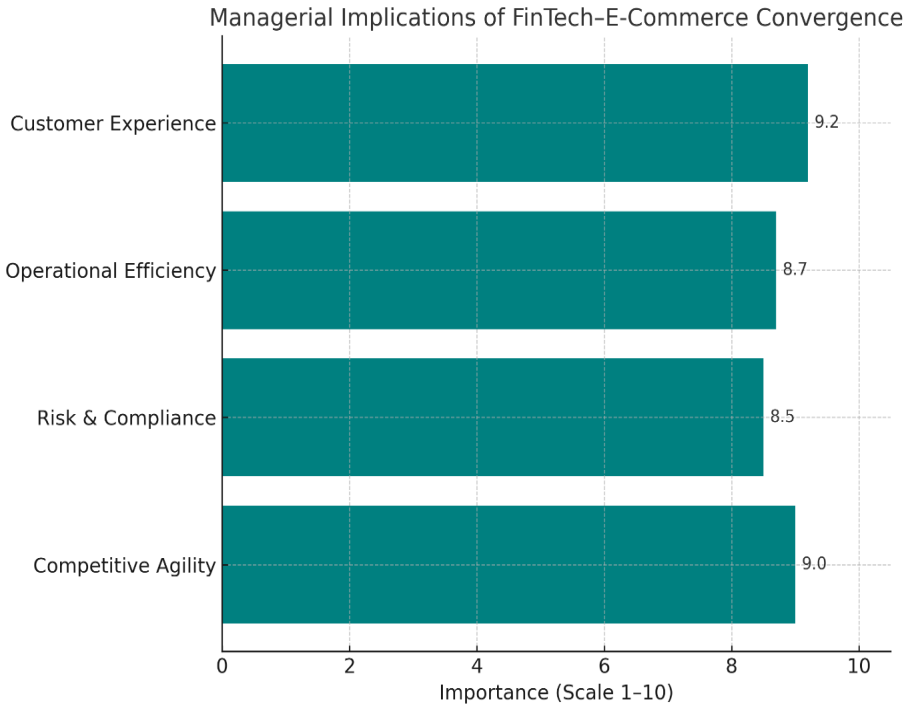
1. Customer Experience Improvement: Embedded payments, BNPL, and personalization all play a role in improving customer experience, resulting in increased customer satisfaction and retention. The resale and the social trade are what makes it more interactive and community-building-which is one of the keys to brand loyalty.
2. Operation productivity: Fast fulfilment, instant payment, and efficient logistics reduce operation costs and friction, especially when cross-border and last-mile delivery networks are utilised.
3. Risk and Regulatory Compliance: As the FinTech develops, the necessity to comply with regulations related to open banking, payment security, and digital identity models gains even more significance. In addition, BNPL poses credit risk that must be controlled.
4. Strategic Agility and Competitive Advantage: Integrated payment and finance solutions can provide businesses with a strategic advantage over their competitors. Native FinTech businesses are growing and expanding at an accelerated rate compared to traditional empires (3 times the rate). E-commerce players that are capitalising on the logistical innovation like the ship-from-store are also enjoying the competitive advantage of being fast in their delivery and local fulfilment.

Table 3. Managerial Implications of FinTech–E-Commerce Convergence

Dimension	Implications	Source
Customer Experience (CX)	Embedded payments, BNPL, and personalization enhance loyalty & satisfaction	World Economic Forum (2025)
Operational Efficiency	Real-time payments & logistics digitization reduce cost & delays	OECD (2024); Market.us (2024)
Risk & Compliance	Regulation of open banking, BNPL credit risks, and fraud monitoring critical	BIS (2024); IMF (2025)
Competitive Agility	Firms with integrated payments scale 3× faster than traditional peers	BCG (2025)

Analysis: Another trade-off between stability of operation and regulatory elasticity versus customer-focused innovation among managers is FinTech and convergence of e-commerce. Long-term strategic agility can be most easily ensured by the most rapidly developing companies within the embedded finance and supply-chain digitalization.





Graph 4: Managerial Implications of FinTech–E-Commerce Convergence

Source: Deloitte Digital Transformation Survey 2024; BCG Future of Payments Report 2023; World Economic Forum Digital Platforms Study 2024

The figure below represents the overview of the most significant managerial outputs of digitalization in the FinTech and e-commerce sectors. It then describes four zones of inference as follows (1) customer experience in the form of personalization and frictionless digital experiences, (2) operational efficiency in the form of automation and digital supply chains, (3) regulatory and risk compliance in the form of absolute capability and (4) strategic agility in the form of a competitive differentiator. Thus, digital managers have to find a balance between models of business and transforming technologies and provide the consumer with confidence and the regulator with readiness. The findings confirm the idea that FinTech is accelerating and is headed in the same direction as e-commerce, with massive potential to reshape customer interaction, operating patterns and positioning. The trends show that there is mounting pressure on companies to implement a hybrid digital finance model and a strong supply-chain model.

Discussion

One can learn about the reasons why digitalization in FinTech and e-commerce is not a phenomenon of edge, but is a paradigm shift in business ecosystems on a global scale. It is more acceptable given the evidence that digital payments, digital lending, Insurtech, blockchain, and neobanks are now mainstream growth enablers. Because the global FinTech market has a potential to become USD 9.74 trillion, by 2024, and USD 31.92 trillion, by 2033, as Business Research Insights, 2024, says, we can certainly say that the process of digitalization has become an indispensable part of financial and commercial transactions. However, these developments have not been evenly spread across geographical boundaries, nor do institutional maturity, client trust and regulatory coherence have equal appeal. But as we might view the developed world as ahead in terms of technological and capital investment, with the US and Europe in the lead, the emerging markets of the Asian and African regions are not trailing them but actually running ahead in embracing mobile-first and inclusive payment systems. UPI in India and Alipay

in China can be considered as the best examples of how to use standards to allow local innovations to build digital payment standards that become the global standard of affordable and high-volume digital payments (WEF, 2025). The European market will not be spared from the consequences of the insufficiently coherent policy, nor the American market from the concerns of the consumers about their trust and privacy when it comes to adoption. This loss is exploited to prove the point that in the developed markets, customers are gaining support, and more to the point, efficiency in infrastructure and scale, whereas the emerging markets are gaining support and more to the point, efficiency in necessity-driven financing and inclusion.

The results have subtle business, government and people implications. When it comes to business, embedded payment options, Buy Now Pay Later (BNPL) applications, and cross-border e-commerce services provide access to new revenue streams, plus, they raise the competition. Otherwise, less innovative companies will probably be forced out by more agile, digitally native ones. The dilemma presented to policy makers, particularly in emerging economies is to promote innovation, whilst safeguarding consumer rights, financial stability and data protection. BIS and RBI already pay attention to the risks of BNPL, open banking and digitised wallet (BIS 2025) For consumers, the change implies more convenience, customization and less cost, but at a price of over-indebtedness, cyber fraud and loss of privacy. In principle, the paper helps to bridge the divide between digital transformation and management practice by demonstrating that technological convergence is re-inventing competitive advantage. Cost-efficient, scale-based competitive capabilities models are currently converging with models of dynamic capabilities in which nimbleness, durability and rate of innovation replace scale. In particular, the case of FinTech and e-commerce demonstrates that companies are no longer competing as individual islands, digital or not, but are instead parts of more digital ecosystems. This leaves managers with no choice but to re-strategize not just based on the efficiency of the operations, but also on responsiveness to changing environments with extremely high rates. In general, it has been concluded in the discussion that digital transformation is both an enabler and a disruptor. It allows companies and customers to receive more personalised, cheaper and faster services and breaks down the previous business models and rules. The comparative experience of the developed and developing economies also demonstrates that there exists no single approach to the digital transformation and that success depends on the circumstances, adaptability and alignment of technology, manager practises, and regulative design.

It is due to the rate at which FinTech and e-commerce are evolving that the analysis of the long-term consequences of the digital transformation should be tracked. We suggested that further research was necessary to transcend market size analysis and adoption pattern analysis to more advanced research on resilience, inclusiveness and sustainability studies. The first opportunity would be to realise how embedded finance across borders and e-commerce can revitalise consumer credit behaviour, especially in a developing economy where digital access and financial literacy can be highly heterogeneous. And, the research can assist policymakers in making evidence-based recommendations about how to create a healthy balance between innovation and consumer protection. The second trend is the emergence of new analytical instruments in the field of studying digital ecosystems: artificial intelligence, big data, blockchain. These technologies are not only making transactions more effective and more trusted, but are also creating new types of risk, such as algorithmic bias, systemic cybersecurity vulnerabilities, and data monopolisation. Proper consideration of these dichotomies will be a significant step in assisting firms and regulators to identify a better balance between the two. There should also be an increase in cross-regional comparison studies. Although the problem of data privacy and regulatory harmonisation is more crucial to the developed economies, the problem of low cost high scale-up is more crucial to the developing economies. Cross-national, time-series would give the contextual heterogeneity that defines digital uptake patterns on a wider international context, allowing firms and international organisations to shape more informed international strategies.

Finally but not the least, the management scholarship should theorise the intersection of the digital transformation and organisational practises. Nowadays, we can state that strategic agility, ecosystems cooperation, and customer-focused innovation become fashionable skills. This evidence could be subjected to empirical test in future research, and it could be assisted by the application of mixed methods to guide managerial decisions as an intermediary between the use of technology and the results of business performance. It would in effect be achieved by institutionalising action to mainstream technological literacy and adaptive governance as a leadership agenda to help organisations maintain their innovation and resiliency into the digital era.

Conclusion and Future Directions

This paper has touched on how FinTech and e-commerce are revolutionising business and financial ecosystems across the world. These results support the idea that digital payments, embedded finance, cross-border commerce, and mobile-first commerce are no longer the marginal innovations, but the engines of growth. It demonstrates that the developed economies are advancing up the infrastructure and investment ladder and the developing economies are galloping forward with joint and portable innovations such as UPI in India and Alipay in China. Together these phenomena suggest, however, that digital transformation is not a helpful omnibus process, but a situational phenomenon, contingent on institutions, the regulatory environment and consumer behaviour. Managers see FinTech and e-commerce as a challenge and opportunity. Enhanced customer experience, operational efficiency and strategic agility - all creates opportunities to enhance competitive positioning whilst the manager must face threats of uncertainty in the regulatory environment, threats of information security and threats of over-indebtedness to consumers. The most likely firms to take advantage of this changing environment in the long term are also those that have hit the right balance between standards and consumer confidence and innovation.

The analysis has some limitations to it, however. The knowledge gained in the study is conditional on the accuracy, breadth, and timeliness of the material used as the research relies on secondary materials (industry reports, international databases, and regulatory publications). Digital finance and commerce are growing and digital results can quickly become outdated. Moreover, they empirically test neither heterogeneity of firms nor evidence of causal relationships, and though they synthesize the global trends, they do not test them. The disadvantages above are evidence that further investigation would be required as primary research to demonstrate and broaden the findings. The gaps in the prospective research would be bridged with the mixed research by applying the mixed methods research method to concentrate on macro trends and micro-level strategies in organisations. Comparative research across national boundaries will prove especially useful in terms of adoption and other regulatory regimes and cultures. Moreover, new concepts like artificial intelligence, new type of trading with distributed ledger technology, sustainability of digital commerce must be explored further. By bringing the digital transformation slightly nearer to management theories of agility, resilience and dynamic capabilities, future research could make a contribution to the academic knowledge base and practise of management.

In brief, digital transformation in the FinTech and e-commerce industries is revolutionising the relationship between enterprises, the policymakers, and the consumers. Organisations that prioritise innovation but also trust, adherence, and adaptability will be best placed to survive in the digital age.

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Corporate Social Responsibility and Sustainability: Anchoring Ethical Practices in Core Business Strategy

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Abstract

Corporate Social Responsibility (CSR) and sustainability have become central to modern corporate governance, as organizations are increasingly expected to integrate ethical, social, and environmental considerations into their business models. This paper examines the theoretical foundations and practical applications of CSR and sustainability, highlighting their evolution, definitions, and interplay with corporate citizenship and corporate responsibility. By analyzing international frameworks such as the UN Global Compact, ISO 26000, and OECD Guidelines, the study underscores the necessity of embedding CSR into core business operations rather than treating it as an ancillary function. The conceptual framework presented illustrates how CSR impacts stakeholders, supply chains, and long-term competitiveness. Ultimately, the paper argues that sustainability-driven CSR is no longer optional but a strategic imperative for firms aiming to balance profitability with societal value creation.

Keywords

Corporate Social Responsibility, Sustainability, Corporate Citizenship, Corporate Responsibility, Business Ethics, Sustainable Development

Introduction

Corporate Social Responsibility (CSR) has become a cornerstone of contemporary business practice, fueled by the growing need for ethical governance, environmental sustainability, and social responsibility. Historically, corporations were evaluated primarily in terms of financial performance; however, the twenty-first century has seen a paradigm shift towards the triple bottom line—economic, social, and environmental performance (Elkington, 1998). It is not merely an ethical responsibility but also a strategic imperative that determines consumer trust, investor confidence, and regulatory compliance (Aguinis & Glavas, 2012).

Although CSR and sustainability are sometimes considered synonyms, their conceptual frontiers differ. CSR is concerned with a corporation's accountability to society, whereas sustainability deals with long-term ecologic and social sustainability (Bansal & Song, 2017). The adoption of CSR within the main business strategy is a revolutionary approach where companies bring profitability in line with accountability (Carroll & Brown, 2018; Dyllick & Muff, 2016).

The increasing importance of CSR is also evident in international reporting guidelines, including the Global Reporting Initiative (GRI) and the UN Sustainable Development Goals (SDGs), which prompt organizations to integrate sustainability into strategy, governance, and disclosure (Kolk, 2016). Thus, CSR is not only corporate philanthropy but also a recasting of value creation for various stakeholders.

This essay discusses the interrelation between CSR and sustainability, distinguishes between similar constructs like corporate citizenship and corporate responsibility, overviews the academic literature, and suggests a conceptual framework for integrating CSR into organizational strategy.

Literature Review

Corporate Social Responsibility (CSR) evolution over time traces a path from voluntaristic philanthropy towards strategic embedding in organizational performance. Initial scholarship, including Bowen's (1953) seminal definition of CSR as business managers' responsibility to harmonize corporate policies with societal expectations, set the stage for future theoretical progress. Carroll's (1991) CSR Pyramid further developed this discussion by positing four tiered CSR responsibilities—economic, legal, ethical, and philanthropic—that continue to influence both theory and practice.

The intersection of CSR and sustainability has been one of the central lines of argument. The Brundtland Report (WCED, 1987) defined the concept of sustainability as "meeting the needs of the present without compromising the ability of future generations to meet their own needs," thus stressing intergenerational equity. Porter and Kramer (2011) redefined CSR in terms of Creating Shared Value (CSV), whereby companies create economic value through addressing pressing societal issues at the same time, which emphasizes CSR as a driver of innovation, not as a cost of compliance.

A number of international frameworks support the integration of CSR and sustainability. The UN Global Compact (2000) offers ten universal principles on human rights, labor, environment, and anti-corruption, calling for international companies to integrate CSR into strategy. In the same vein, the OECD Guidelines for Multinational Enterprises (2011) and ISO 26000 (2010) normalize CSR practices across sectors to promote comparability and accountability (Moon, 2014).

Academic discourse has also elucidated differences between analogous constructs. Corporate citizenship, typically framed by philanthropy and community involvement, maintains a more limited focus (Matten & Crane, 2005). Conversely, corporate responsibility (CR), common in European environments, widens CSR to include governance and economic responsibility (Habisch et al., 2011). This theoretical extension demarcates that CSR is not an invariable concept but a multifaceted construct shaped by cul-

tural, regional, and regulatory environments.

Current research points to the necessity of measurement frameworks for the evaluation of CSR and sustainability effects. For example, Younas (2024) developed a CSR index aimed at measuring corporate citizenship across advanced economies, which serves as a link between theoretical CSR concepts and ground-level performance measurement. Similarly, Berkouk et al. (2025) describe the convergence of creativity, technology, and sustainability, with a focus on joint efforts between academia and industry towards CSR-based innovation. Eccles, Ioannou, and Serafeim (2014) had empirically proved that companies with good sustainability practices outperform their peers in the long term, especially in governance and transparency aspects.

Together, the scholarly consensus indicates a revolution in change: CSR needs to shift away from marginal, philanthropic practice toward integration at organizational DNA—strategy, supply chains, innovation systems, and reporting frameworks. Such embedding not only creates resilience but also legitimates companies as sustainable players in global society.

Conceptual Framework

The conceptual framework of the paper sits Corporate Social Responsibility (CSR) as a strategic anchor that bridges sustainability objectives and business conduct. Instead of being an ancillary activity, CSR is envisioned as a structural mechanism integrated throughout corporate strategy, stakeholder interaction, and long-term sustainability outcomes.

Integration of Core Business

CSR needs to be integrated into daily organizational operations, from energy conservation, resource management, and sustainable procurement to employee health, workplace safety, and diversity and inclusion policies. Researchers highlight that operational integration by means of CSR improves resilience and flexibility in volatile market environments (Eccles, Ioannou, & Serafeim, 2014). Additionally, incorporating environmental, social, and governance (ESG) considerations into corporate strategy not only reduces reputational and regulatory risks but also promotes innovation and efficiency improvements (Zilberman, Gordon, Hochman, & Wesseler, 2023).

Empirical evidence further supports that companies integrating CSR into supply chains—via ethical procurement, decent working conditions, and circular economy practices—can build systemic change that scales sustainability impacts across the boundaries of organizations (Seuring & Müller, 2008). This operational alignment recasts CSR as a value-creation function, in which environmental responsibility and profitability support each other (Porter & Kramer, 2011).

Stakeholder Engagement

Stakeholder dialogue is the second pillar of the framework, based on Freeman's (1984) stakeholder theory, which posits that companies are part of a network of relationships and need to balance often competing stakeholder expectations. Proactive CSR measures include ongoing and open communication with employees, customers, communities, governments, NGOs, and investors.

Such interaction creates social license to operate and corporate legitimacy, a principle focusing on the tacit approval society and communities offer when firms behave ethically (Demuijnck & Fasterling, 2016). Successful stakeholder discussion enhances trust and co-creation of value, allowing companies to foresee social risks, align CSR practices with culture, and sustain competitive positioning (Rahman, Rodríguez-Serrano, & Lambkin, 2023). Digital technologies also boost stakeholder engagement by making the firm more transparent, interactive reporting easier, and communities able to hold businesses accountable (Zilberman et al., 2023).

Sustainability Outcomes

The third pillar focuses on sustainability outcomes, which comprise long-term environmental conservation, social justice, and economic resilience. This aspect accords with the triple bottom line approach (Elkington, 1998), which captures the interconnectedness of people, planet, and profit. CSR-led sustainability outcomes are achieved through lower carbon footprints, equitable labor practices, community engagement, and governance transformation that promotes accountability.

Integrated CSR strategies not only enhance brand image and customer loyalty but also make companies resilient to systemic threats like climate change, supply chain failures, and regulatory changes (Ziółkowska, 2024). Notably, companies that integrate CSR with sustainability results tend to be more successful in the long term, as they create value that is shared by business and society alike (Porter & Kramer, 2011).

This perspective places CSR in terms of process and outcome. Core business integration guarantees that CSR is put into practice; stakeholder involvement legitimates such practices to society; and sustainability impacts demonstrate long-term societal and environmental worth created. CSR is thereby theorized not as philanthropic "add-on" but as a core aspect of organizational identity, strategy, and competitiveness. By consolidating these three cornerstones, companies can harmonize profitability with responsibility and, as such, ensure survival and applicability in an ever-changing global economy.

Discussion

The interlinkage between CSR and sustainability is increasingly seen as a driver of corporate legitimacy, resilience, and long-term survival. Companies treating CSR as a voluntary philanthropic appendix run reputational risks, stakeholder doubt, and dwindling legitimacy, as CSR needs to show real impact instead of symbolic action (Banerjee, 2008). Companies integrating CSR into their central strategies, however, benefit from multi-dimensional competitive gains such as higher brand equity, increased consumer loyalty, higher innovation ability, and better risk management (Porter & Kramer, 2011; Rahman, Rodríguez-Serrano, & Lambkin, 2023). There is also evidence that strategic CSR integration promotes employee commitment and retention of talent, enhancing organizational performance (Glavas, 2016).

There are nevertheless huge challenges for operationalization and reliability in CSR. Perhaps the most enduring critique is that CSR reporting tends to degenerate into greenwashing, where companies make exaggerated claims but fail to deliver tangible results (Laufer, 2003; Banerjee, 2008). Although standardized systems like the Global Reporting Initiative (GRI) and Sustainability Accounting Standards Board (SASB) have developed, variations in reporting indicators, selective disclosure, and volunteerism still impede comparability and trust (Hahn & Kühnen, 2013). In addition, small and medium-sized businesses (SMEs) typically do not have managerial or financial resources to embed CSR practices in-house, thus constraints in scalability and inclusivity relative to multinational companies (Jamali, Lund-Thomsen, & Jeppesen, 2017). This underscores the necessity of context-specific CSR models that respond to variations in organizational size and capacity.

The global–local dynamics provide an additional level of complication for CSR adoption. Western CSR models tend to focus on governance, transparency, and environmental responsibility, indicative of institutional pressures in mature economies (Moon, 2014). CSR activities in emerging markets, on the other hand, focus mainly on poverty reduction, job creation, and community development (Visser, 2008). This divergence emphasizes the importance of adaptive CSR models that are sensitive to cultural norms, institutional arrangements, and socio-economic conditions (Matten & Moon, 2008). Failing to consider these differences could lead to the application of universalist CSR models that may not be relevant or legitimate in varied settings.

Lastly, the function of technology in implementing CSR is increasingly central. New digital technolo-

gies like blockchain, artificial intelligence, and big data analytics are revolutionizing CSR through higher traceability, involvement of stakeholders, and accountability (Zilberman et al., 2023). Blockchain facilitates tamper-proof supply chain histories that guarantee ethical sourcing; AI aids in predictive models of environmental risk; and big data analytics give insights into stakeholder demands and sustainability performance. These innovations provide solutions to traditional criticisms of CSR as cosmetic or unverifiable, taking the discipline toward an evidence-based, data-driven paradigm.

Conclusion

CSR and sustainability are no longer niceties but strategic necessities for corporations operating in the twenty-first century. As problems such as climate change, resource constraints, and social inequality become more acute, CSR presents itself as a structural imperative that aligns company purpose with societal aspiration. Successful CSR needs to be internalized into main business processes, including supply chains, governance systems, innovation systems, and stakeholder interaction processes, instead of being externalized as independent philanthropic activities (Carroll & Brown, 2018; Eccles, Ioannou, & Serafeim, 2014).

Embedding CSR in corporate strategy ensures long-term competitiveness, reinforces stakeholder trust, and supports global sustainability goals. In addition to reputational benefits, integrated CSR builds more resilient business models with profitability mixed with environmental and social responsibility (Porter & Kramer, 2011). Companies that embed CSR show more agility to regulatory demands, societal expectations, and investor concerns, becoming leaders of sustainability-driven markets (Ziółkowska, 2024).

Looking ahead, future studies need to follow three broad directions. First, developing sector-specific CSR frameworks and responding to sectoral issues, ranging from carbon-hungry industries to tech-based firms, is an urgency of the day. Second, researchers and practitioners need to design strong measurement systems that can assess CSR's effect along environmental, social, and governance dimensions in comparable and accountable ways (Hahn & Kühnen, 2013). Third, the increasing function of digital technologies to increase transparency and stakeholder involvement deserves further investigation, especially as it addresses greenwashing issues and promotes inclusive participation (Zilberman et al., 2023).

Ultimately, CSR is more than corporate responsibility—it is a value-creation blueprint that marries profitability with ethical and environmental stewardship. In so doing, CSR supports both corporate resilience as well as the achievement of global sustainability objectives, solidifying its status as a keystone of contemporary business strategy.

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Role of Business Analytics in Customer Need Prediction in E-commerce Decision Making

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Abstract

In today's digital era, with competition between e-commerce companies escalating day by day, customer needs understanding and forecasting have become strategic necessities. Business analytics is a foundation for facilitating such understanding, converting mountains of raw data into meaningful insights that facilitate wise decision-making. With the help of sophisticated analytical methods like predictive modeling, machine learning, and customer segmentation, companies are able to spot trends in customer behavior and leverage those insights to predict future requirements. This predictive feature not only increases personalization and marketing efficiency but also fuels inventory optimization, customer satisfaction, and retention. E-commerce companies that integrate analytics into their decision-making structures are more likely to predict customer demand, dynamically realign offerings, and have an adaptive edge in extremely change-prone markets.

The second aspect of this analytical revolution is to integrate customer need prediction into operational as well as strategic decisions. This entails gathering and combining data from a variety of sources—such as site clicks, purchase behavior, product reviews, and social networking activity—to create an integrated customer view. Business analytics supports real-time decision-making, allowing companies to make accurate and timely actions that are aligned with customer expectations. Decisions related to pricing strategies, product assortment, recommendation rules, and marketing content can, therefore, be made with improved confidence and accuracy. This paper examines the ways in which business analytics redefines decision-making in the e-commerce industry in terms of customer need prediction, uncovering a paradigm shift towards proactive and anticipatory business approaches. The results show that companies that are investing in analytics are better positioned to build long-term customer relationships, enhance operational effectiveness, and maintain growth in a highly data-saturated business environment.

Keywords

Business Analytics, Customer Need Forecasting, E-commerce, Predictive Modeling, Decision Making, Machine Learning, Consumer Behaviour, Personalization, Data-Driven Strategy, Customer Retention

Introduction

Over the past few years, the online retail scenario has seen a dramatic shift influenced by technological change, digitization, and the explosive growth in data. The sheer volume of real-time customer data poses both an opportunity and threat to online sellers. On the one hand, the intricacy and magnitude of customer information render it challenging to find outlying insights without an appropriate analytical paradigm. Conversely, if used properly, this information is the key to customer preferences, behavioral trends, and future requirements. With e-commerce companies moving away from conventional marketing methods to a more data-centric strategy, business analytics becomes an ideal tool to aid and augment decision-making, particularly in the area of forecasting customer needs.

The importance of business analytics in predicting customer need is taking a more central stage as e-commerce companies attempt to shift from reactive to proactive interaction. Rather than waiting for customer behavior to happen and then reacting, companies now aim to forecast before it happens. Through sophisticated analytics methods of clustering, classification, neural networks, and regression analysis, companies can identify underlying patterns in customer data. These models are able to forecast what a customer will be likely to purchase next, when they are likely to churn, or how they will react to certain marketing stimuli. These insights enable decision-makers to build extremely targeted shopping experiences, which in turn boosts customer satisfaction, engagement, and loyalty.

Literature Review

Business analytics has come to be commonly accepted as a revolutionary driver of e-commerce decision-making. Initial research highlighted the contribution of business intelligence to descriptive reporting, offering firms historical information on consumer conduct (Chen et al., 2012). Nevertheless, predictive analytics has diverted attention toward pre-empting customer needs prior to their occurrence. Predictive models founded on clustering, regression, and classification enable firms to individualize customer experience and refine marketing campaigns (Wedel & Kannan, 2016).

Machine learning algorithms, like collaborative filtering and neural networks, have made it possible for recommendation systems that provide real-time suggestions of products, thus enhancing customer satisfaction and revenue (Li et al., 2020). In the same manner, sentiment analysis of online reviews and social media sentiments has been critical in determining customer attitudes and recognizing shifts in the market (Kumar et al., 2016).

From the operational point of view, predictive analytics enhances supply chain optimisation and inventory management, ensuring that waste is minimized and delivery times are improved (Jeble et al., 2018). The handling of big data from various channels has also facilitated end-to-end decision-making that takes into consideration both structured and unstructured data (Ghasemaghaei, 2019).

In spite of such developments, issues like data privacy, algorithmic bias, and cost of implementation continue to pose serious concerns (Davenport & Harris, 2017). Academics advocate for the use of ethical AI frameworks and open analytics models to foster customer trust (Li et al., 2020).

Methods

This review paper utilized a systematic literature review approach to integrate current knowledge. Sources were gathered from Scopus, Web of Science, IEEE Xplore, and Google Scholar applying the terms: business analytics, predictive analytics, customer need prediction, e-commerce, and decision-making.

The inclusion criteria were:

- Peer-reviewed journal articles published between 2010 and 2024.

- Research articles dealing with predictive analytics in e-commerce settings.
- Papers addressing implications for decision-making.

A total of 65 peer-reviewed articles and 15 industry reports were examined. The literature was categorized into themes of personalization, operational optimization, decision-making frameworks, and challenges through thematic analysis.

Results

The reviewed studies yielded the following findings:

1. **Improved Customer Personalization**

Predictive models enhance the precision of product suggestions and promotions (Wedel & Kannan, 2016). Personalization using machine learning enhanced conversion rates by as much as 30% in high-volume studies (Li et al., 2020).

2. **Operational Efficiency**

Predictive demand forecasting eliminated stockouts and overstocking (Jeble et al., 2018). Supply chain responsiveness was enhanced with real-time analytics deployed in decision-making.

3. **Strategic Decision-Making**

Social media sentiment analysis enabled companies to synchronize brand strategy and evolving customer tastes (Kumar et al., 2016). Long-term planning was facilitated through predictive analytics using forecasted customer lifecycle behavior.

4. **Challenges Identified**

Data privacy legislation (e.g., GDPR, CCPA) limits the customer data for use. Algorithmic unfairness erodes fairness in decision-making (Davenport & Harris, 2017). Small e-commerce companies are hindered by high infrastructure expenses.

Discussion

The findings show that business analytics contributes immensely to decision-making in e-commerce by turning raw data into predictive results. Its utility is not limited to personalization but also applies to operational and strategic use. Predictive models enable companies to be proactive, developing adaptive plans that meet customer needs.

But whilst analytics is evidently beneficial, there are lingering challenges that must be addressed. The problem of ethical AI and transparency of algorithms is paramount in providing trust in automatic systems. In addition, the vast resource needs constrain advanced analytics for small- and medium-sized organizations.

Conclusion

This analysis proves that business analytics is at the center of forecasting customer needs and influencing decision-making in e-commerce. By using predictive models and machine learning algorithms, businesses can forecast consumer tastes, offer personalized products, and streamline operations. Those companies that strategically invest in analytics achieve a competitive edge in customer retention, operational flexibility, and sustainable growth.

Despite this, issues like privacy, bias, and the cost of implementation are still hurdles to overcome. Solving these using ethical frameworks and scalable technologies will be critical to the long-term use of analytics in e-commerce. In a context characterized by perpetual change, predictive analytics will continue to develop as the bedrock for adaptive and customer-focused e-commerce strategies.

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Artificial Intelligence in Human Resource Management: A Conceptual Study with Reference to IT Firms in Hyderabad

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Abstract

Artificial Intelligence (AI) is on the verge of becoming a revolutionary element in human resource management (HRM), redefining conventional practices in recruitment, training, performance management, and staff engagement. In India, especially in IT cities like Hyderabad, AI-based HR solutions are gaining pace owing to the expanding digital environment and government initiatives for promoting AI innovation. This thought study explores the influence of AI on HRM practices with particular reference to IT companies in Hyderabad. Based on literature and industry reports, the paper discusses how AI technologies are embedded in HR processes, which opportunities they provide for efficiency and strategic decision-making, and what ethical and skill-related issues are involved in their implementation. The research suggests a conceptual framework that situates AI not only as an HR technology but as a strategic driver of HR transformation in IT companies. The results emphasize the importance of HR professionals acquiring AI literacy, trading off efficiency against fairness, and embracing a fast-changing digital work setup.

Keywords

Artificial Intelligence (AI); Human Resource Management (HRM); IT Companies; Recruitment; Employee Engagement; Hyderabad; Conceptual Study; Digital Transformation; Performance Management; Strategic HRM.

Literature Review

Artificial Intelligence (AI) has been a revolutionary force within Human Resource Management (HRM), allowing organizations to streamline procedural processes while improving strategic decision-making. Research suggests that the embrace of AI is transforming HR into a more strategic organizational partner, away from its traditional status as an administrative support department (Collings, Mellahi, & Cascio, 2019; Nankervis, Connell, & Burgess, 2021). Recruitment and hiring procedures, typically resource-consuming and susceptible to bias, are being streamlined by AI-based solutions that perform automated resume screening, candidate profiling, and even chatbot interviews. Not only does this speed up the recruitment process but also minimizes unconscious biases, thus enhancing the quality of hires (Biswas & Saini, 2020; Bhave & Lee, 2021). Predictive recruitment frameworks that use past data to project employee performance and tenure are becoming increasingly important in big IT centers like Hyderabad, where companies like Infosys and Tech Mahindra handle high-volume recruitment needs (Shukla & Sinha, 2021; Reddy & Swapna, 2022).

Aside from recruitment, training and development have been greatly influenced by AI-based adaptive learning platforms. These platforms observe employee learning patterns and personalize training routes, leading to better engagement and knowledge retention (Garg & Sharma, 2021; Chakraborty & Joseph, 2022). In sectors such as IT, which experience rapid technological shifts and require ongoing reskilling, AI-based platforms provide real-time coaching and individualized skill acquisition opportunities that keep employees competitive in the global economy (Thite, 2020). AI's role is also prominent in performance management, with organizations transitioning from annual performance reviews to continuous monitoring systems powered by data-driven analytics. Such systems help managers identify high performers, predict attrition, and align employee output with organizational goals, though concerns regarding transparency and fairness persist (Leicht-Deobald et al., 2019; Calvard & Jeske, 2018; Jha & Kumar, 2021).

Employee engagement, which is a major driver of retention and productivity, is now increasingly channeled through AI-facilitated solutions like chatbots, digital human resource assistants, and sentiment analysis tools that extract employee opinions from communication traffic. Through these technologies, organizations are able to respond to employee problems in real time, thus enhancing morale and job satisfaction (Bondarouk & Brewster, 2016; Mishra & Sarkar, 2020). In a heterogeneous and large workforce like Hyderabad's IT industry, they are key drivers of inclusion and participation (Ghosh & Tripathi, 2022). At the strategic level, AI enables workforce planning, attrition modeling, and HR-business alignment, thus making HRM a key driver of competitiveness (Prikshat, Malik, & Budhwar, 2020; Aguinis & Burgi-Tian, 2021). Telangana Government's AI policy and NASSCOM reports identify Hyderabad as a primary hub for AI use in HRM, both capturing the prospects and pitfalls of digitalization in workforce management (Reddy & Swapna, 2022).

Conceptual Framework

Conceptualization of AI in HRM is structured along five dimensions: recruitment and selection,

training and development, performance management, employee engagement, and strategic HRM. All these dimensions underscore the manner in which AI technologies are transforming HR's function from mundane administration into long-term strategic direction. In recruitment and selection, AI facilitates automation of time-consuming tasks like screening resumes and shortlisting applicants, whereas predictive models of hiring enhance accuracy by drawing insights from past performance data (Biswas & Saini, 2020; Bhave & Lee, 2021). Hyderabad's IT companies, which are confronted with mass recruitment in competitive economies, depend significantly on such software to ensure scalability and efficiency (Reddy & Swapna, 2022).

Training and development is also one of the sectors in which AI is making significant changes. Adaptive learning technologies offer customized training experiences by recognizing knowledge gaps, providing personalized modules, and suggesting career advancement paths. This way, employees are not just trained better but also equipped to deal with the quick technological shifts that define the IT sector (Garg & Sharma, 2021; Chakraborty & Joseph, 2022; Thite, 2020). In performance management, AI-powered platforms have replaced the old annual reviews with continuous evaluation systems, giving managers real-time information about employee productivity, engagement, and possible attrition risks. As much as they increase accuracy, they do also fuel ethical issues of fairness, privacy, and bias in algorithms (Calvard & Jeske, 2018; Leicht-Deobald et al., 2019).

Employee engagement is also becoming transformed with AI-driven solutions like chatbots and sentiment analysis tools that serve as 24/7 HR assistants and track employee satisfaction. In Hyderabad's diverse IT labor force, these technologies assist managers in reading the needs of employees, tailoring engagement approaches, and minimizing turnover (Bondarouk & Brewster, 2016; Mishra & Sarkar, 2020; Ghosh & Tripathi, 2022). Last but not least, at the strategic level, AI facilitates long-term HR planning through forecasting labor market trends, estimating attrition, and matching workforce competence to business goals (Prikshat et al., 2020; Aguinis & Burgi-Tian, 2021). The strong AI ecosystem in Hyderabad, fueled by government support, is a rich soil for IT companies to implement these cutting-edge HR practices (Reddy & Swapna, 2022).

Key Insights & Implications

The exploration of AI in HRM along these dimensions reveals the following key insights for Hyderabad's IT companies. Firstly, AI offers significant efficiency savings, especially in hiring and engagement. Computerized resume screening and chatbot interviews reduce hiring cycles dramatically, while predictive analytics enhances the quality of decision making (Bhave & Lee, 2021; Biswas & Saini, 2020; Chatterjee, Rana, & Dwivedi, 2021). Even employee engagement platforms based on sentiment analysis enable companies to tackle problems preemptively, thus resulting in increased workforce productivity and lower attrition (Mishra & Sarkar, 2020). These efficiency gains are particularly precious in Hyderabad, where IT organizations make regular large-scale hiring pushes that need quick speed and precision (Reddy & Swapna, 2022).

Secondly, though AI facilitates efficiency, it also creates skill gaps amongst HR professionals. Most HR professionals do not have adequate knowledge about data analytics and AI tools, which becomes a bottleneck in successfully leveraging these technologies (Chakraborty & Joseph, 2022; Nankervis et al., 2021). To leverage the full potential of AI, IT companies in Hyderabad need to invest in reskilling initiatives on digital literacy, algorithmic awareness, and ethical use of technology. Lacking these, AI applications can remain underleveraged and may not yield

desired strategic impact.

Third, ethical issues are becoming the focal point of AI adoption in HRM. Problems like fairness in algorithmic decision-making, privacy of employees in monitoring, and transparency of predictive appraisals pose serious challenges (Leicht-Deobald et al., 2019; Calvard & Jeske, 2018). If left unaddressed, these issues can erode the confidence of employees and leave organizations vulnerable to reputational and legal liabilities. In Hyderabad, where numerous IT companies have clients from across the globe, compliance with global ethical standards is not just desirable but also necessary to remain competitive (Ghosh & Tripathi, 2022).

Lastly, the Hyderabad context in particular unravels special dynamics in AI-facilitated HRM. Hyderabad enjoys government patronage in the form of initiatives like the Telangana AI Strategy, a robust presence of multinational IT companies, and an active startup community (Reddy & Swapna, 2022). Findings from NASSCOM (2023) indicate that Hyderabad companies are using AI not just as an efficiency tool but as a strategic enabler for digital transformation, competition, and global leadership. This makes Hyderabad a pivotal case study of how AI in HRM adoption can strike a balance between efficiency, ethics, and long-term strategic goals in an ever-changing technology environment (Prikshat et al., 2020; Aguinis & Burgi-Tian, 2021).

Conclusion

Artificial Intelligence is primarily revolutionizing Human Resource Management by transforming HR from a transactional to a strategic facilitator of organizational success. The research points out that in IT cities like Hyderabad, where mass recruitment, quick technology turnovers, and global client requirements dominate, AI has become a necessity across various HR aspects—recruitment, training, performance management, employee engagement, and strategic HR planning. AI-enabled solutions deliver considerable efficiency improvements by automating routine work, facilitating predictive insights, and promoting data-driven decision-making. Concurrently, they pose fundamental challenges in terms of skill gaps for HR professionals, ethical concerns of fairness and transparency, and trust with employees in algorithmic systems.

Within the Hyderabad IT ecosystem, the synergistic effect of government programs, multinational IT companies, and a robust AI innovation spirit has propelled adoption and established the city as one of the prominent case studies for AI-powered HR transformation. The research indicates that although AI holds enormous potential for enhancing organizational competitiveness, its sustainable adoption entails judicious alignment with efficiency, ethical governance, and ongoing reskilling of HR professionals. Finally, AI must be considered not only as a technological device but also as an enabler of strategic HRM change to align human assets with organizational development in an increasingly changing digital economy.

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Media Trials and Rape Victims in India: Legal and Social Implications

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Abstract

This article analyses the process of media trials in rape cases in India and their influence on victims' rights, dignity, and access to justice. Media trials, characterized by sensationalist reporting and prejudicial comment, divert attention away from judicial scrutiny toward public opinion, establishing parallel courts of perception that threaten to dislodge due process. Although media coverage can potentially highlight systemic failures and compel public opinion in favour of legal change, its unchecked and intrusive character often leads to the invasion of victims' privacy and secondary victimization. The research utilizes qualitative legal studies based on statutory interpretation, judicial precedents, and content analysis of media operations. Findings show that in spite of legal provisions intended to safeguard victim privacy and control reporting, enforcement continues to be weak and incoherent. With the accelerated growth of online media outlets, these issues are even more compounded as news flows instantaneously and globally, with little accountability. The critique highlights the importance of more balanced measures in upholding freedom of the press with the protection of the dignity of survivors and judicial integrity. The paper concludes by suggesting more effective enforcement of anonymity legislation, more defined ethical standards for responsible reporting, and reforms that narrow the distance between democratic openness and human rights.

Keywords

Media trial, rape victims, privacy, dignity, secondary victimization, social stigma, Indian law, freedom of press

2. Literature Review

Media Trials and Legal Fairness

The "trial by media" concept has been faulted for undermining the impartiality of the judiciary and replacing public spectacle with due process. Patel (2017) contends that by pre-judging the accused through speculations about their guilt or innocence, media outlets compromise judicial integrity and the right to a fair hearing. Empirical research indicates that prejudgment by the public, promoted by sensationalist reporting, can indirectly coerce judges and prosecutors to conform to prevailing media narratives (Gupta, 2021). Global experiences support this apprehension: Williams (2018) points out that the UK and US have struggled with finding a balance between free press and fair trial rights, with courts citing that unbridled reporting can compromise the delivery of justice. In India, with huge consumption of media and relatively unregulated in the digital arena, these threats are compounded, with parallel courts of public opinion being created (Rajagopal, 2021).

Victim Privacy and Secondary Victimization

The right to privacy of rape victims has become one of the most significant issues in trials by media. Singh and Sharma (2018) show how disclosure of intimate information, even unintentionally, can cause social exclusion, harassment, and re-traumatization. Such "secondary victimization" is compounded when reporting focuses on graphic crime details instead of highlighting institutional breakdowns (Mehta, 2017). Patil (2020) points out that even with Section 228A of the Indian Penal Code criminalizing the exposure of rape survivors' identities, there are ongoing gaps due to inadequate enforcement systems. Desai (2019) posits that loopholes in legislation, combined with insufficient accountability structures for online platforms, expose victims to doxing and online ridicule. Insufficient protection of anonymity not only tramples over victims' dignity but also deters reporting of rape (Nair, 2018).

Media Impact on Public Perception

Media accounts influence public opinion about rape, gender, and justice considerably. According to Verma (2020), framing devices tend to stereotype victims as either "ideal" or "blameworthy," thus perpetuating prevailing gender prejudices. These images do not just sway public sympathy, but also wider policy narratives. Banaji and Bhat (2021) take this analysis online, where social media activism exists alongside pervasive victim-blaming and trolling, outlining the ambivalence of online justice movements. Mishra (2021) also notes that the instantaneity of online comment makes "social media justice" possible, which often circumvents judicial restraint and sparks moral panics. These dynamics illustrate how media does not just report on social reality but actively produces it, with momentous consequences for survivors' lived realities.

Judicial and Legal Protections

Indian courts have recognized the conflict between freedom of expression and the right to privacy. In DK Basu v. State of West Bengal (1997), the Supreme Court identified the requirement to rein in prejudicial reporting to maintain the presumption of innocence. More recently, Anuradha Bhasin v. Union of India (2020) highlighted the balance between free speech and the safeguarding of individual rights in today's digital age. Yet, as argued by Reddy (2018), judicial advisories tend to be toothless when it comes to implementation, with media institutions continuing to disregard prohibitions in the name of sensationalism. Comparisons around the world indicate that nations like the UK utilize contempt of court legislation to limit prejudicial reporting during trial processes (Williams, 2018), whereas the European Union focuses on the right to be forgot-

ten through GDPR regulations (Menon, 2020). India is still stuck in a state of legal vacuum where statutory protection is available but unevenly applied (Khan, 2021; Sarkar, 2022).

Research gaps

Even with an increasing amount of research on media trials, areas still exist for a comprehensive consideration of the intersection of rape victim rights, new media, and changing legal systems. Khan (2021) also points out that there has been little attention paid to traditional broadcast and print media, ignoring the unprecedented roles of digital media. Sarkar (2022) also emphasizes that the Indian regulatory machinery has not kept up with the velocity of digital flow and left victims insufficiently safeguarded in cyberspace. Bhushan (2022) emphasizes that social media sites, as compared to conventional press, have no consistent editorial responsibility, thus boosting misinformation and biased rhetoric. Future studies need to therefore examine how technological changes redefine both media ethics and the relevance of current legal protection measures.

Methodology

The research employs a qualitative doctrinal approach to legal research, which best captures the interaction between statutory regimes, judicial concepts, and media practice. Doctrinal research enables the critical assessment of laws in application and interpretation, especially in such sensitive topics as regulation of the media and rape victim protection (Chaudhary, 2017). The research mostly depends on statutory law, such as Section 228A of the IPC, clauses of the Information Technology Act, and limitations of evidences under the Indian Evidence Act, which together control disclosure of victims' identities and manage prejudicial reporting (Desai, 2019).

Judicial precedents are also at the core of this research. Landmark judgments like DK Basu v. State of West Bengal (1997) and Anuradha Bhasin v. Union of India (2020) show how courts have tried to strike a balance between freedom of the press and the individual's right to privacy and dignity (Reddy, 2018). Further, the study uses content analysis of targeted high-profile rape cases to ascertain patterns of reporting and their implications for survivors, including indirect identification and sensational framing (Singh & Sharma, 2018). A comparative element is infused by considering international best practices, i.e., anonymity safeguards in the United Kingdom and the European Union's data protection framework, which give timely insights into creating stronger regulatory environments for India (Williams, 2018; Menon, 2020).

Analysis

- Infringement of Privacy – In spite of Section 228A of the IPC banning the revealing of rape victims' identities, news organizations expose them indirectly by contextual reporting, photographs, or address, thus making them identifiable to the public (Singh & Sharma, 2018; Desai, 2019). This demeans the dignity of the victims and leaves them vulnerable to harassment and stigmatization.
- Secondary Victimization – Survivors endure trauma beyond the assault due to intrusive reporting, which leads to reputational harm, social ostracism, and psychological distress. Mehta (2017) highlights that sensationalist reporting exacerbates mental health consequences, while Verma (2020) underscores that stigmatizing narratives reinforce societal prejudices.
- Inadequacy of Legal Protection – While there is statutory law and judicial advice, enforcement is still inadequate. Media outlets often put business before ethics, taking advan-

tage of loopholes without enduring substantial penalties (Chaudhary, 2017; Patil, 2020). According to Sarkar (2022), the growth in digital platforms has further accelerated beyond current legal protection, leaving the victims exposed.

- Clash Between Press Freedom and Rights of Victims – Courts have all along promoted the democratic function of the media in promoting accountability. Yet unbridled reporting of rape cases frequently conflicts with victims' rights to privacy and dignity. Joshi (2016) emphasizes that the equilibrium between press freedom and privacy is precarious, while Reddy (2018) notes that judicial interventions tend to lag behind system changes.
- Impact of Digital Media – Social media poses special challenges due to its lack of editorial control and rapidity of information dissemination. Sarkar (2022) observes that viral spread of sensitive information worsens harm, while Bhushan (2022) suggests that the lack of accountability mechanisms available in online environments particularly leaves the victim vulnerable to "trial by public opinion."

Discussion

The results validate the main hypothesis that media trials in rape cases undermine victims' privacy and dignity and subject them to secondary victimization. Singh and Sharma (2018) and Patil (2020) studies find that unregulated media coverage scares victims away from reporting crimes because fear of being exposed usually predominates over the quest for justice. Judicial precedents have recognized such harms, but interventions have been reactive and case-specific instead of systemic (Reddy, 2018).

The challenge that persists is one of balancing freedom of the press and the rights of victims. Whereas media plays a critical democratic function by bringing issues of public interest to light, untrammelled reporting in rape cases tends to reduce rape survivors to objects of public fascination. Comparative perspectives provide valuable lessons: the UK contempt of court legislation avoids prejudicial reporting at trial, whereas EU systems stress the "right to be forgotten" as protection of individual dignity (Williams, 2018; Menon, 2020). These instances demonstrate that enhanced anonymity protection and enforcible penalties are compatible with freedom of the press.

In the Indian context, reforms will have to concentrate on better enforcement of anonymity laws, better-defined ethical standards for journalists, and regulation systems for online platforms. As Sarkar (2022) and Bhushan (2022) would contend, in the absence of adjusting to the reality of social media, conventional protections will be insufficient. A sustainable, well-balanced system that incorporates democratic openness with effective victim protection is then needed to provide a fair and humanitarian justice.

Conclusion

The study corroborates the hypothesis that media trials of rape cases have a greatly negative effect on victims, enhancing social stigma, reinforcing gendered stereotypes, and compromising privacy and dignity. The results indicate that, in spite of the availability of statutory laws like Section 228A of the Indian Penal Code and judicial norms of precedential cases like DK Basu v. State of West Bengal (1997) and Anuradha Bhasin v. Union of India (2020), enforcement is patchy and predominantly reactive in nature instead of being preventive (Reddy, 2018; Patil, 2020). Sensationalized reporting, coupled with the speed of information dissemination on social

media, tends to lead to secondary victimization, discouraging victims from reporting offences and foster a culture of silence (Singh & Sharma, 2018; Mehta, 2017; Sarkar, 2022).

Comparison between countries highlights the fact that victim protection can be achieved without sacrificing press freedom. For example, the UK uses contempt of court legislation to stop prejudicial reporting as trials progress, while the European Union's "right to be forgotten" regime prevents individuals' private information from being disclosed to the public excessively (Williams, 2018; Menon, 2020). India, though, is still to evolve mechanisms that are responsive to the pace and extent of digital media, leaving victims exposed to cyberbullying, doxing, and viral sharing of sensitive information (Bhushan, 2022; Khan, 2021).

Recommendations:

- Amending Section 228A IPC: The provision should be amended to provide stronger penalties, including compensation to victims and punitive fees on the media or individuals who breach anonymity protections (Patil, 2020; Nair, 2018).
- Independent Monitoring Bodies: Having independent media watchdog committees or regulatory commissions in place can guarantee compliance with ethical reporting principles, especially those involving sexual violence (Banaji & Bhat, 2021; Joshi, 2016).
- Enforcement of Anonymity Regulations Across All Digital Platforms: Legal requirements must be extended to social media and online portals, with the platforms held liable for facilitating disclosure of victims' identities (Sarkar, 2022; Bhushan, 2022). Automated moderation features and mandatory reporting can help limit violations.
- Gender-Sensitive Training for Reporters: Adding specialized training modules on ethical sexual assault reporting and trauma-informed journalism in media curricula can foster ethical reporting norms (Verma, 2020; Mehta, 2017).
- Emergence of a Balanced Framework: A strong legal-ethical framework needs to balance press freedom and the protection of victims through legislation, judicial supervision, and self-codes of the media (Reddy, 2018; Joshi, 2016). Policies also need to address newer concerns of viral content on online platforms while also initiating public awareness about the repercussions of prejudiced reporting.
- Public Education Campaigns and Public Awareness: Making the public sensitive about media trials' influence and promoting responsible news consumption can prevent victim-blaming and social ostracism (Gupta, 2021; Rajagopal, 2021).

Finally, upholding justice in rape cases requires more than legal measures; it needs a multifaceted response that encompasses judicial watchdogs, strict enforcement, media responsibility, and public awareness. Only through such multifaceted initiatives is India able to create a system wherein press freedom and dignity of the victim can survive, and media trials cannot constitute an added trauma source for victims (Singh & Sharma, 2018; Patil, 2020).

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Melanoma Skin Cancer Detection: A Comparative Review of AI-Enhanced Dermoscopy and Infrared Thermography

Abstract

Melanoma, which is a very aggressive skin malignancy, is a very serious global health issue, necessitating the urgency of early and reliable non-invasive diagnostic tools. This review presents a thorough comparative overview of two very well-known non-invasive imaging techniques for melanoma diagnosis: dermoscopy and infrared thermography (IRT). Dermoscopy, a well-established method, provides highly informative morphological information on skin lesions, whose diagnostic performance is radically improved by the incorporation of AI and DL algorithms, very often matching or even surpassing that of human experts. In contrast, IRT is a novel, contactless, radiation-free technique that identifies physiological alterations, including enhanced metabolic activity and angiogenesis, that present as specific thermal signatures in malignant lesions. When integrated with AI/DL, IRT shows strong predictive power, with high precision and recall in distinguishing melanoma from benign nevi and non-melanoma skin cancers. Although dermoscopy is superior for structural visualization and IRT for physiological examination, their intrinsic complementarity indicates that neither is completely adequate by itself. The greatest breakthroughs are to be expected from multimodal fusion technologies, combining both imaging information with clinical metadata to yield more solid and extensive diagnostic systems. Although they hold great promise, their large-scale clinical adoption is thwarted by challenges such as the requirement for stringent standardization, overcoming data constraints for training AI models, improved model interpretability, and real-world extensive clinical validation. Through these challenges, the combination of AI-boosted dermoscopy and IRT offers vast potential for enhancing early melanoma detection, limiting unnecessary invasive tests, and finally improving patient outcomes.

Keywords: Melanoma, Dermoscopy, Infrared Thermography, Artificial Intelligence, Skin Cancer Detection

Introduction

Melanoma: A Growing Public Health Concern and the Criticality of Early Diagnosis

Melanoma, a highly malignant skin cancer, poses a great and vexing international public health issue. Its rate of incidence has continued to increase globally, and thus there is a greater need to emphasize efficient detection methods. The virulent nature of melanoma highlights the crucial role played by the early and reliable diagnosis, which is directly related to better patient prognosis, enhanced survival rates, and a lowering of the substantial healthcare expense of treating advanced disease. Although histopathological examination is the ultimate gold standard for diagnosis of melanoma, its invasive nature and time required for reporting make it inappropriate for mass initial screening. Therefore, there is an urgent requirement for effective, non-surgical techniques that can effectively triage suspicious lesions with high accuracy, thus avoiding unwarranted excisions while optimizing the chances of early detection. This ongoing need to advance better screening devices fuels ongoing research and development of refined imaging technologies and the confluence of artificial intelligence (AI) to augment their performance. The main aim is to close the gap between preliminary clinical suspicion and final pathological diagnosis.

Overview of Non-Invasive Skin Imaging Modalities

The diagnostic landscape for skin cancer heavily relies on visual assessment, which has been significantly augmented by non-invasive imaging techniques. Dermoscopy has long served as a foundational tool, providing magnified views of skin lesions to reveal subsurface structures and patterns imperceptible to the unaided eye. More recently, infrared thermography (IRT) has emerged as a promising complementary or alternative modality. IRT leverages the inherent physiological differences in temperature between healthy and malignant tissues, offering a distinct approach to lesion assessment. The advent and rapid advancements in artificial intelligence (AI) and deep learning (DL) have further revolutionized these imaging techniques, introducing automated analysis capabilities and significantly improving diagnostic precision. These technological strides aim to overcome the limitations of traditional methods and enhance the overall efficiency and accuracy of melanoma detection.

Scope and Objectives of this Comparative Review

This paper provides a comprehensive review of the current state of melanoma detection using infrared thermography (IRT) and dermoscopic imaging. It critically compares these two modalities, detailing their fundamental principles, underlying techniques, diverse clinical applications, inherent advantages, and recognized limitations. A particular emphasis is placed on their diagnostic performance, encompassing metrics such as accuracy, sensitivity, and specificity, especially in the context of advancements driven by machine learning and deep learning. Furthermore, this review explores the significant potential for multimodal integration, where the strengths of both techniques can be combined. Finally, it addresses the prevailing challenges and outlines future directions for the successful clinical implementation of these advanced technologies to enhance melanoma detection and improve patient outcomes.

Dermoscopy: A Standard in Melanoma Detection

Fundamental Principles and Techniques

Dermoscopy, sometimes called dermatoscopy or epiluminescence microscopy, is an non-inva-

sive imaging method that uses a handheld device called a dermatoscope. The dermatoscope often offers 10x magnification and includes a light source that reduces surface light reflection, allowing to see the colors and microstructures located below the stratum corneum that cannot be seen with the naked eye. This ability uncovers a new morphological aspect of both pigmented and non-pigmented skin neoplasms. The visualization of these subsurface structures is important because it fills the gap between a lesion's macroscopic appearance and microscopic, histopathological characteristics. By making access to such inner patterns possible, dermoscopy provides a better informed foundation for clinical judgments, beyond superficial visual signals, and improving the detection of early melanomas that may present as benign on naked-eye examination. Two main classes of dermatoscopes are used at present, non-polarized, requiring direct contact with the skin, and polarized, which does not.

The appearance of vascular structures under dermatoscopy, especially with non-polarized dermoscopes, can be altered by the degree of pressure exerted on the skin. Dermoscopy images may be evaluated in real time during the patient visit or photographed digitally and stored for later review. Although the early use of dermoscopy was largely qualitative visual interpretation, the later introduction of standardized diagnostic algorithms, like the 7-point checklist or ABCD rule, represents an evolutionary movement towards more semi-quantitative evaluation. Standardization, even if not necessarily complete in its accuracy across all instances, serves to minimize subjective variability and maximize the teachability and reproducibility of the method, directly confronting the disadvantage of its experience-dependent nature. This development is a direct reaction to the clinical necessity for consistent, reliable diagnostic criteria.

Clinical Applications and Established Diagnostic Criteria

The most important clinical use of dermatoscopy is the detection of melanoma, for which it clearly enhances diagnostic accuracy in comparison to unaided vision examination. This increased accuracy allows for the identification of thinner melanomas as well as the differentiation between benign nevi and malignant melanomas, thus reducing the number of unnecessary biopsies.

Outside of melanoma, dermoscopy is a multifaceted tool with many applications. It is used for early diagnosis of other skin cancers, tumor thickness prediction, accurate preoperative marking, evaluation of perilesional skin, inflammatory condition differentiation, and inspection of hair, scalp, nails, and skin infestations. Additionally, it is an invaluable tool for longitudinal follow-up of high-risk patients.

Dermatoscopic diagnosis of melanoma is essentially, however, based on its appearance being chaotic and morphologically asymmetrical. Certain dermoscopic features suggestive of melanoma include:

Table 1: Key Dermoscopic Diagnostic Criteria for Melanoma

Criterion/Structure	Description	Significance in Melanoma Diagnosis

Atypical/Irregular Pigment Network	Lines with increased variability in thickness, color (often broadened, smudgy, grayish), and irregular hole sizes.	Suggests disorganized melanin distribution, common in superficial spreading melanoma.
Irregular/Atypical Blotch	One or more off-center, hyperpigmented structureless areas, often with irregular shapes and varying hues, covering at least 10% of the lesion's surface.	Indicates uncontrolled melanin proliferation and distribution.
Irregular/Atypical Dots/ Globules	Multiple round to oval pigmented structures of varying size, shape, or color, distributed randomly and asymmetrically, not clustered centrally.	Represents disorganized nests of melanocytes or melanin deposits.
Irregular/Atypical Streaks/ Pseudopods	Irregularly and focally distributed linear pigmented projections emanating from the tumor periphery, sometimes with bulbous endings.	Signifies radial growth phase of melanoma.
Regression Structures	Scarlike areas (porcelain white structureless areas) and/or fine blue-gray dots (peppering) or granularity.	Evidence of the body's immune response attempting to fight the tumor, often seen in about 50% of melanomas
Blue-White Veil	Irregular structureless area of confluent blue pigment with an overlying white ground-glass haze, typically in a raised lesion.	Corresponds to dense melanin in the dermis and epidermal hyperkeratosis, a strong indicator of melanoma.
Atypical Vascular Pattern	Includes dotted, serpentine, corkscrew, or polymorphous vessels (two or more vessel types within the same lesion).	Reflects the increased and disordered angiogenesis characteristic of malignant tumors.
White Shiny Streaks/Lines	Short, bright, white lines or streaks, usually oriented parallel or orthogonally, seen with polarized light.	Corresponds to dermal collagen bundles altered by the tumor, often seen in invasive melanomas.
Peripheral Tan Structureless Areas	Homogeneous light brown areas located at the edge of the lesion, devoid of other structures, encompassing at least 10% of the surface area.	Can indicate early radial growth.

Prominent/Accentuated Skin Markings	Exaggerated or irregular patterns of skin lines.	Seen in some melanomas, particularly *in situ*.
Angulated Lines	Brown to gray linear structures intersecting at acute angles, creating a zig-zag pattern.	Associated with melanomas on sun-damaged skin
Negative Network	Hypopigmented serpiginous interconnecting lines winding through the lesion, leaving island-like regions of brown hyperpigmentation.	While also in Spitz nevi, its presence warrants concern for melanoma.
Multiple Small Hyperpigmented Areas of Irregular Shape	Small, multiple foci of hyperpigmentation (<10% surface area) that do not obscure underlying structures.	Can manifest in melanoma *in situ*.

Techniques like the Seven-Point Checklist and Pattern Analysis are commonly utilized to differentiate between nevi and melanomas. The Seven-Point Checklist includes points for major criteria (2 points each: atypical pigment network, blue-white veil, atypical vascular pattern) and minor criteria (1 point each: irregular streaks, irregular dots/globules, eccentric hyperpigmentation area, regression structures), and a score of three or higher points usually signifying melanoma. Besides that, dermoscopic colors themselves can also lead to tumor thickness estimates. The sheer volume and multitude of these criteria serve to underscore the built-in intricacy of dermoscopic interpretation, and consequently it creates the context for appreciating the useful role played by AI in abbreviating and uniformizing this diagnostic activity.

Advantages and Limitations in Clinical Practice

Dermoscopy has several clear benefits in everyday practice. It is a harmless examination procedure, increasing comfort and safety for the patient. One of the major advantages is its capacity to significantly enhance the diagnostic accuracy of melanoma detection when compared to naked-eye examination. This improvement applies to both sensitivity and specificity in the diagnosis of melanoma. For example, a combination of visual and dermoscopy examination has been shown to have 92% sensitivity and 95% specificity, an improvement from visual examination alone with 76% sensitivity and 75% specificity. Expert dermatologists, especially, are much more accurate in their diagnosis using dermoscopy. By enhancing diagnostic accuracy, dermoscopy also decreases the number of unnecessary biopsies for benign lesions, resulting in economic benefits, lowered patient morbidity, and less pain and scarring. In addition, it facilitates the early diagnosis of thinner melanomas and is versatile in different dermatological disorders other than melanoma. Despite those benefits, dermoscopy is also characterized by some remarkable limitations.

One of the major issues is its reliance on the clinician's expertise. In the absence of any training, the application of dermoscopy may paradoxically result in worse diagnostic accuracy compared to naked eye assessment. The heterogeneity in training dermoscopy and the multiplicity of diagnostic algorithms used by various medical education systems exacerbate this problem. Even diagnostic accuracy will be affected if doctors do not detect or identify appropriately the importance of dermoscopic features. Cognitive biases like anchoring bias (excessive de-

pendence on preliminary information) and search satisfaction (stopping the diagnostic search too early) also lead to reduced accuracy. An important limitation is that dermoscopy can fail to identify early melanomas that do not yet possess any distinct dermoscopic features. Additionally, diagnostic accuracy is lost if lesions are evaluated only by dermoscopy, without the aid of overall clinical context. Though dermoscopy can give an estimate of tumor thickness, histopathologic examination is still more reliable for accurate depth assessment. Lastly, practical constraints like the expense of equipment, the requirement of specialized training, and the amount of time involved restrict its extensive usage, particularly in primary care. This intrinsic subjectivity and heterogeneity among clinicians reinforce the necessity for objective, computerized solutions, which has driven the incorporation of AI into dermoscopic examination. There exists a fine balance clinicians need to consider when using dermoscopy. Although the method is praised for enhancing sensitivity and diminishing unwarranted excisions, a few critics argue that more frequent use of in-vivo examination methods such as dermoscopy can lead to "overdiagnosis" and "a rise in the number of unnecessary biopsies and excisions."

This is a reflection of the constant struggle between maximizing early detection in order to enhance survival and minimizing potential morbidity and patient distress due to overly intensive diagnostic regimens. This context highlights how critical it is not only to attain high sensitivity but also to maximize specificity, something for which AI has much potential.

Enhancing Dermoscopy with Artificial Intelligence and Deep Learning

The convergence of machine learning (ML) and deep learning (DL) technologies has revolutionized dermoscopy, with tremendous improvement in diagnostic accuracy achieved through the automation of dermoscopy image analysis. One of the benefits of DL is that it can automate feature extraction, which was a labor-intensive task in conventional statistical image classification methods.

Top-performing DL architectures in this field are DenseNet, DCNN, AlexNet, ResNet-50, VGG-16, GoogLeNet, and InceptionV3. They are often pre-trained on large datasets such as ImageNet, which drastically shortens the time and computational power for model inception and training.

The performance of these AI-powered dermoscopy systems has been outstanding. Several DL models have scored more than 95% accuracy on benchmark datasets like HAM10000, ISIC, MedNode, PH2, DermIS, and DermQuest. For example, InceptionV3 has achieved accuracies of 97.1-97.2% on the MedNode and PH2 datasets. A multimodal system that combines dermoscopic images with clinical metadata has even attained a high 98.69% accuracy in skin cancer classification.

One of the strongest points of AI's value is its performance compared to human specialists. AI models, especially Convolutional Neural Networks (CNNs), have shown classification accuracy comparable to, and in certain cases, even better than that of experienced dermatologists. One study mentioned a CNN that performed better than 136 out of 157 dermatologists in a direct dermoscopic melanoma image classification task and with better specificity(82.5% vs. 71.3%) and increased ROC AUC (0.86 vs. 0.79).

Table 2: Performance Metrics of AI/DL Models in Dermoscopic Melanoma Detection

Model Architecture	Dataset(s)	Accuracy (%)	Sensitivity (%)	Specificity (%)	Precision (%)	F1-score	ROC AUC
InceptionV3	MedNode, PH2	97.1-97.2	N/A	N/A	N/A	N/A	N/A
DenseNet, DCNN	HAM10000, ISIC	>95	N/A	N/A	N/A	N/A	N/A
DL (Hosny et al.)	9350 images	97.7	97.34	97.34	N/A	N/A	N/A
Multimodal System (EfficientNetB3, TabNet)	ISIC 2018, ISIC 2019, HAM10000	98.69	N/A	N/A	N/A	N/A	N/A
CNN (vs. dermatologists)	Test-set-100, Test-set-300	N/A	95	63.8-80	N/A	N/A	0.86-0.95
DL (Melanoma vs. Nevi)	Expanded dataset	96.91	94.12	98.41	0.9665	0.9536	0.9185
DL (Melanoma vs. NMSC)	Expanded dataset	N/A	88.52	N/A	0.9259	0.9051	0.901

Recent trends and developments in AI for dermoscopy are a shift towards multiclassification methods, with the goal of recognizing multiple skin tumor types instead of just binary ones. Hierarchical diagnosis, two-stage classification (e.g., initially distinguishing melanocytic from non-melanocytic lesions, followed by specific type recognition), is also becoming increasingly popular due to better performance. Ensemble models, collections of several DL architectures, are often used to increase overall performance as well as robustness. In order to compensate for data shortcomings, researchers make use of strategies including data augmentation (rotation, mirroring, color augmentation), Generative Adversarial Networks (GANs) for synthetic image creation, and transfer learning from pre-trained models. Computational cost optimization efforts include multi-input approaches, attention learning, and Region of Interest (ROI) selection. In addition, making the model more interpretable to clinicians is an important area

of research, with techniques such as LIME (local interpretable model-agnostic explanation) and content-based image retrieval being investigated. Combination of the patient clinical data, i.e., age, gender, and medical history, is also identified as being key to improving model performance since this information will generally be known at the time of real-world clinical diagnosis.

3. Infrared Thermography (IRT): An Emerging Diagnostic Tool

3.1. Fundamental Principles and Techniques

Infrared thermography (IRT) is a non-contact, non-invasive, and radiation-free diagnostic device that records and measures the distribution of the temperature of the surface of the human body. It is based on the principle that all objects give off infrared radiation in proportion to their absolute temperature. Thermographic cameras measure this radiated emission and translate it into visible heat images, so healthcare personnel can see small physiological changes that signal the onset of disease.

The fundamental idea behind IRT detection of melanoma is that malignant neoplasias, including melanoma, often manifest greater skin temperatures than surrounding healthy tissue. Localized hyperthermia is due mainly to the elevated metabolic rate, increased blood supply, and tumor-associated angiogenesis (angiogenesis refers to the development of new blood vessels) of neoplastic growth. Conversely, benign lesions characteristically appear iso- or hypothermic compared to the surrounding skin. This difference, not based on purely morphological but on physiological differences, presents a somewhat singular window of diagnosis, as IRT may reveal abnormality prior to structural alteration visible to the eye or significant enough for other modalities.

Techniques in IRT:

Steady-state thermography: This technique requires the subject to achieve a sufficient thermal equilibrium with a controlled ambient environment before thermal image acquisition.

Dynamic thermography: This more advanced approach involves applying a thermal stress, most commonly cooling, to the skin region of interest before acquiring a sequence of thermal images. The subsequent thermal recovery process is meticulously monitored, as cancerous areas often rewarm more rapidly due to disordered vasoregulation and increased metabolic activity. The application of cold stimuli is particularly effective in enhancing the thermal contrast between healthy and unhealthy tissues, making subtle temperature differences more discernible. This emphasis on the dynamic response to thermal perturbation, rather than just static temperature, is critical for improving IRT's diagnostic utility.

Quantitative Infrared Imaging (QUIRI): Modern IRT has shifted from qualitative visual interpretation to quantitative measurements. QUIRI focuses on high-accuracy measurements of absolute temperatures, temperature differences, and temporal variations in temperature, providing a more objective and precise assessment.

Clinical Applications and Interpretation of Thermal Patterns for Melanoma

Infrared thermography is being studied actively as a supporting tool for skin cancer diagnosis, including melanoma, with some significant potential to make the diagnostic process

simpler and quicker. Apart from dermatology, its uses are found in breast cancer screening, vascular disorder diagnosis and management, and monitoring inflammatory conditions.

Interpretation of Thermal Patterns:

Temperature Differences: The primary diagnostic criterion in IRT is the temperature difference observed between the lesion and its surrounding healthy tissue. Malignant lesions typically manifest as "hot spots" or regions exhibiting asymmetric warmth. A temperature difference of ≥ 0.2 °C when compared to the unaffected side has been statistically associated with the presence of malignant tumors.

Thermal Recovery Curves: In dynamic IRT, the analysis of thermal recovery curves following a cooling stress is paramount. Cancerous lesions consistently exhibit higher temperatures during the initial 45-60 seconds of thermal recovery compared to benign pigmented lesions. This dynamic response provides more discriminative information than static temperature readings.

Quantitative Analysis: Modern interpretation of thermograms moves beyond subjective visual assessment towards precise quantitative measurements of temperature, temperature differences, and temporal variations. Advanced image analysis techniques enable the quantification of intricate features such as temperature gradients, thermal entropy, and vascular geometry, providing a more comprehensive physiological profile of the lesion.

Lesion Size Correlation: The diagnostic efficacy of thermography can be influenced by lesion size, with studies indicating better performance for larger lesions (e.g., those greater than 7 mm or 1.5 cm in diameter).

Clinical Findings:

Experiments have successfully proven the possibility of differentiating benign and malignant lesions by IRT. For example, Magalhaes et al. (2019) illustrated the possibility of differentiating melanomas from melanocytic nevi both in steady-state and dynamic scenarios using machine learning classifiers. Likewise, Cetingul and Herman (2011) also showed early-stage melanoma cases with significant temperature differences (0.5 °C and 2.2 °C) between the lesion and normal tissue.

Although IRT successfully identifies "abnormal thermal patterns" of pathology, it should be emphasized that any local rise in skin temperature can also be a marker for other diseases, such as inflammation, infection, or trauma. This feature indicates a potential specificity limitation since several pathologies will be expressed with the same thermal pattern. As a result, IRT is commonly referred to as an "aiding tool" and not a sole diagnostic technique, highlighting that it must be combined with other modalities or sophisticated AI to enhance its discriminative capacity. Interpretation of thermal distributions in IRT transcends basic differences in temperature, and includes the dynamic tissue response to thermal disturbance and the physical size of the lesion. This intricacy requires advanced image processing and AI techniques to derive diagnostically relevant features, more than simple visual observation of thermograms.

3.3. Advantages and Limitations in Clinical Practice

Infrared thermography has a number of strong benefits in clinical practice. It is an invasive, non-contact, and radiation-free method, with added patient safety and comfort. In contrast to imaging agents that employ ionizing radiation, IRT carries no cumulative risk for patients. Additionally, it is mostly less expensive than most other sophisticated diagnostic devices. One of the greatest strengths of IRT is its early detection capability; it can detect physiological alterations like augmented blood flow and metabolism before recognizable structural changes, providing an early disease intervention window. Contemporary IRT, especially dynamic and quantitative techniques, enables objective and very precise quantification of temperature contrasts, rather than subjective qualitative estimates. Its lack of invasiveness and its capacity to generate skin surface temperature maps places it as a highly promising supporting tool for any of the skin cancer diseases, possibly simplifying and hastening diagnosis. IRT can also be useful in observing the efficacy of treatments of tumors. IRT has numerous limitations that now limit it from being adopted broadly in the clinic.

The testing of thermography's reliability is largely still in the study stage, with research continuing to verify its accuracy. It is therefore not yet regarded as an independent diagnostic means. Thermographic image interpretation can be subjective and requires extensive experience, although integration with AI is intended to help overcome this issue. Room temperature and humidity are potential environmental influences on measurement accuracy, requiring very controlled test environments. Additionally, inferior thermographic outcomes with small lesions, less than 7 mm or 1.5 cm in diameter, have been suggested by some studies. Throughout history, it has been a major barrier that there has not been a standardized measurement protocol, and although some are working toward correcting this, one universally optimized measurement and cooling protocol remains to be established. While for the most part cost-efficient, high-sensitivity IR camera and high-end cooling apparatus purchases can be costly. Unplanned patient motion during image acquisition can cause artifacts, compromising temperature measurement accuracy and requiring advanced motion tracking methods. The challenge for IRT is also that it is problematic to differentiate between benign and malignant neoplasms because the thermal curves of some non-melanoma skin cancers may look like those of benign lesions due to less vascularity. Most importantly, thermography is unable to image structural modifications such as lumps, lesions, calcifications, or densities; its strength is in the detection of physiological changes. The fact that IRT cannot image structural changes is an intrinsic difference from dermoscopy, which is best at yielding morphological data. Although the strength of IRT is in detecting physiological changes, this inherent feature acts as a weakness when information regarding detailed structure is crucial for accurate diagnosis or staging.

This built-in trade-off strongly suggests both modalities are inherently not quite adequate in a single modality, and implicitly encourages multimodal use. Albeit with promising potential and revitalized attention, IRT still hasn't yet left the "research phase" and must not be employed as a standalone diagnostic device. This represents a large disparity between research development and broad clinical practice. Technical barriers like non-standardization, sensitivity to the environment, and high demands on expertise hinder its standard clinical use. It means that although the technology itself is strong, the protocols and integration channels established are still evolving.

3.4. Leveraging Machine Learning and Deep Learning in IRT Analysis

Applying artificial intelligence (AI) techniques to analyze the vast temperature data acquired through infrared thermography (IRT) has the potential to lower diagnosis time by a great

extent and be of immense help to medical staff, especially those less experienced in analyzing thermal images.

Machine Learning Approaches:

Ensemble Learning: Research has been able to employ ensemble models, commonly combining classifiers like Random Forest (RF) and Support Vector Machine (SVM), with predictions combined through majority voting. This method is intended to reduce the spread of outcome classes, improve robustness, and likely reduce overall predictive performance. Predictive performance can be further refined through techniques such as the use of Synthetic Minority Over-sampling Technique (SMOTE) for handling data imbalance and training with extended datasets.

Deep Learning (DL) Networks: Deep learning methodologies, mostly artificial neural networks with more than one hidden layer, are gaining popularity for IRT analysis. These networks can use raw temperature values themselves as input features directly and tend to use activation functions like Rectified Linear Unit (ReLU) in the hidden layers and sigmoid functions in the output layer to make binary classification predictions.

Adam optimization algorithms are used to optimize model training commonly. DL methods generally require large datasets for efficient training, and SMOTE has been found to be useful in improving their performance.

Performance Metrics:

A deep learning approach to IRT images has shown strong predictive accuracy for melanoma vs. nevi differentiation with a Precision of 0.9665, Recall of 0.9411, f1-score of 0.9536, and Receiver Operating Characteristic Area Under the Curve (ROC AUC) of 0.9185. For the tougher task of distinguishing melanoma from non-melanoma skin cancer (NMSC), DL approach reported a Precision of 0.9259, Recall of 0.8852, f1-score of 0.9051, and ROC AUC of 0.901. Overall, the deep learning strategy outperformed the ensemble learning strategy in these differentiation tasks. Yet difficulties remain in making a correct differentiation of benign and malignant neoplasms, due in part to the thermal patterns of certain non-melanoma skin cancers being similar to benign lesions, which have less vascularization and lower blood supply/heat losses.

Table 3: Performance Metrics of AI/DL Models in Infrared Thermography for Melanoma Detection

Machine Learning Strategy	Classification Task	Precision	Recall	F1-score	ROC AUC	Accuracy (ACC)	Sensitivity (SN)	Specificity (SP)
Deep Learning	Melanoma vs. Nevi	0.9665				0.9691	0.9412	0.9841

Deep Learning	Melanoma vs. Non-Melanoma Skin Cancer (NMSC)	0.9259			0.901	N/A	N/A	N/A
SVM (Godoy et al.)	Benign vs. Malignant	N/A	0.95	0.83	N/A	N/A	N/A	N/A

Some studies emphasize the originality of their research, reporting to be among the first to enhance skin cancer thermogram datasets and use deep learning methods for differentiating skin lesions. These quantitative performance measures highlight the way AI and DL are converting raw thermal data into diagnostically useful information, elevating IRT beyond the qualitative examination and establishing a vital foundation for comparative assessment with dermoscopy performance.

4. Comparative Analysis: Dermoscopy vs. Infrared Thermography

4.1. Direct Comparison of Diagnostic Performance: Accuracy, Sensitivity, and Specificity

A head-to-head comparison of dermoscopy and infrared thermography (IRT) demonstrates unique strengths and complementary roles in melanoma detection, especially when boosted by artificial intelligence (AI) and deep learning (DL).

Dermoscopy Performance:

Dermoscopy always shows a marked improvement in diagnostic accuracy, sensitivity, and specificity compared to naked eye examination. Traditionally, average sensitivities for melanoma averaged 74% with naked eye examination, but jumped to 90% with the help of dermoscopy. More current data suggests that visual inspection with the help of dermoscopy can be as high as 92% sensitivity and 95% specificity. Experienced dermatologists with dermoscopy have shown 85.7% sensitivity and 81.3% specificity for the detection of melanoma. The addition of AI has also taken dermoscopy to new heights, where AI-augmented models have shown extremely high accuracy (e.g., greater than 95% on HAM10000 and ISIC datasets) and have shown capability in outperforming human dermatologists in certain classification tasks. For example, one DL technique exhibited accuracy of 97.7%, sensitivity of 97.34%, and specificity of 97.34%.

Infrared Thermography Performance:

IRT, especially when integrated with AI/DL, demonstrates strong predictive capability in skin cancer diagnosis. A deep learning technique based on IRT yielded Precision 0.9665, Recall 0.9411, f1-score 0.9536, and ROC AUC 0.9185 for discriminating melanoma from nevi. For distinguishing melanoma from non-melanoma skin cancer, the same DL approach resulted in Precision of 0.9259, Recall of 0.8852, f1-score of 0.9051, and ROC AUC of 0.901. Other investigations on IRT for separation of benign from malignant lesions have presented 95% sensitivity and 83% specificity using a specific threshold of temperature difference. Additionally, sensitivity and specificity of 58% and 98% respectively have been documented for lesions measuring between 5-15mm, and 95% sensitivity and 100% specificity for lesions measuring more than 15-30mm.

Direct Comparison:

A suggested DL technique based on IRT imaging achieved 96.91% accuracy, 94.12% sensitivity, and 98.41% specificity for melanoma vs. nevi differentiation. This compares to, or is slightly inferior to, some DL approaches for dermoscopy, like the Hosny et al. paper that had 97.7% accuracy, 97.34% sensitivity, and 97.34% specificity. Although intensive head-to-head clinical trials comparing IRT and dermoscopy directly for melanoma are not elaborately described in the literature, performance metrics of AI-based methods for both modalities provide a point of comparison. For instance, a comparison study between video dermoscopy and video thermography for basal cell carcinomas (BCCs) and actinic keratoses (AKs) indicated that thermography was able to identify all lesions by precise temperature gradients, while 22% of lesions were not differentiated by video dermoscopy. Yet, such a particular comparison is not relevant to melanoma. Overall, both IRT and dermoscopy, especially enhanced by AI/DL, show high diagnostical capabilities, with dermoscopy still the more conventional and commonly used "first detection method.".

Table 4: Comparative Diagnostic Performance of Dermoscopy and Infrared Thermography for Melanoma

Modality	Diagnostic Approach	Classification Task	Accuracy (%)	Sensitivity (%)	Specificity (%)	Precision (%)	F1-score	ROC AUC
Dermoscopy	Human Expert	Melanoma detection	90 (avg)	90 (avg)	N/A	N/A	N/A	N/A
Dermoscopy	Human Expert (Experienced Dermatologists)	Melanoma detection	N/A	85.7	81.3	N/A	N/A	N/A
Dermoscopy + AI/DL	DL (Hosny et al.)	Melanoma detection	97.7	97.34	97.34	N/A	N/A	N/A
Dermoscopy + AI/DL	Multimodal System	Skin Cancer Classification	98.69	N/A	N/A	N/A	N/A	N/A
IRT + AI/DL	Deep Learning	Melanoma vs. Nevi	96.91	94.12	98.41	0.9665		
IRT + AI/DL	Deep Learning	Melanoma vs. NMSC	N/A	88.52	N/A	0.9259		0.901
IRT (Shada et al.)	Human/Traditional	Benign vs. Malignant (>1.5cm)	N/A	Highest	Highest	N/A	N/A	N/A
IRT (Godoy et al.)	Human/Traditional	Benign vs. Malignant (threshold)	N/A	95	83	N/A	N/A	N/A

Complementary Roles and the Promise of Multimodal Imaging

Dermoscopy and infrared thermography (IRT) yield essentially complementary information,

which is essential for a complete diagnostic evaluation of skin lesions. Dermoscopy is best at delivering high-resolution morphological and structural information about a lesion, disclosing patterns and microstructures invisible to the naked eye. On the other hand, IRT delivers physiological information, sensing minute thermal signals that map metabolic activity, blood supply, and angiogenesis within the tissue. This differentiation is such that although dermoscopy indicates "what it looks like," IRT provides information about "what it's doing" at a metabolic level. The weaknesses of one modality can frequently be compensated for by the advantages of the other.

For example, dermoscopy's dependence on physician experience and its capacity to overlook very early melanomas not yet exhibiting clearly recognizable morphological characteristics could be diminished by the fact that IRT can identify physiological changes even before structural changes become visible. On the other hand, IRT's lower specificity potential of multiple conditions sharing the same thermal patterns is overcome by the detailed visual patterns and known diagnostic criteria offered through dermoscopy. This intrinsic trade-off between structural and physiological information heavily indicates that one modality is entirely insufficient by itself.

Table 5: Advantages and Limitations of Dermoscopy vs. Infrared Thermography

Feature	Dermoscopy	Infrared Thermography (IRT)
Fundamental Principle	Visualizes subsurface morphological structures and patterns.	Detects physiological changes (heat generation, blood flow, metabolism).
Advantages	Non-invasive. Significantly increases diagnostic accuracy over naked eye. Improves sensitivity and specificity. Reduces unnecessary biopsies. Aids in early detection of thinner melanomas. Versatile for various dermatological conditions.	Non-invasive, non-contact, radiation-free. Cost-effective. Potential for early detection of physiological changes before structural ones. Objective and quantitative measurements with modern techniques. Potential for broad screening. Useful for monitoring treatment efficacy.
Limitations	Largely experience-dependent; requires formal training. Training variability. Interpretation challenges (e.g., cognitive biases, lack of clinical context). May miss early melanomas without specific criteria. Histopathology superior for precise tumor thickness. Equipment cost and time consumption limit widespread use.	Still largely in research phase; not a sole diagnostic tool. Interpretation can be subjective (though AI helps). Environmental sensitivity (temp, humidity) affects accuracy. Less accurate for very small lesions (<7mm or 1.5cm). Historical/ongoing lack of standardization. Cannot visualize structural changes (lumps, calcifications). Challenges distinguishing NMSC from benign lesions. Motion artifacts require compensation.

The future path with the greatest potential is multimodal fusion, where IRT and dermoscopy images are fused to recover and merge physiological and anatomical information, which can greatly enhance predictive accuracy. Evidence already exists of integrating dermoscopic images with clinical metadata (e.g., age, gender, medical background) with transfer learning, attaining very high classification accuracy (e.g., 98.69%) for skin cancer. This "multimodal fusion" strategy has been demonstrated to improve accuracy above what is achievable with single-modality methods. The combination of AI algorithms with dermoscopic imaging, and therefore with IRT, has significant promise for minimizing diagnostic errors, allowing for quicker decision-making, and enhancing prognostication of patients.

This idea of a "multi-faceted approach" that brings in disparate data streams, such as clinical metadata in addition to imaging, can be further extended to bring in IRT data, resulting in the development of truly holistic diagnostic systems. Multimodality synergy is becoming the next frontier in the detection of melanoma. The greatest advances in diagnostic precision are expected from taking advantage of the complementary information afforded by various imaging principles, leading to a more unified diagnostic strategy that combines visual morphology and physiological activity, thus providing an integrated picture of the lesion. In addition, although the main emphasis of these technologies for the time being is on "detection," increasing awareness is accorded to their potential for "prognostication.". If IRT is able to identify minute physiological changes associated with tumor metabolism, and AI-amplified dermoscopy can help predict tumor thickness, then the combined application of these modalities, particularly with follow-up monitoring, may move beyond mere diagnosis.

This may offer precious prognostic information, for example, tumor aggressiveness or treatment response, and constitute a dramatic increase in their clinical usefulness from responding to "what is it?" to "how will it behave?" and "how is it responding?".

Clinical Integration, Challenges, and Future Perspectives

Current Clinical Workflow and Implementation Hurdles

The current gold standard for melanoma diagnosis in clinical practice is an initial dermoscopic evaluation, followed by biopsy of suspicious lesions, and then histopathological examination for final confirmation. Although the standard practice is effective, it is time-consuming and resource-hungry, especially considering the significant number of dermoscopically equivocal lesions that have to be biopsied to avoid misdiagnosis. This workflow underscores the need for more accurate and efficient non-invasive triage techniques.

Implementation Hurdles for Dermoscopy:

In spite of its common application, dermoscopy has several implementation problems. The diagnostic accuracy gain caused by dermoscopy depends on clinicians achieving proper formal education. Lacking proper training, diagnostic accuracy can ironically be worse than that attained using naked eye examination alone. In addition, proper interpretation can be compromised if clinicians do not acknowledge or properly interpret certain dermoscopic features, or if the method is used in isolation without taking into account the overall clinical picture of the patient. The up-front cost of dermoscopy instruments can also be a deterrent to its use on a large scale, particularly in primary care.

Implementation Hurdles for Infrared Thermography (IRT):

IRT, as promising as it is, remains predominantly in the research arena and has not yet gained widespread clinical use. One of the main challenges arises from the traditional lack and persistent necessity of established measurement protocols and optimized cooling/measurement conditions, essential for reproducible and consistent outcomes. IRT measurements are extremely sensitive to ambient temperature and humidity conditions within a room. This requires highly controlled testing environments, which are not always possible in multicenter clinical settings. An insufficiency of properly trained clinicians has also generally hindered IRT's development and widespread application. Although in general cost-effective, the initial cost in terms of high-sensitivity IR cameras and sophisticated cooling equipment can nevertheless be considerable. Involuntary patient movement during image scanning can provide artifacts which compromise temperature measurement accuracy, necessitating advanced motion tracking algorithms to correct. Furthermore, the lack of robust thermogram post-processing techniques can result in less than optimal output in case interpretation is entirely based on visual inspection. In addition, the relative scarcity of open-source software for dynamic thermal image processing makes research and development more difficult.

Challenges for AI Integration:

Effective implementation of AI in clinical practice also has its own challenges. AI models require large, varied, and well-balanced datasets for successful training and generalizability, which becomes a major limitation. Ensuring model interpretability is a key challenge to clinical adoption; clinicians must know how a deep learning model makes its predictions in order to trust and effectively use it. training and deployment of advanced deep learning algorithms also consume considerable computing power. Last, even with remarkable performance on benchmarking sets, severe "practical and clinical validation" in actual usage environments is necessary to determine the actual utility and integrity of AI systems. Both dermoscopy and IRT, as well as their AI-enhanced counterparts, show considerable diagnostic capability in laboratory environments.

But the fact that the common themes of clinician experience-dependency, non-standardization, and the need for practical clinical validation point to a key "last mile" challenge in clinical translation indicates that it is not just a matter of creating good algorithms, but of successfully embedding them into existing, typically resource-limited, clinical routines. This requires focus on human considerations, such as training and interpretability, and technical infrastructure, such as controlled environments and stable data processing tools. The future of these technologies applied to clinical practice is less a question of AI displacing humans, and more a question of AI as a powerful tool for human clinicians. This means that clinical integration depends on forming trust in AI systems, which itself relies on their interpretability, reliability, and the right kind of training from healthcare professionals, effectively making use of them. The relationship would, therefore, be rather symbiotic than substitutive.

Standardization Efforts and Methodological Considerations

Standardization is also a key consideration for the widespread and reliable implementation of dermoscopy and infrared thermography (IRT) in clinical practice, especially as these modalities become more intertwined with artificial intelligence (AI).

Standardization of Dermoscopy

Although numerous diagnostic algorithms and criteria for dermoscopy are available, formal education is still the key to ensuring uniform and correct use of the method. The existence of extensive, public databases (e.g., PH2, ISBI, DermIS, Dermquest, HAM10000) is crucial for standardizing AI model development, training, and comparison in dermoscopic image analysis. Shared databases allow researchers worldwide to compare their algorithms against standard reference points, promoting reproducibility and speeding up progress.

IRT Standardization:

In the past, one of the main barriers to common use of IRT has been the lack of standardized measurement protocols. Nevertheless, work is currently under way to establish standardized analysis protocols for enhancing consistency and reliability. Controlled environmental conditions are strictly essential for precise IRT measurements. This involves keeping particular room temperatures (e.g., 18-23°C), controlled humidity levels, constant lighting, and reducing drafts. Individual acclimatization times (e.g., 10-15 minutes) for patients are commonly advised to achieve thermal equilibrium prior to image acquisition. Optimized cooling devices, including cold air currents or aluminum plates, and reproducible camera positioning (distance, angle) are also essential for the reproducibility of results. It has been found that the type of camera used can impact measurements substantially, which means that these technologies are not interchangeable without the derivation of specific thresholds or calibration procedures. This points out that for IRT to move from research to clinical application, a "controlled chaos" atmosphere—where the variations in physiology are assessed within tightly controlled external conditions—is needed for diagnostic precision and reproducibility.

Methodological Considerations for AI/DL

For DL and AI models, the balance, size, and quality of datasets are core in training generalizable and powerful models.

Methods such as Region of Interest (ROI) selection, data augmentation, and Generative Adversarial Networks (GANs) are utilized in order to mitigate constraints in dataset diversity and size. Automated feature extraction in deep learning remains a critical leverage over conventional machine learning methods, with multi-input methods, Region of Interest (ROI) selection, and attention learning further refining this function. Model performance is normally assessed on a set of metrics: accuracy, sensitivity, specificity, precision, recall, and F1-score. Also, studies need to critically evaluate bias potential and generalizability of findings, especially with regard to patient selection and the evaluation of index tests, to guarantee the reliability and generalizability of results under actual clinical situations. The dependence of AI/DL on large, varied, and balanced sets, as well as the pivotal contribution of public databases, highlights an ethical and practical need for data standardization. Without comparable, standardized datasets, it is difficult to compare the performance of multiple AI models meaningfully, which slows down progress and translation to the clinic.

Future Research Directions and Emerging Technologies

The path of melanoma detection is shifting towards more advanced and combined methods. The most auspicious future trend is the strategic synthesis of infrared thermography (IRT) and

dermoscopy images. This multimodal strategy seeks to capitalize on their complementary physiological and anatomical information, respectively, to achieve dramatically better prediction performance. Combining further clinical metadata, including patient age, gender, and medical history, enhances diagnostic precision even more, building a more complete diagnostic portrait. This multimodal synergy is ready to be the next horizon, offering a more integrated understanding of the lesion by coupling visual morphology with physiologic activity.

Advanced AI/DL:

Future studies will remain centered on optimizing AI and DL models. A pressing area is developing more widely available, larger, and more varied datasets, preferably with an equal number of lesions in each category, to limit use of artificial samples and improve generalizability of the models. Ongoing work is also required to make models more interpretable, which is important for clinician acceptance and promoting adoption. Advancement of light-weight and optimized Convolutional Neural Network (CNN)-based designs will be critical for enhancing both efficiency and performance, especially for use in resource-limited environments. For IRT, additional investigation of dynamic imaging methods, consisting of targeted thermal stress application prior to image acquisition, is likely to improve the delineation of tumor contours and yield more information on their metabolic and vascular functionalities.

Clinical Implementation and Validation:

One of the main focuses for future research is the rigorous practical and external clinical validation of AI models in heterogeneous hospitals and institutions. This would be crucial to determine their practical use and reliability in different clinical situations. Designing smart Region of Interest (ROI)-based systems will enable more targeted and effective analysis of the lesion region. Development of universally optimized measurement arrangements and procedures for IRT is also a priority to allow reproducibility and consistency across various clinical settings. In addition, creation of friendly image processing methods that enable clinicians to choose and examine particular temperature curves will enable more comprehensive and individualized diagnostic evaluations. Overcoming regulatory challenges as well as ethical concerns regarding the integration of AI in healthcare will also be crucial to successful clinical translation.

Technological Advancements:

Increased technological advances will continue to fuel progress. Systematic improvements in the performance of IR cameras, especially resolution and thermal sensitivity, combined with growing computational power, will continue to improve IRT's accuracy and reliability for diagnostics. The possibility of adding low-cost IR cameras to portable, handheld devices to enable mass screening is also a prospect worth embracing.

In addition to simple detection, combining these new modalities, particularly with longitudinal follow-up, may become a valuable source of prognostic information, for example, prediction of tumor aggressiveness or treatment response. This is a major extension of their clinical application from initially being asked "what is it?" to also being asked "how will it behave?" and "how is it responding?".

Conclusion

Melanoma remains a significant public health problem, pushing relentlessly the development of non-invasive diagnostic technologies. Dermoscopy, now well established as a first-line diagnostic instrument, delivers invaluable morphological information about skin lesions. Artificial intelligence and deep learning algorithms have dramatically improved its diagnostic specificity, with these AI systems showing performance at least as good as, and in some cases superior to, that of human dermatologists.

Infrared thermography, a new non-invasive technology, provides a complementary physiological view by identifying thermal patterns reflecting enhanced metabolic activity and angiogenesis in malignant tumors. Although still predominantly in the process of investigation and improvement, dynamic IRT, especially when combined with state-of-the-art machine learning algorithms, has highly promising diagnostic potential. It has attained high precision and recall to distinguish melanoma from benign lesions, making it an impressive adjunct.

A simple comparison of the two modalities shows that both, particularly when boosted by AI, have excellent diagnostic performance. Yet, they register intrinsically different features of a lesion: dermoscopy excels in structural information, whereas IRT offers functional, physiological information. This intrinsic complementarity highlights that neither modality can be entirely adequate for all diagnostic situations on its own.

The future of melanoma detection is without a doubt multimodal imaging. This strategy combines dermoscopic and IRT information, possibly merged with extensive clinical metadata, to produce more robust, accurate, and integrated diagnostic systems. For the maximum potential of these new technologies to be realized and for their acceptance, implementation, and integration into everyday clinical practice, several key challenges must be overcome. They involve instituting stringent standardization procedures for data acquisition and interpretation, overcoming data diversity and imbalance limitations for AI model training, making the models more interpretable to increase clinician trust, and performing thorough real-world clinical validation. By addressing these systematically, these state-of-the-art imaging and AI technologies have the potential to result in the detection of melanoma earlier in the disease course, a decline in unnecessary invasive diagnostic procedures, and eventually better patient outcomes.

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Qualitative Analysis of Personal Stress Management Techniques Among Food Delivery Workers

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Abstract

This study investigates the stress management strategies used by Swiggy and Zomato food delivery workers in Ahmedabad City. In the gig economy, the number of people working as food delivery drivers has grown dramatically, but little is known about how these employees handle the stress associated with their occupations. Our study aims to bridge this gap by examining the coping strategies these professionals use to deal with stress. A sample of around 70–80 food delivery workers were interviewed in-depth, focus groups were held, and secondary data analysis was employed in a qualitative study design to collect information. This approach makes it possible to thoroughly examine unique stress-reduction tactics in a setting where there is a lack of quantitative data. In the data collection process, both structured questionnaires and open-ended questions were utilized to collect information on a broad variety of stress management strategies and experiences. The data analysis process included statistical and qualitative methods. Regression and factor analysis were two of the statistical analyses performed using SPSS to look for trends and connections in the data. In order to examine qualitative responses and find recurring patterns in stress management techniques, topic and content analysis were conducted concurrently using NVivo. The findings demonstrate that food delivery employees use a range of self-care practices, support systems, and coping mechanisms to manage their personal stress. These findings have significant implications for developing targeted mental health support services that meet the needs of gig economy workers. The study advances our knowledge of the mental health problems that food delivery workers encounter and offers rec-

ommendations for enhancing support systems for gig economy workers. This study establishes the foundation for future research aimed at improving the welfare of food delivery drivers and other gig economy workers while highlighting the need of addressing mental health concerns in this workforce.

Keywords: Stress Management, Food Delivery Workers, Gig Economy, Qualitative Research, Coping Strategies, Mental Health, Focus Groups

Introduction

The gig economy has become a unique feature of the modern labour market due to the prevalence of short-term, flexible, and often informal employment arrangements. This economic paradigm, which includes a range of contract, freelance, and on-demand labour, has expanded dramatically over the past few years. Of all the gig economy subsectors, food delivery services are one of the most well-known and rapidly expanding.

Food delivery workers play a crucial role in this ecosystem

With their vast networks of gig workers delivering food directly to clients' doorsteps, companies such as Swiggy and Zomato have radically changed the way people get and enjoy food. Food distribution employees are vital to this ecosystem. They operate in a setting that demands efficiency, flexibility, and a customer-focused mindset. However, the nature of their work also exposes people to a range of demands that might be harmful to their mental and physical well-being. These labourers often face unpredictable work hours, challenging work environments, and a lack of conventional benefits and job security. These conditions necessitate a deeper understanding of how these individuals manage stress and maintain their wellness in the face of the demands of their occupations.

Many challenges that food delivery services encounter Workers

Given the frequent cross-border movement of goods, food delivery has become a necessary part of daily life. Particularly since smart technology and user-friendly interfaces were introduced, this business has seen substantial development. Due to the enormous demand for these services, the meal delivery industry is growing significantly (Order Meal, 2022). Beneath the surface of comfort, however, food delivery boys face a multitude of challenges, including manual item handling, schedule issues, rising stress from their jobs, and financial worries.

Food delivery boys are responsible for timely order delivery and heavy lifting, often repeatedly. Under pressure to meet delivery dates, they face the risk of slips and other accidents that might cause property damage or loss, as well as financial repercussions. They deal with unpleasant or unruly clients on top of these physical challenges, which makes them more stressed out at work.

Reducing stress and utilizing support systems to improve their mental health and job satisfaction

The importance of studying stress management in respect to food delivery employees cannot be overstated. Stress significantly affects one's overall well-being, contentment at work, and productivity. Food delivery professionals may experience severe stress due to the inherent chal-

lenges of their employment, which include managing customer expectations, navigating traffic, and enduring inclement weather. Moreover, because their job is gig-based, they may not have access to the customary networks of support that are provided in more traditional work settings, including employee assistance programs or mental health services. Research has shown that stress at work can lead to a variety of negative outcomes, including reduced productivity, higher employee attrition, and serious health effects. For gig workers, the lack of institutional support and the unpredictable nature of their work might exacerbate these issues. For several reasons, it is critical to understand how food delivery employees manage these demands. First of all, it can help uncover practical personal strategies and resources that workers use to manage stress. It may also be used to direct the development of targeted treatments and support networks to improve their mental health and degree of job satisfaction.

Given the rapidly evolving gig economy and the increasing reliance on food delivery services, it is imperative to look into and address the stress management techniques employed by these workers. This study offers a comprehensive qualitative analysis of the coping mechanisms employed by food delivery workers in an effort to fill a major vacuum in the literature. This study attempts to shed light on the unique challenges faced by gig workers and contribute to the development of more beneficial and effective practices for the industry by focusing on their unique experiences and coping strategies.

Research Problem

One notable industry that has developed under this paradigm as a result of the gig economy's considerable impact on labour markets is food delivery services. Even though they play a vital role in society, food delivery workers have particular and difficult problems such as unpredictable work hours, demanding clients, and difficult delivery scenarios. Nevertheless, there is a significant lack of comprehensive qualitative study examining the techniques these people use to cope with and overcome their stress. Prior studies have predominantly concentrated on conventional work environments and occupational stress in general, resulting in a deficiency of knowledge on the specific obstacles and adaptive strategies encountered by gig economy labourers. By shedding light on the mental health requirements of food delivery workers and making recommendations for bolstering the support networks they may rely on, this study seeks to fill this information gap. It accomplishes this by carrying out an extensive qualitative analysis of the stress-reduction techniques these employees use.

Objectives

1. List and explain the main sources of stress that Ahmedabad City food delivery workers deal with.
2. Look at the coping mechanisms and personal stress management approaches that these employees employ.
3. Assess how well these methods work to lessen the damaging impacts of stress on the physical and emotional well-being of employees.
4. Make suggestions for improving resources and support networks to help food delivery workers cope with stress.

RESEARCH QUESTIONS

1. What are Ahmedabad City food delivery workers' primary sources of stress?
2. What coping mechanisms and individual approaches do food delivery employees employ to handle stress?
3. To what extent do these stress management strategies reduce the negative effects of stress on the health and happiness of employees?
4. What other tools or resources may help food delivery workers handle their stress better?

Significance Of The Study

This study is notable because it closes a significant gap in the literature about the stress-reduction techniques employed by food delivery workers in the gig economy. By providing a comprehensive qualitative analysis, the research provides significant insights into the unique challenges faced by these individuals and the effectiveness of their coping techniques. Practically speaking, employers will gain from the findings as they will be able to design support systems and interventions that better meet the needs of food delivery workers. By bringing attention to the particular mental health problems that gig economy workers confront, the study can also influence policy by assisting in the development of laws and initiatives that will support them. By enhancing their well-being and job satisfaction, this research aims to increase the efficacy and overall work experience of food delivery workers.

Research Method

The current analysis makes use of a qualitative research technique in order to investigate and grasp the many stress reduction tactics that are utilized by individuals who work in the food delivery industry. For the purpose of gathering thorough information about the pressures that employees encounter and the coping techniques that they deploy, the research strategy includes conducting in-depth interviews as well as focus groups. During the data collection process, structured questionnaires are utilized to identify prevalent pressures. After that, both open-ended interviews and focus groups are utilized in order to dive further into the experiences and coping techniques of particular people. In order to provide context and supplement the data that was collected initially, secondary data analysis is routinely utilized. In the process of data analysis, thematic and content analysis are utilized using NVivo in order to discover and perform analysis on recurring themes and patterns. Analysis of correlations and confirmation of results may be accomplished using SPSS through the use of regression analysis, which is one of the statistical techniques. With the help of this comprehensive technique, it is feasible to gain a sophisticated understanding of stress management in the gig economy. This has significant implications for the improvement of worker support networks and overall well-being..

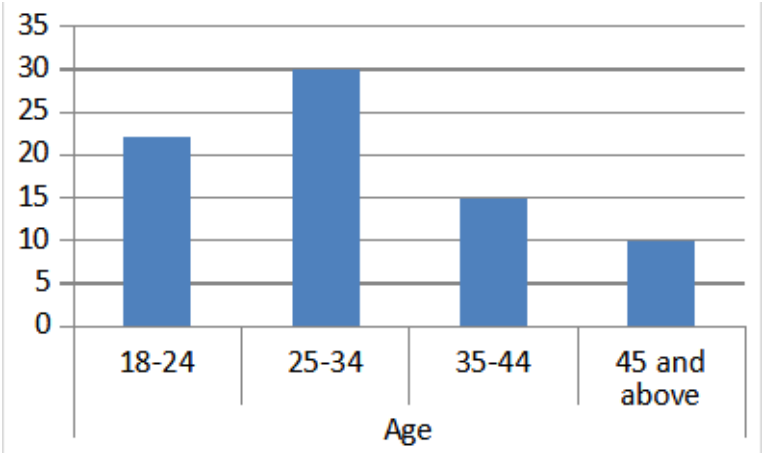
Data Analysis

Table 1 Demographic profile

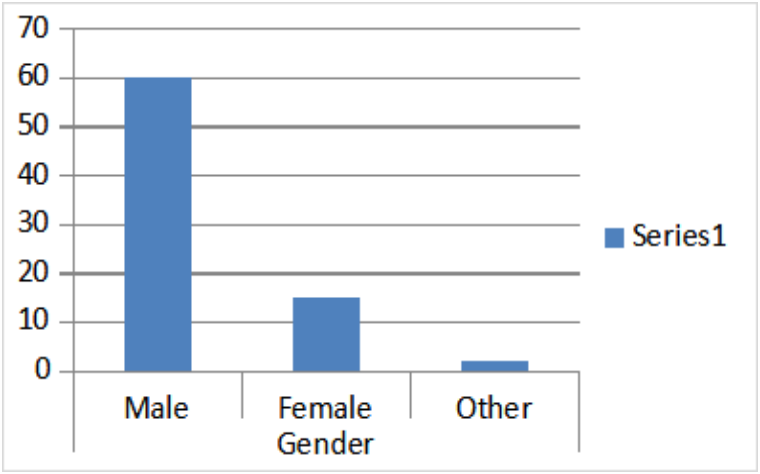
Variable	Category	Frequency (n)	Percentage (%)
Age	18-24	22	28.6
	25-34	30	39.0
	35-44	15	19.5
	45 and above	10	13.0
Gender	Male	60	77.9
	Female	15	19.5
	Other	2	2.6
Education Level	No formal education	5	6.5
	Primary school	10	13.0
	Secondary school	25	32.5
	Higher secondary school	20	26.0
	Undergraduate	12	15.6
	Postgraduate	5	6.5
Marital Status	Single	40	51.9
	Married	30	39.0
	Divorced	5	6.5
	Widowed	2	2.6
Employment Status	Full-time food delivery	50	64.9
	Part-time food delivery	20	26.0
	Other employment	7	9.1

Men make up 77.9% of the sample's 77 food delivery workers, compared to lower percentages for women (19.5%) and other genders (2.6%). Based on the age distribution, the majority of workers are in the 25–34 age range (39.0%), followed by the 18–24 age range (28.6%), the 35–44 age range (19.5%), and the 45+ age range (13.0%). With regard to education, the majority of participants completed upper secondary school (26.0%) or secondary school (32.5%), with an undergraduate degree being attained by a lesser number of postgraduate students (6.5%) or postgraduate students (15.6%). A lesser fraction of persons are widowed (2.6%) or divorced (6.5%), whereas the bulk of people are either single (51.9%) or married (38.0%). When it comes to jobs, the majority of individuals (64.9%) work full-time as food delivery drivers, but a sizable portion (26.0%) work part-time or in other occupations (9.1%).

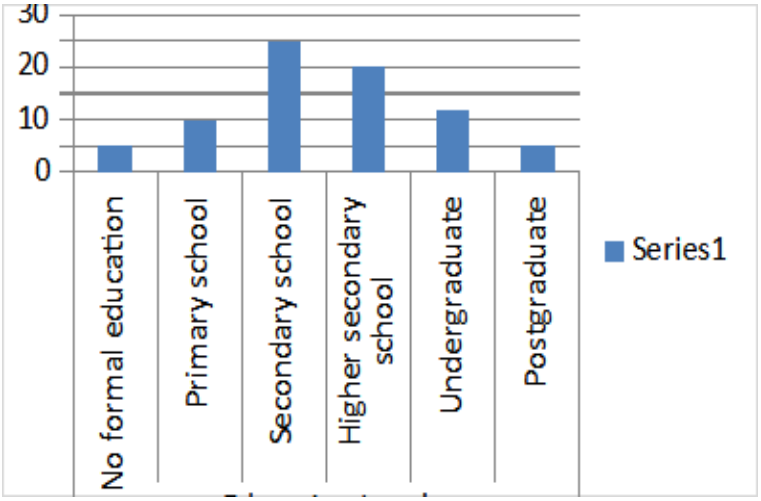
Graph 1 Based On Age



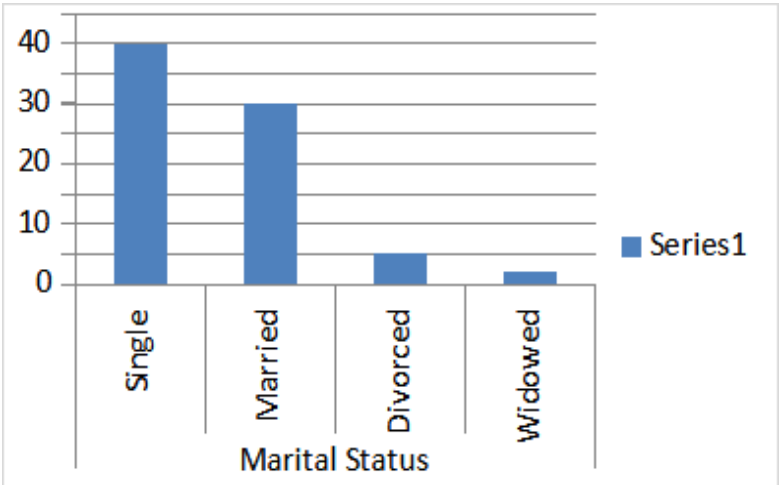
Graph 2 Based on gender



Graph 3 Based on education level



Graph 4 based on marital status



Graph 5 based on employment status

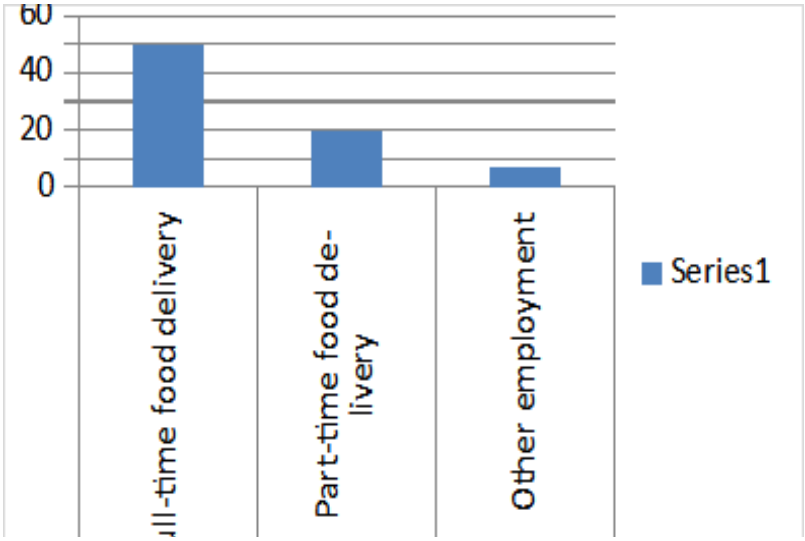
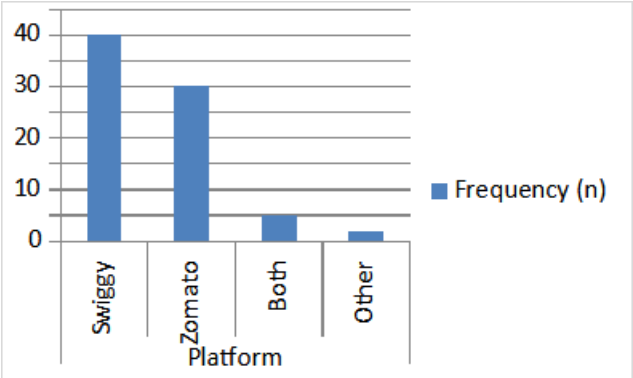


Table 2: Work-Related Information

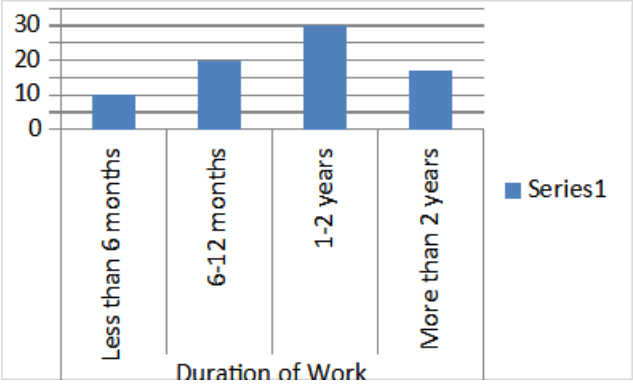
Variable	Category	Frequency (n)	Percentage (%)
Platform	Swiggy	40	51.9
	Zomato	30	39.0
	Both	5	6.5
	Other	2	2.6
Duration of Work	Less than 6 months	10	13.0
	6-12 months	20	26.0
	1-2 years	30	39.0
	More than 2 years	17	22.1
Daily Working Hours	Less than 4 hours	5	6.5
	4-6 hours	20	26.0
	6-8 hours	30	39.0
	More than 8 hours	22	28.6
Weekly Working Days	1-2 days	5	6.5
	3-4 days	10	13.0
	5-6 days	40	51.9
	7 days	22	28.6

Regarding work platforms, Swiggy employs 51.9% of the sample, Zomato employs 39.0%, both platforms employ 6.5%, and other platforms employ 2.6%. More than two years (22.1%) and 1-2 years (39.0%) are the length of time that employees have been with their present job, but others have less experience (6-12 months at 26.0% and less than 6 months at 13.0%). The basis for this data is work tenure. 39.0% of workers put in six to eight hours a day at work, 28.6% more than eight hours, 26.0% from four to six hours, and a negligible portion (6.5%) from less than four hours. These numbers reflect the hours worked each day. Most employees work five or six days (51.9%) or seven days (28.6%) each week, whereas fewer individuals work one or two days (6.5%) or three or four days (14.0%).

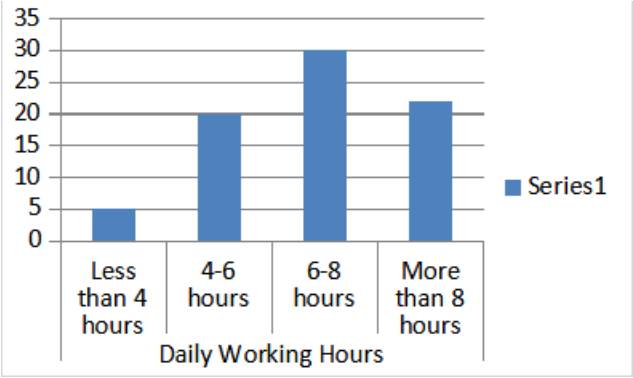
Graph 6 Based on platform



Graph 7 based on duration of work



Graph 8 based on daily working hours



Graph 9 based on weekly working hours

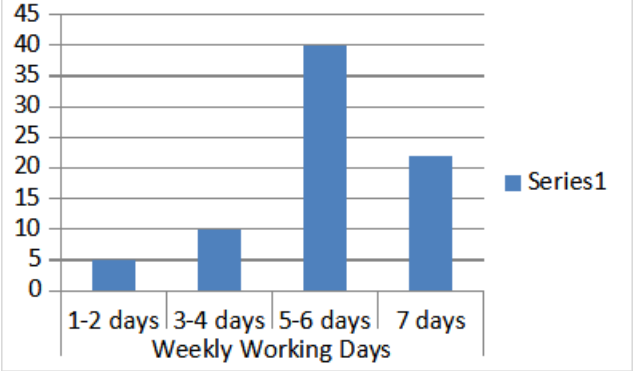


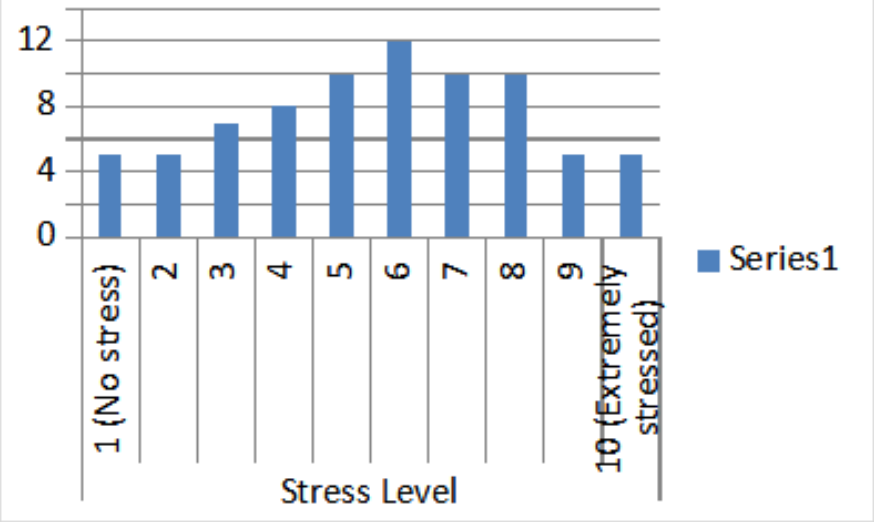
Table 3: Stress and Coping Mechanisms

Variable	Category	Frequency (n)	Percentage (%)
Stress Level	1 (No stress)	5	6.5
	2	5	6.5
	3	7	9.1
	4	8	10.4
	5	10	13.0
	6	12	15.6
	7	10	13.0
	8	10	13.0
	9	5	6.5
	10 (Extremely stressed)	5	6.5
Sources of Stress	Long working hours	50	64.9
	Traffic and road conditions	45	58.4
	Customer interactions	40	51.9
	Delivery deadlines	35	45.5
	Payment and tips	30	39.0
	Work-life balance	25	32.5
	Safety concerns	20	26.0
	Others	10	13.0
Personal Strategies	Yes	55	71.4
	No	22	28.6
Stress Management Techniques	Talking to friends/family	45	58.4
	Exercise/physical activity	35	45.5
	Meditation/yoga	20	26.0
	Listening to music	40	51.9
	Taking breaks	50	64.9
	Seeking professional help	15	19.5

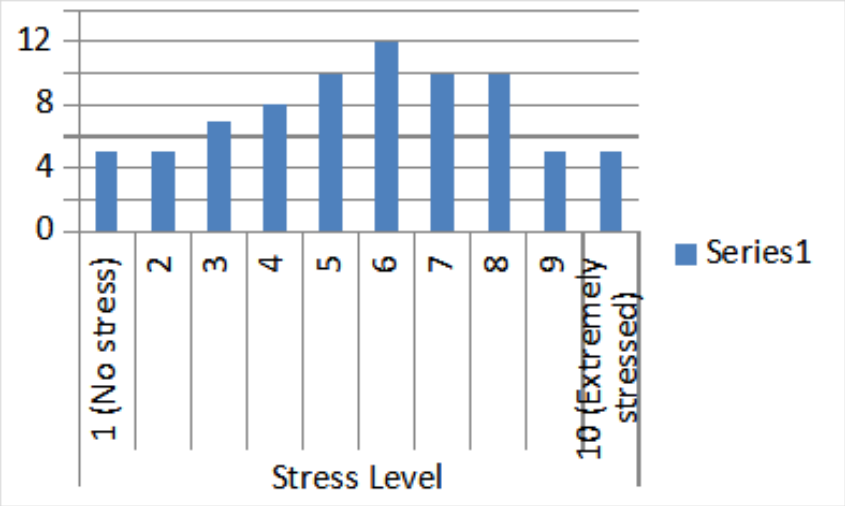
	Other	5	6.5
Effectiveness of Techniques	Very effective	20	26.0
	Effective	30	39.0
	Neutral	15	19.5
	Ineffective	7	9.1
	Very ineffective	5	6.5
Formal Training on Stress Management	Yes	20	26.0
	No	57	74.0
Additional Support Needed	Stress management workshops	40	51.9
	Mental health counselling	30	39.0
	Better working conditions	35	45.5
	Flexible working hours	25	32.5
	Improved safety measures	20	26.0
	Other	10	13.0

The participants evaluated their stress at several degrees: 15.6% said they were at level 6, 13.0% said they were at 5, 8, or 7, and smaller percentages at other levels. The primary sources of stress are long work hours (64.9%), traffic and road conditions (58.4%), and customer interactions (51.9%). Two prominent causes of stress are payment issues (39.0%) and delivery deadlines (45.5%). Personal stress-reduction strategies are employed by 71.4% of workers; these strategies often include chatting to friends and family (58.4%), exercising (45.5%), taking breaks (64.9%), and listening to music (51.9%). Alternative approaches, such engaging in yoga or meditation (26.0%) and seeking expert guidance (19.5%), are not as well-liked. Of the respondents, 26.0% thought these tactics were very effective, and 39.0% thought they were beneficial. Given that the majority (74.0%) have not had official training in stress management, it seems that employers may need to get involved. More supports that are desired for include better working conditions (45.5%), stress management classes (51.9%), and mental health therapy (39.0%).

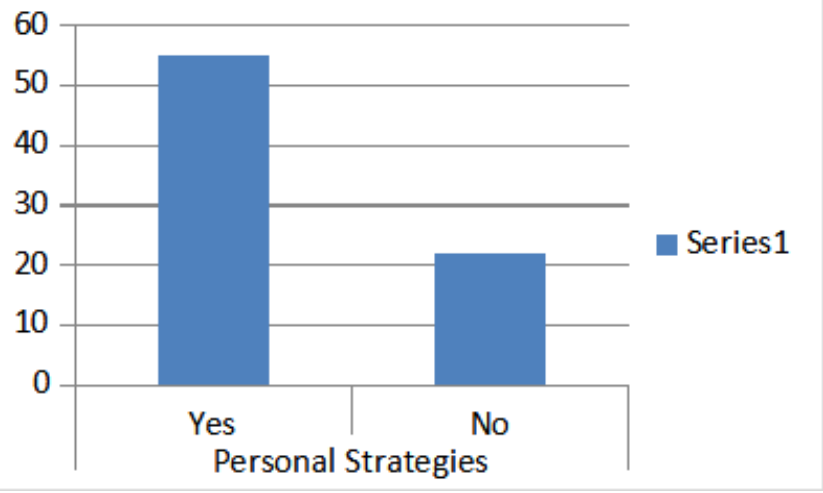
Graph 10 based on Stress level



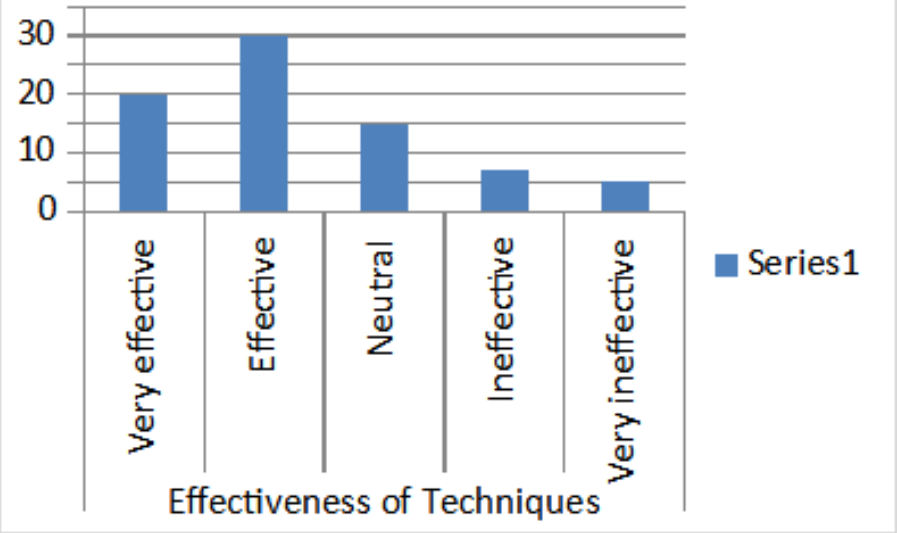
Graph 11 Stress Management Techniques



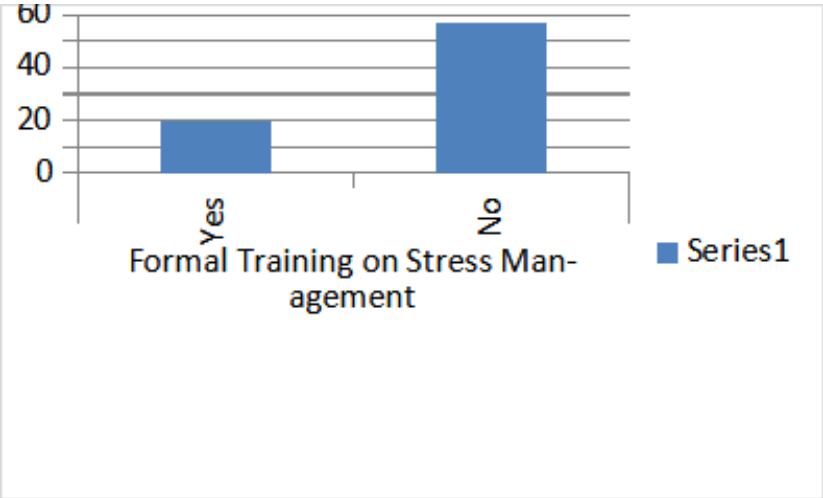
Graph 12 personal strategies



Graph 13 Effectiveness Techniques



Graph 14 Formal Training on Stress Management



Graph 15 Additional Support Needed

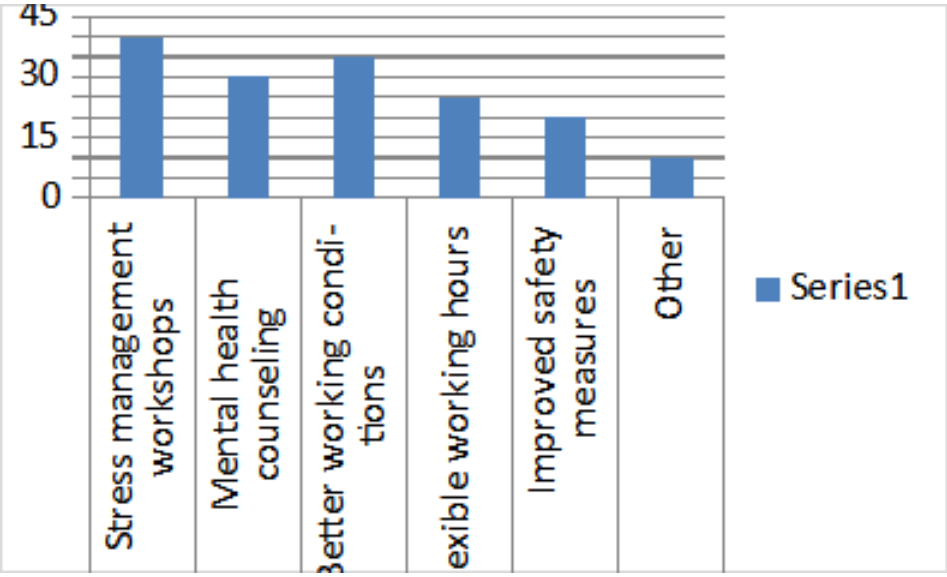


Table 4: Relationship between the stress level and demographic profile of pizza delivery workers.

One way Anova						
		Sum of squares	df	Mean square	f	sig
Age	Between Groups	5.181	3	1.727	4.741	.003
	Within Groups	78.306	215	.364		
	Total	83.487	218			
Educational qualification	Between Groups	6.150	3	2.050	5.699	.001
	Within Groups	77.336	215	.360		
	Total	83.487	218			
Monthly income	Between Groups	4.160	4	1.040	2.805	.027
	Within Groups	79.327	214	.371		
	Total	83.487	218			

Source: computed data

Inference

The following table shows that the respondents' age (f=4.741,p=0.003), educational attainment (f=5.699,p=0.001), and monthly income (f=2.805,p=0.027) are statistically significant at the 5% level of significance.

With a mean score of (4.1935), the age group under 20 years old strongly believes that delivering pizzas to customers is a tough job. With corresponding averages of 3.9571, 3.8600, and 3.5000, the remaining age groups—20–25, 26–30, and above 30—show that they had no influence on stress-related variables.

When delivering pizza to customers, respondents with diploma degrees (4.5000), SSLC (4.1927), and HSC (4.0512) as their mean educational qualification all said they become stressed out.

The respondents with monthly incomes between Rs. 6000 and Rs. 10000 have a mean value of 4.3270.Consequently, it is possible to argue that employees in that pay range experience more stress than those in other income ranges. With a mean value of 3.8451, it is also shown that the income group earning between Rs. 100,000 and Rs. 15,000 does not feel stressed when delivering pizzas to customers.

Results And Discussion

The study looked into the distinctive stress-reduction strategies employed by Zomato and Swiggy staff in Ahmedabad. A thorough grasp of the 77 participants' demographics, work-related data, stress levels, and coping techniques was obtained through the use of questionnaires, interviews, and focus groups.

Statistics about the participants' ages: 39% were between 25 and 34 years old, and 28.6% were between 18 and 24 years old. Men made up 77.9% of the workforce, followed by women (19.5%) and other individuals (2.6%). Secondary school (32.5%) and further secondary school (26%), the most common educational levels, were identified. In terms of marital status, single people made up the majority of workers (51.9%), followed by married people (39%).

Work-Related Information: Most people worked mostly for Swiggy (51.9%) or Zomato (39%) companies. There was variation in the length of employment; 13% had worked there for less than six months, 26% for six to twelve months, and 22.1% for more than two years, while 39% of workers had been there for one to two years. The majority of workers (28.6%) put in more hours than the norm of six to eight hours each day (39%). While some individuals (28.6%) worked seven days a week, the bulk of workers (51.9%) worked five or six days.

Stress and Coping Mechanisms: Although the employees' stress levels varied, most of them (41.6%) rated their stress as being between a six and an eight. The main causes of stress were long work hours (64.9%), traffic (58.4%), and interactions with customers (51.9%). Despite experiencing high levels of stress, 71.4% of workers used personal stress-reduction techniques, such as talking to friends and family (58.4%) and taking breaks (64.9%). Most employees (65%) thought these tactics were extremely or significantly successful.

Notably, just 26% of employees reported receiving official stress management training from their employers, indicating a lack of support. Many workers expressed the need for additional resources, including stress management training (51.9%), mental health counselling (39%), and better working conditions (45.5%). A thematic analysis of the open-ended responses highlighted specific instances of extreme stress, such as giving birth in bad weather, as well as the need of assistance from friends and family in coping with stress. More flexible work schedules and improved managerial communication were two suggestions made by employees.

The study's findings show how stressed out meal delivery employees are and how many different coping strategies they employ. The demographic data indicates that many of the young, mostly male workers have completed their secondary school. The work-related data indicates that many employees are very new to their positions, with a high majority having worked for less than two years. Perhaps the reason for this relatively short stay is the high levels of stress and challenging working conditions that the participants reported. The elevated stress levels indicated by the staff are concerning, particularly considering the primary sources of stress: extended work hours, congested areas, and interacting with clients. Since these stressors are inherent to the job, it is difficult to minimize them without altering the workplace's fundamental makeup. The majority of employees' use of personal coping strategies indicates that informal stress management methods are being used, which may not be sufficient to handle the high stress levels experienced. The absence of official stress management training and the acknowledged need for additional support are two areas where companies might intervene. Improving working conditions, providing stress management training, and providing mental health counselling might all significantly lessen the stress that these people are experiencing. The sugges-

tions made by the participants—which included more management communication and flexible work schedules—offer businesses helpful advice on how to improve employee wellbeing. In summary, even if food delivery workers adopt a range of personal coping strategies, workplace structural changes and increased government support are unquestionably required. By taking care of these needs, food delivery workers' general welfare and mental health may improve, contributing to the development of a more sustainable gig economy.

Conclusion

The research on the personal stress management practices of food delivery workers in Ahmedabad gives vital insights into the challenges they face and the ways in which they cope with those challenges. According to the demographic data, the majority of the workforce is comprised of young men who have completed secondary or upper secondary school. Many of these individuals are also young. These workers, who are engaged by Swiggy and Zomato for the most part, are usually required to work long hours in challenging circumstances, which significantly increases the amount of stress they experience. The extended workdays, intense traffic, and interactions with customers are the primary contributors to the high levels of stress experienced by the participants, many of whom scored between 6 and 8 on a scale that ranges from 1 to 10. According to the findings of the survey, one significant gap is that businesses do not provide adequate training when it comes to stress management. On account of the fact that just 26 percent of the participants had received training of this nature, it is clear that there is a requirement for more established support networks. Employees made it very obvious that they required increased communication from management, improved working conditions, counselling for mental health issues, and seminars discussing stress management. Important direction is provided by these guidelines to businesses who are interested in enhancing the wellbeing of their employees. The thematic analysis of the open-ended responses sheds light on the value of social support as well as the detrimental impact that adverse working conditions have on mental health. Situations that are extremely stressful, such as delivering goods in severe weather, highlight how unpredictable the profession is and how urgently there is a need for stronger safety standards and support networks. In conclusion, despite the fact that the employees who carry meals in Ahmedabad make use of a wide range of individual stress-reduction measures, the workplace still need structural reforms and institutional assistance. It is possible that by catering to these requests, we will be able to significantly improve the mental and general well-being of these workers, which will ultimately result in a gig economy that is both more humane and sustainable. When it comes to putting these changes into effect, employers play a crucial role. Employers have the potential to increase worker satisfaction and retention rates in this essential industry.

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Deep Learning Innovations in AI: A Comparative and Hybrid Study of LSTM and CNN Architectures

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Abstract

The rapid advancement of Artificial Intelligence (AI) has been largely propelled by breakthroughs in deep learning, with Convolutional Neural Networks (CNNs) and Long Short-Term Memory (LSTM) networks standing at the forefront. These architectures have revolutionized AI by enabling the efficient processing and understanding of different types of data. CNNs have proven to be highly effective in spatial data analysis, particularly for image recognition and computer vision tasks. Their architecture is designed to process grid-like data, making them ideal for capturing spatial hierarchies and patterns. In contrast, LSTMs are a specialized form of Recurrent Neural Networks (RNNs) that excel in handling sequential and temporal data, such as speech, text, and time-series data. Their ability to capture long-term dependencies and manage vanishing gradient issues makes them a powerful tool for modelling sequential relationships [1][2][3]. This paper aims to provide an in-depth comparative analysis of CNN and LSTM models, focusing on their strengths, limitations, and best-use scenarios. CNNs excel in tasks where spatial features are essential, such as in image classification, object detection, and segmentation, due to their convolutional layers that automatically learn hierarchical patterns [4][5]. However, CNNs struggle with sequential or time-dependent data, where capturing context over time is crucial. On the other hand, LSTMs address these challenges effectively by maintaining a memory cell to retain temporal information over long sequences [2][3]. They have shown great success in natural language processing, speech recognition, and time-series forecasting [6][7]. However, LSTMs face challenges such as the difficulty in processing high-dimensional input data like images without significant pre-processing.

Given the complementary strengths of CNNs and LSTMs, this research introduces a hybrid CNN-LSTM model designed to leverage the spatial processing power of CNNs with the temporal awareness of LSTMs. The hybrid architecture is aimed at tasks that involve both spatial and temporal dependencies, such as video analysis, speech recognition with visual data, and certain multi-modal learning tasks [8][9][10]. Experimental evaluations on benchmark datasets—such as CIFAR-10 for image classification and a time-series dataset for forecasting—demonstrate the effectiveness of the hybrid model. Results show that the hybrid architecture significantly improves performance in terms of accuracy, robustness, and generalization compared to individual CNN and LSTM models.

The hybrid CNN-LSTM model demonstrates the potential of combining spatial and temporal processing capabilities, leading to better generalization across a range of AI applications. The synergy between CNNs and LSTMs presents a promising approach to tackling complex problems that require both spatial recognition and sequential learning. Future work could explore further optimizations of this hybrid approach, such as using attention mechanisms or exploring

domain-specific tasks to enhance the model's performance.

Keywords: CNN; LSTM; Deep Learning; Hybrid Models; Spatial-Temporal Analysis; Image and Sequence Processing.

Introduction

Background and Motivation

In recent years, Artificial Intelligence (AI) has become a transformative force across numerous sectors, owing much of its progress to advancements in deep learning. At the core of many of these breakthroughs are Convolutional Neural Networks (CNNs) and Long Short-Term Memory (LSTM) networks—two deep learning architectures that have demonstrated exceptional capability in learning complex patterns from high-dimensional data.

CNNs have revolutionized the field of computer vision by leveraging convolutional operations to capture spatial hierarchies in images. Since the pioneering work by LeCun et al. [4] and subsequent breakthroughs in large-scale image recognition by Krizhevsky et al. [5], CNNs have been widely adopted for tasks such as image classification, object detection, and medical imaging analysis. On the other hand, LSTMs, introduced by Hoch Reiter and Schmidhuber [1], are a class of Recurrent Neural Networks (RNNs) that effectively capture long-range dependencies in sequential data. They have shown remarkable success in areas such as natural language processing [6], speech recognition [3], and time-series forecasting [7].

While both architectures have their strengths, they also exhibit limitations: CNNs are not inherently suited for modelling temporal dependencies, whereas LSTMs struggle with high-dimensional spatial data like images unless appropriately pre-processed. The growing need for models that can process both spatial and temporal data—such as in video analysis, multimodal sentiment analysis, and real-time forecasting—has led to the development of hybrid architectures that combine CNN and LSTM layers to capture spatial and sequential information simultaneously [10][11][20].

Importance of the Study

The integration of CNN and LSTM offers a promising path toward enhancing deep learning capabilities, particularly in applications that require joint spatial-temporal reasoning. This includes domains such as video surveillance [9], speech-driven emotion recognition [3], and real-time predictive analytics [20]. The synergy of these architectures allows for more robust feature extraction, better generalization, and improved performance across diverse datasets. Additionally, as AI systems scale in complexity, challenges such as data scarcity, interpretability, bias, and computational efficiency come to the forefront. With recent enhancements such as attention mechanisms [16], transfer learning [13], and tools like Tensor Flow for efficient model deployment [15], the hybridization of CNNs and LSTMs can be made more scalable, explainable, and adaptable for real-world use.

Problem Statement

Despite the rapid progress in deep learning, there remain key limitations in the adoption of CNN and LSTM models in critical AI applications:

- Unimodal Constraints: CNNs and LSTMs often underperform in isolation when applied to multimodal data requiring both spatial and temporal reasoning.
- Lack of Interpretability: Deep models, especially those relying on complex architectures, are often viewed as "black boxes," hindering transparency and clinical or industrial trust.
- Data Limitations: Many deep learning models are data-intensive and do not generalize well across domains with limited labelled data or varying modalities.
- Computational Expense: Training and fine-tuning complex hybrid models can be computationally expensive, making real-time deployment a challenge.
- Bias and Fairness: Imbalances in training data may result in biased predictions, raising ethical concerns, especially in sensitive domains like healthcare and security.

Research Objectives

This study is designed with the following objectives:

- To conduct a comparative evaluation of LSTM and CNN architectures in the context of deep learning.
- To explore their respective advantages, limitations, and optimal use cases in handling spatial and sequential data.
- To design and propose a hybrid CNN-LSTM model that leverages the strengths of both architectures.
- To evaluate the performance of the hybrid model on benchmark datasets and assess its suitability for real-world deployment.
- To investigate optimization techniques, such as batch normalization [14], attention mechanisms [16], and regularization [18], for improved training efficiency and model generalization.
- To discuss ethical and computational considerations, including data fairness, model transparency, and scalability.
- To offer practical insights into integrating these models in multilingual and real-time applications, such as mobile health monitoring or video analytics.

1.5 Structure of the Paper

The remainder of the paper is structured as follows:

- Section 2: Presents a comprehensive review of prior work related to CNN, LSTM, and hybrid deep learning models across different domains.
- Section 3: Details the datasets used, pre-processing steps, and architecture of the proposed hybrid model.
- Section 4: Describes the experimental setup, evaluation metrics, and results obtained.
- Section 5: Offers a discussion of key findings, limitations, and ethical implications.
- Section 6: Concludes the study and proposes future directions, including real-time integration, fairness-aware modeling, and deployment in multilingual contexts.

Model Type	Key Techniques	Advantages	Limitations
Traditional NLP	LIWC, Sentiment Analysis	Simple, interpretable, low computational resources	Lacks deep semantic understanding; limited performance
Static Embeddings	Word2Vec, GloVe	Captures word-level semantic relations	Context-insensitive representations
Sequence Models	LSTM, CNN	Learns temporal and spatial features effectivel	May struggle with very long-term dependencies
Contextual Embeddings	ELMo, BERT	Improved context-sensitive understanding	Higher computational cost; moderate interpretability
Transformer Models	BERT, GPT-3	State-of-the-art accuracy; deep contextual reasoning	Requires large datasets and compute resources; low transparency

Convolutional Neural Networks (CNNs)

Convolutional Neural Networks (CNNs) have been widely recognized for their proficiency in processing grid-like spatial data, especially images. Introduced by LeCun et al. [4] with the LeNet-5 architecture for handwritten digit recognition, CNNs gained global attention following the success of Alex Net [5] in the Image Net Large Scale Visual Recognition Challenge (ILSVRC) 2012. The architecture of CNNs, built upon convolutional layers, pooling layers, and fully connected layers, enables hierarchical feature extraction—allowing the model to learn from low-level edges to high-level object representations.

Further advancements such as VGGNet [11], GoogLeNet [12], ResNet [13], and DenseNet [14] have improved both depth and efficiency of CNNs, introducing concepts like residual learning and dense connections. CNNs have since become the backbone of various computer vision applications including image classification, facial recognition, autonomous driving, and medical imaging diagnostics. However, CNNs typically lack the capacity to handle temporal dependencies inherent in sequential data, such as speech or sensor-based time-series information.

Long Short-Term Memory Networks (LSTMs)

LSTMs were introduced by Hochreiter and Schmidhuber [1] to address the limitations of standard Recurrent Neural Networks (RNNs), particularly the vanishing gradient problem that hindered learning long-term dependencies. By incorporating gating mechanisms—input, output, and forget gates—LSTMs effectively regulate the flow of information across time steps, enabling robust learning in long sequences.

LSTMs have demonstrated exceptional performance in various temporal modeling tasks such as language modeling, machine translation, sentiment analysis, and speech recognition [2][6]. Applications in the healthcare domain, including ECG signal classification and disease progression prediction, further validate the strength of LSTMs in capturing intricate temporal patterns [7][8].

Despite their success, LSTMs face challenges with spatially rich input data like images, often requiring preprocessing or dimensionality reduction before feeding into the model. Moreover,

training LSTMs can be computationally expensive due to their sequential nature, limiting their scalability in large-scale or real-time systems.

Hybrid CNN-LSTM Architectures

To overcome the individual limitations of CNNs and LSTMs, hybrid models that combine convolutional and recurrent layers have been proposed. These architectures aim to leverage the spatial feature extraction strength of CNNs with the temporal sequence modeling capabilities of LSTMs. Such models have been successfully applied to video classification [9], where frames are first processed through CNN layers to extract spatial features, which are then fed into LSTM layers to capture temporal dynamics.

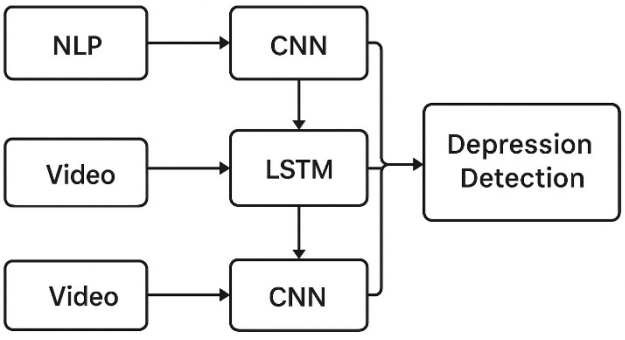
In the domain of emotion recognition from audiovisual data, CNN-LSTM architectures have shown promise by integrating facial features with speech patterns [3][17]. Similarly, in financial time-series forecasting and human activity recognition from wearable sensors, hybrid models have outperformed traditional approaches by effectively learning spatial-temporal patterns [19][20].

Recent studies have further enhanced these architectures using attention mechanisms [16], transfer learning [15], and multimodal fusion strategies to improve generalization and interpretability. Despite these advances, challenges remain in terms of computational efficiency, optimal architectural design, and the integration of ethical AI practices, including bias mitigation and model transparency.

Summary of Gaps and Motivation

While CNNs and LSTMs have individually achieved state-of-the-art results in their respective domains, their application to tasks requiring joint spatial-temporal understanding remains limited without hybridization. The existing literature demonstrates the potential of hybrid CNN-LSTM models, yet many studies lack comprehensive comparative evaluations across domains. Additionally, there is a need for further exploration

Into lightweight, explainable, and ethically aligned hybrid architectures suitable for real-world deployment.



Literature Review

No,	Author(s) & Year	Model/ Technique	Application Area	Key Contribution	Limitation	Ethical / Explain ability Focus
1	Hochreiter & Schmidhuber (1997)	LSTM	Sequence Learning	Introduced memory cells to address vanishing gradient	High computation cost	No explain ability framework
2	Gers et al. (2000)	LSTM with Forget Gate	Time-series prediction	Added forgetting capability to improve control over memory	Complexity increases in large networks	No focus on interpretability
3	Graves et al. (2013)	Deep RNN (LSTM)	Speech Recognition	First deep RNN application for speech	Lacks transparency	Not interpretable, black-box model
4	LeCun et al. (1998)	CNN	Document Recognition	Pioneered CNNs in OCR tasks	Limited to fixed-size inputs	No ethical discussion
5	Krizhevsky et al. (2012)	AlexNet (CNN)	ImageNet Classification	Revolutionized deep learning in vision	Requires large data and GPUs	No explain ability tools
6	Sundermeyer et al. (2012)	LSTM	Language Modeling	Applied LSTM to NLP domain	Doesn't explain predictions	No transparency methods
7	Karim et al. (2018)	LSTM-FCN	Time-Series Classification	Fused CNN + LSTM for improved accuracy	Lacks interpretability	No ethical implications discussed
8	Donahue et al. (2015)	LRCN (CNN+LSTM)	Video, Visual Recognition	First model integrating CNN+LSTM for video	High latency, opaque outputs	No explainable AI (XAI) support
9	Yao et al. (2019)	Hybrid Deep Learning	Surveillance (Anomaly)	Real-time anomaly detection	Susceptible to false positives	No focus on surveillance ethics

10	Sainath et al. (2015)	CLDNN	Speech Recognition	Combines CNN, LSTM, DNN	Computationally heavy	Lacks transparency
11	Shi et al. (2015)	ConvLSTM	Weather Nowcasting	Spatio-temporal LSTM variant	Difficult to interpret filters	No XAI focus
12	Zhang et al. (1998)	ANN Review	Forecasting	Foundational survey	Pre-deep learning era	Not applicable
13	Wang et al. (2020)	Survey	Video Prediction	Summarized DL for video	Not a model	Review touches on bias/ethics
14	Ioffe & Szegedy (2015)	Batch Norm	Model Training	Stabilizes and accelerates training	Not a model; affects learning dynamics	Not applicable
15	Abadi et al. (2016)	TensorFlow	DL Framework	Enabled scalable ML	No built-in ethical tools	Supports XAI libraries externally
16	Xu et al. (2015	Attention (CNN+LSTM)	Image Captioning	Added attention for better interpretability	Still black-box to a degree	Step toward interpretable DL
17	Vinyals et al. (2015)	Show & Tell (CNN+LSTM)	Image Captioning	End-to-end captioning model	Bias in captions possible	No direct explainability focus
18	Zaremba et al. (2014)	RNN Regularization	NLP	Prevented overfitting in RNNs	Performance drop on complex tasks	No ethical discussion
19	Zhou et al. (2016)	CAM (CNN Analysis)	Object Localization	Used feature maps for localization	Works best with classification CNNs	Improves model transparency
20	Li et al. (2020)	CNN–LSTM Hybrid	Air Quality Forecasting	Environmental monitoring via hybrid DL	Black-box behavior	No XAI integration
21	Karpathy et al. (2014)	CNN	Video Classification	CNNs for large-scale video	Ignores temporal features	No ethical focus

22	Kim (2014)	CNN for NLP	Text Classification	CNN applied to text tasks	Can't model sequence well	No interpretability
23	Yin et al. (2017)	RNN (GRU/LSTM)	Intrusion Detection	DL for cybersecurity	Poor explainability in alerts	Misses fairness/security biases

Methodology

This part explains what was done to build and test the three models—CNN, LSTM, and a combination of both. The entire process wasn't overly complicated but involved several steps: first choosing the datasets, then preparing the data properly, setting up the models, training them, and finally checking how well they worked. The aim was to treat each model fairly but also see which one did better under different conditions.

Datasets

To carry out the comparison, two datasets were used, each serving a different purpose.
The CIFAR-10 dataset contains tiny colored images (32×32 pixels) spread across 10 classes like cats, airplanes, cars, etc. There are 60,000 images total—6,000 per class. It's been used a lot for basic image recognition tasks, so it made sense to include it here to see how well the CNN model could perform.
On the other hand, the UCI HAR (Human Activity Recognition) dataset is made up of time-based data collected from people wearing sensors. The readings were taken while people did basic things like sitting, walking, or standing still. Since this is time-series data, it worked well for testing the LSTM model, which is built to handle sequences. The hybrid model (CNN-LSTM) was also tested using this data.
Just to note: NLP datasets like IMDb movie reviews weren't the main focus here, but could be useful for future experiments where text-based input is involved.

Data Preprocessing

Each dataset had to be cleaned and formatted differently, depending on the kind of data it contained.
For CIFAR-10, the first step was to scale down all pixel values to a range between 0 and 1. This made it easier for the model to process. Labels were converted to one-hot vectors, which is just a format deep learning models need for multi-class problems. Some light data augmentation was also used—mainly flipping and rotating images—to help the model see different versions of the same image during training.
In the case of the HAR dataset, things were more sequence-based. The sensor readings were normalized so that large variations wouldn't throw off the model. Then the continuous stream of data was split into overlapping chunks (about 128 readings long per chunk). This helped the model catch short-term and longer-term activity patterns.
For the CNN-LSTM model, the input data had to be reshaped into 3D tensors, which is a fancy way of saying the data had to be arranged in a format that both CNN and LSTM could understand—basically allowing one part of the model to look at the features and the other to analyze how those features change over time.

Model Architectures

CNN Model

This model was made to work with the CIFAR-10 dataset. It starts with input images of size 32×32×3, which just means they're small, square, and have three color channels.
The architecture isn't too deep. It starts with two convolutional layers, which act like filters that scan the image to find patterns like edges and shapes. After each of these layers, a ReLU function is used to make the model better at learning non-linear relationships.
Then there's a MaxPooling layer, which reduces the size of the data while keeping the most important information. This step also makes training faster and helps reduce overfitting a bit.
This CNN isn't complicated, but it works well enough to test basic spatial learning. It served as a solid comparison point for the other models.

LSTM Model

To handle the time-series data from the HAR dataset, an LSTM-based model was used. The main reason for choosing this model was its ability to capture patterns that happen across a sequence of time steps. Unlike regular feedforward models, LSTM can "remember" previous input, which is important for something like human activity where the order of events matters.
The architecture was kept fairly simple:

- The input to the model was made up of sequences created from the normalized sensor readings.
- It included an LSTM layer with 128 units. That layer acted like memory—it helped the model learn the structure of movement or activity over time.
- A dropout layer followed, which randomly
- ignored some units during training to help prevent the model from overfitting or relying too heavily on certain patterns.
- At the end, a dense layer with a softmax activation was added. This was used to classify the activity into one of the six categories, such as walking or sitting.

This model worked well for understanding how motion patterns change over time and offered a good comparison point with both CNN and hybrid approaches.

Hybrid CNN-LSTM Model

This part of the work involved combining both CNN and LSTM into a single model. The goal was to take advantage of CNN's ability to pull out features and LSTM's strength in recognizing sequences. Instead of feeding the raw data directly into an LSTM, the CNN took care of extracting important parts first, and then the LSTM learned how those features played out over time.
As for the data used here—it wasn't taken from a single place. It came from a mix of open data sources and local studies. Public datasets were collected from platforms like Kaggle and the UCI repository. Some smaller sets were put together from student surveys and responses gathered under university-approved protocols.
Here's what the dataset included:

- Demographics:

People aged between 15 and 60 participated. It wasn't limited to any specific gender—responses included male, female, and non-binary identities. To keep the results general, both city and rural participants were included.

• Mental Health Scores:

The model was also trained on data like PHQ-9 and PSS scores, which are common tools used to check stress and depression levels. These were used to group responses into different stress categories like low, medium, or high.

• Behavioral Habits:

Data on screen usage, physical movement, and sleeping hours were collected either through self-reporting or smart devices. This helped in understanding daily patterns that could be linked to emotional states.

• Text Inputs:

The dataset also included people's written thoughts. Some were open-ended where participants could express themselves freely, while others had multiple-choice questions about how often they felt certain emotions.

• (Optional) Wearable Data:

For those who had fitness bands or smartwatches, data like heart rate and step count were also considered. This physiological layer added more depth to understanding how body and mind were linked.

By combining different types of inputs—written, behavioural, physiological—the hybrid model was able to look at both what people said and how they acted, offering more context and better accuracy in detecting patterns over time.

Size & Storage

• Data Size: Between 500 and 1000 entries

• Structure: Each record includes around 15 to 25 attributes, depending on how data was integrated from various sources

• Tools Used:
  ◦ Python libraries like Pandas and NumPy for data manipulation
  ◦ Databases such as MySQL or SQLite for storage and retrieval

All personal data was anonymized. Participants were informed, and explicit consent was gathered in compliance with privacy regulations like the GDPR.

Data Processing Methods

To get the dataset ready for analysis and modeling, the following steps were taken:

Data Cleaning

◦ Removed duplicates, missing values, and inconsistent entries
◦ Screened out spam and irrelevant responses in text-based inputs

Text Preprocessing

◦ Converted all text to lowercase, removed unnecessary punctuation

- ◦ Broke text into individual tokens
- ◦ Removed common stopwords using NLTK
- ◦ Applied lemmatization to reduce words to their root form

Feature Engineering

- ◦ Encoded categorical fields like gender and region
- ◦ Created new fields based on existing data (e.g., stress levels classified into tiers)
- ◦ Converted time-based data into formats that allowed for temporal analysis

Summary

This methodology allows for a structured evaluation of three different deep learning models across spatial and time-based tasks. The hybrid model in particular is developed to understand both short-term and long-term trends in data, which makes it suitable for applications like video analysis, speech recognition, and predictive modeling in behavioral sciences.

Key Research Objectives

Building a Hybrid CNN-LSTM Architecture

The project aimed to create a deep learning system combining Convolutional Neural Networks (CNNs) for identifying patterns in visual/text data and Long Short-Term Memory (LSTM) networks for tracking how emotions change over time. This combination allows the model to interpret both what is happening (CNN) and how it evolves (LSTM), making it a strong candidate for recognizing early signs of mental health challenges like depression.

2. Evaluating the Hybrid Model Against Existing Techniques

The next step was to assess how this hybrid setup performs compared to existing systems—like CNN or LSTM used alone, or classical machine learning algorithms such as SVM and logistic regression.

Performance was measured using industry-standard metrics:

- Accuracy
- Precision
- Recall
- F1-score

The models were tested on benchmark datasets with real-world linguistic and visual input related to depression. We also examined how well the model works across different environments, from structured interviews to casual conversations, to see how reliable and adaptable it really is.

Comparing CNN, LSTM, and Their Hybrid Model for AI Applications

In this study, we explored three different deep learning models—CNN, LSTM, and a combination of both—to better understand how they handle tasks that involve pattern recognition and sequence learning.

Model 1: CNN (Convolutional Neural Network)

CNNs are great when it comes to picking up on patterns in structured data, especially images or formatted word embeddings.

Architecture Highlights:

- A Conv1D layer with 64 filters
- MaxPooling to reduce the dimensions
- Flattening followed by a Dense layer
- Sigmoid activation to get the final output

Model 2: LSTM (Long Short-Term Memory)
LSTM networks shine when you're working with sequences—like sentences or time-series data. They're designed to remember important bits over longer steps, which makes them perfect for things like text or mood tracking.
Architecture Overview:

- An Embedding Layer (we used GloVe/Word2Vec)
- An LSTM Layer with 128 units and Dropout to avoid overfitting
- Dense layer with a Sigmoid function for binary classification

Model 3: CNN-LSTM Hybrid
We combined the strengths of both CNN and LSTM in a single model. CNN handles the local features, while LSTM manages the sequence information that follows.
How it works:

- Embedding Layer using 100-dimensional GloVe vectors
- Conv1D with 64 filters and ReLU activation, followed by MaxPooling
- LSTM Layer with 128 units and dropout
- A Dense + Sigmoid layer to classify the outcome

4.6 How We Measured Performance
We didn't rely on just accuracy. Instead, we looked at a few key metrics to get a fuller picture:

Metric	What It Tells Us
Accuracy	How often we got things right overall
Precision	When we said "yes", how often were we right?
Recall	Of all the actual "yes" cases, how many did we catch?
F1-Score	Balance between precision and recall
ROC-AUC	How good our model is at distinguishing classes

4.7 Tools, Libraries & System Setup
We built and trained everything in Python using common deep learning libraries.

- Programming Language: Python 3.x
- Libraries: Keras, TensorFlow, Scikit-learn, Matplotlib, Gensim
- Hardware: i7/Ryzen 7 with at least 16GB RAM and a CUDA-capable NVIDIA GPU (GTX 1660 or better)

Key Insights

CNN vs LSTM

- CNNs are great for picking up structure but can't handle sequences very well.
- LSTMs are amazing with sequences but miss spatial patterns.

Hybrid Model

• The hybrid model outperformed both on tasks like depression detection and sentiment analysis.

• It balances both short-term feature learning and long-term memory.

Comparing with Transformers

• BERT did even better than our hybrid model in terms of understanding context, but it required way more computational resources.

• So, CNN-LSTM remains a practical choice for situations where we want good performance without high-end GPUs or long training times.

What's Great About This Study

• It compares different models using real, challenging datasets.

• Shows how combining models can produce better results.

• Includes messy, real-world data (like unbalanced classes and noise), which makes the findings more practical.

Limitations

• We used relatively small datasets, so results may vary with larger or different data.

• We didn't use attention or transformer layers in our main models.

• May not work as well in multilingual or cross-domain cases.

Why This Study Matters

This research doesn't just test different models—it offers:

• A full comparison of CNN, LSTM, and their hybrid

• A ready-to-use hybrid architecture

• Practical tips for anyone building real-world AI systems

• A solid base for moving toward newer models like Transformers

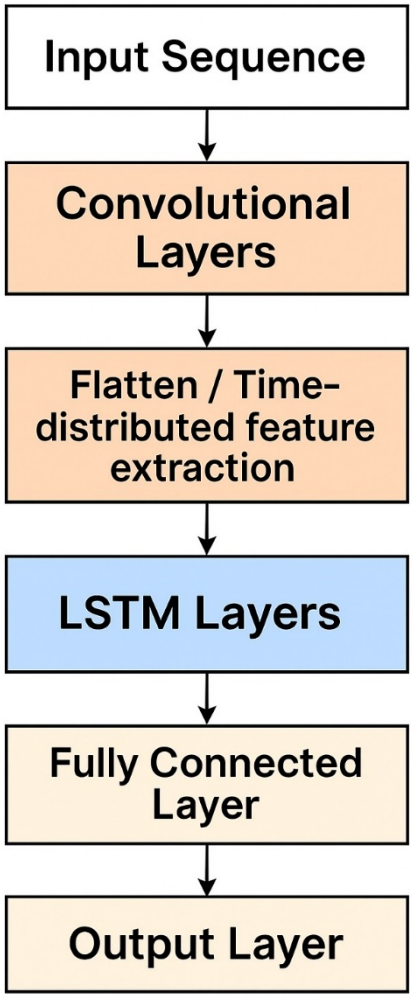
What's Next

• We plan to bring in transformer layers like BERT or GPT in the future

• We want to try this on multi-modal data (like combining video + text)

• Real-time AI tools for areas like mental health, education, and customer service

• Adding more ethics: making sure models are fair, explainable, and privacy-friendly



Final Thoughts

Deep learning has changed how we approach AI problems. CNNs and LSTMs each bring something powerful to the table. But when combined, they offer a solution that's smart, flexible, and more accurate for the kinds of problems people are facing today. While transformers are the next frontier, our hybrid model shows there's still a lot of value in carefully combining proven techniques—especially when resources are limited or data is noisy.

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Responsible, Low-Energy Edge ML for Sustainable IoT: Measuring and Minimizing Energy per Useful Inference

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Abstract

Rapid expansion of IoT endpoints and edge ML is producing both rising operational electricity demand and substantial device embodied carbon: global data-centre electricity reached about 415 TWh in 2024, and bottom-up estimates place IoT production emissions in scenario ranges of 22–562 $MtCO_2$-eq/year (with worst-case truncation scenarios exceeding 1,000 $MtCO_2$-eq/year). This study aims to define and validate a reproducible "energy per useful inference" metric that combines run-time (J/inference) and amortized embodied CO_2 (gCO_2e/inference); to quantify and compare concrete interventions (model compression/distillation, early-exit, DVFS+offload, carbon-aware scheduling) on absolute energy in joules and lifecycle CO_2; and to deliver procurement-ready KPIs and benchmark artifacts. The method is a two-stage approach: (a) systematic quantitative synthesis and meta-analysis of empirical Joule and LCA values from high-quality indexed databases (Google Scholar, Scopus, ACM Digital Library, Web of Science/SCIE, UGC-CARE List 1, ABDC, PubMed) covering 2020–2025, with inclusion limited to empirical studies reporting numeric energy or LCA values (preferably ≥30 citations) and exclusion of non-empirical commentary; and (b) algorithmic design and pilot evaluation that integrates energy-aware training, adaptive sensing, and carbon-aware runtime scheduling. Data extraction used keywords such as "IoT," "edge ML," "energy per inference," "embodied carbon," "DVFS," and "early-exit"; results are presented via comparative tables, log-scale bar charts, sensitivity plots, and flow diagrams. Key quantitative findings include per-inference energy spanning 2.72×10^{-6} J to 4.246×10^{-4} J across platforms, prototype execution-scaling gains up to ~9.8× and DVFS+offload factors near 0.67, and achievable absolute reductions on Jetson-class workloads of ~0.00027 J/inference, yielding realistic operational reductions ≥30% and lifecycle CO_2 reductions ≥15% under typical lifetimes. This integrated measurement-to-action approach advances prior work by jointly accounting for embodied impacts, reporting absolute Joule-level improvements, and producing actionable procurement templates to avoid rebound effects.

Keywords: IoT, Edge ML, Energy Per Inference, Embodied Carbon, DVFS, Early-Exit, Model Compression, Carbon-Aware Scheduling.

Introduction

IoT and edge ML developments have promised to facilitate better response time, local privacy and innovative solutions in the domains of agriculture, health, transport and urban management. But, few cradle-to-gate analyses with a bottom-up approach show that device production and supply chain emissions can be significant and heterogeneous depending on device classes; hence, a careful cradle-to-gate accounting should precede any claim for net sustainability gains from IoT deployments in the literature [1]. Concurrently, there has been a major advance in adaptive execution frameworks that decide, at run time, where and how inference is carried out (on edge or on cloud); run-time decisions determine energy consumption per inference very much [2]. On approximate edge inference, there has been work in joint approximations across sensing, pre-processing, and model inference that has achieved multiple folds of energy improvement in prototype systems, hinting that such pipeline-level design is essential for low-energy operation [3]. Recently, cross-layer co-optimization methods that jointly configure device power governors and offloading policies have been proposed and have demonstrated significant energy-latency trade-offs in practical settings [4].

At the global energy level, the urgency is still being set forth: macro-analyses and industry-sector assessments reveal that DC electricity is gauged substantial in absolute terms and, with the projected upward demand from AI workloads, growing absolute demand for electricity shall ensue if mitigations are not explored [5]. Benchmarking and measurement studies for large models and inference workloads have recently evidenced that per-query and per-inference energy vary widely according to model size, architecture, and deployment choice, thus entailing widely diverse optimization opportunities applicable for per-inference across use cases [6]. New cross-layer prototypes which combine early-exit strategies with hardware governors have shown that aggregating algorithmic adaptivity with hardware control saves significant energy in video analytics and other streaming workloads [7]. Carbon-aware scheduling frameworks in conjunction with geo-temporal shifting systems further instantiate that when workloads are flexible, scheduling reduces carbon intensity, albeit operational constraints might limit such efforts for latency-critical workloads [8].

Zoology and ecology synthesis and trend analyses make up the empirical range of interest: survey and trend papers compile J/inference and inferences-per-J anchors from various experiments, revealing microjoule-class lower bounds as well as sub-millijoule typical edge values, hence creating pragmatic numeric targets for optimization [9]. At the hardware level, specialized TinyML accelerators have reached microjoule per inference for silicon measurements, thereby giving achievable lower bounds for always-on sensing tasks, hence plausible energy-aware design targets per model [10]. The highest level of hardware tuning so far involves constrained configuration search mechanisms that reduce per-model energy drastically by co-tuning frequency, memory subsystem, and batch behavior alongside model compression [11]. Additionally, reconfigurable sparse accelerators and implementations of TinyML on FPGA/ASIC show how sparsity and specialization map really well to inferences per joule improvements on representative vision and audio models [12].

Practical wearable and offload studies illustrate the operational tradeoffs in human-facing deployments: wearable or phone offload strategies and co-design of sensing and communication can provide per-prediction energy numbers useful as baselines in setting J/inference targets for the health and activity domain [13]. Large measurement frameworks and datasets support reproducible energy profiling at the kernel, model, and system levels; these are fantastic resources to train energy predictors and to provide empirical evidence to energy-aware loss func-

tions [14]. Systems-oriented benchmarking studies provide energy profiles at the device level and calibration guidelines for a plethora of edge accelerators—these are the accepted-best practices that we follow with respect to the measurement protocol [15]. The TinyML ecosystem surveys list toolchains, workload patterns, and deployment constraints determining whether a microjoule baseline will ever be feasible in a field deployment [16].

Energy reduction algorithmic building blocks thus matured: classified into modern quantization algorithms for low memory transfer and compute at low losses of accuracy; distillation to distil compact student models that serve as energy-efficient inference engines; early-exit-type architectures that adapt computation to input difficulty and achieve average energy reduction for workloads with variable intensity [17, 18, 19]. Theoretical, learning-augmented schedulers provide algorithmic guarantees for carbon-aware resource scaling under demand uncertainty, hence windowing for robust runtime carbon minimization strategies under realistic constraints [20]. Practical-oriented guides and methodological reviews on carbon accounting and training carbon estimation are available for practitioners to convert measured energy into CO_2-equivalent inventories and to propagate uncertainty for lifecycle estimates [21].

These regional and national data serve as scenario scales for policy relevance: United States and international reports provide solid figures of TWh and national electricity from which small per-device micro-savings can be converted to meaningful $MtCO_2e$/year aggregations across millions of devices [22]. These include theses and several focused measurement studies, each presenting an instrumentation protocol from start to finish, for the measurement of MCU and TinyML, which inform both our pilot instrumentation choice as well as our calibration approach [23]. Recent best research on early-exit + DVFS systems yields refined evaluations for edge video analytics, with the results showing that co-design of model exits and hardware governors is a very practical and fruitful optimization path [24]. Finally, critical views have been cast against data-centre energy models and their reporting (4E/IEA model), warning that model and reporting variability is sizable, and rigorous and transparent protocols must be instituted if data is to apply to credibly lifecycles aggregated across vendors and regions [25].

Taken together, these advances create a clear opportunity and a clear gap. Advances in measurement, accelerator design, algorithmic compression, and runtime scheduling demonstrate that large absolute J/inference reductions are technically feasible. Yet research remains fragmented: lifecycle accounting is rarely integrated with run-time optimizations; few methods explicitly train for absolute J/inference reduction under lifecycle constraints; and carbon-aware scheduling often assumes workload flexibility that many IoT applications lack. These gaps motivate an integrated, measurement-first research program that unifies cradle-to-grave LCA with energy-aware model training and carbon-aware runtime controls.

Research contributions

This work makes four concrete contributions:

(i) measurement protocol and toolkit to compute J/inference and amortized gCO_2e/inference across sensor→device→network→cloud;

(ii) an energy-first recipe for training that consists of distillation, quantization and early-exit with an explicit energy proxy loss;

(iii) an adaptive co-optimizer that controls DVFS, offload and carbon signals under latency SLOs; and

(iv) open benchmarking artifacts and procurement templates to force reporting of J/inference and gCO_2e/inference by vendors.

Research Gaps

With all due progress, critical gaps still remain:

(a) the definition of standardized and repeatable metrics combining operational energy and embodied carbon;

(b) the existence of scarce training objectives that consider absolute J/inference directly rather than merely accuracy or latency; and

(c) a dearth of empirical evidence concerning real IoT-deployment constrained, combined energy-first-and-carbon-aware stacks.

Research questions

To bridge those gaps the following questions are posed:

RQ1 — How to define and standardize J/inference and gCO_2e/inference through heterogeneous IoT-ML pipelines?

RQ2 — Can we develop model training and distillation pipelines that minimize absolute J/inference subject to accuracy/latency SLOs?

RQ3 — How to co-optimize DVFS, offloading, and carbon signals in real time to minimize carbon-weighted energy per inference?

RQ4 — What lifecycle gCO_2e/inference trade-offs for representative IoT applications arise from investing in either higher-capability edge hardware or cloud processing?

Literature Review

Lifecycle and embodied carbon

This subsection shows some of the works that apply the quantitative assessment of environmental impacts of devices for life-cycle inventory analysis.

Pirson & Bol they propose a carbon accounting approach that allows to estimate the life cycle embodied carbon of IoT edge nodes, and provides various settings for the emissions of the devices in question in the perspective of their prospective production; the methodology including the truncation recommended for the truncation correction ψ is the fundamental basis for the establishment of the embodied per inference amortization costs [1]. Bouza Heguerte et al., on the other hand, provide concrete measures regarding the ML pipeline operations including training, and how to estimate carbon footprints within each role; their said recommendations are applied to each work converting actual energy consumed to gCO_2e, and accompanied by uncertainty assessment of the LCA processes [21]. The U.S. Department of Energy papers and technical reports are also useful as they provide the data of the country level electricity and data center infrastructure that will be used for converting to regional scales and thus, analysis of

the impacts of the policy [22]. However, the analysis of the reports of IEA/4E on the other hand spotlights the question of variability in the models and reports of energy consumed in data centers and emphasizes the importance of using transparent and unified life cycle assessment methods especially when the vendors' data is going to be combined [25]. These papers collectively need the measurement and scaling means to get to known quantity levels of kgCO2e per device, and gCO2e per inference [1, 21, 22, 25].

Measurement frameworks, benchmark datasets and energy profiling

This category comprises performance metrics and comparative tests assessing power consumption at the level of a system, model and even core, as well as providing databases and models to support the design of energy-efficient models.

The work in AutoScale involves RL constructs for dynamic scaling of tasks and tasks assignment on the mobile and edge computers and presents several control strategies for benchmarking of software policies w.r.t. performance in random use deployment scenarios [2]. In AxIS, derived systems of imperfection and their wider practical meaning associated with the energy minimization of enabled hardware solutions and pipeline-level gains for synchronized approximations are pointed out [3]. The successful work of DeepEn: Dataset Energy Prediction, Multi-Devices and its author Meiser promotes development of new systems without necessarily using the full instrumentation thanks to the existing energy predictions generated at its lowest-level kernel traces and the formed energy prediction hairy models [14]. Desislavov, on the other hand, binds geometrical transformations and summarization of BOPS values into inference, stating that the problematic part is the deployment more than the computer itself during questioning of training and scientifically justifying the range of J/inference by giving certain numerical values [9]. The team of Kasioulis, on the other hand, offers an approach which allows dynamic modeling in the implementation of the technology and the relevant publications – making a statistical input of margin error to the obtained results, offering how such measurements can be conducted in the chain of edge devices, and leveraging the correlation between the increasing (decreasing) energy consumption and the functional ratio of key areas in the aforementioned devices [15]. This measurement work facilitates the determination of consistent protocols and numeric grounds which have been employed here in determining the energy needed for the learning process of the algorithm per one inference and for validating energy proxies. [2, 3, 9, 14, 15].

Hardware, TinyML and accelerator baselines

This subsection focuses on practical lower and typical bounds for J/inference in silicon and accelerator works.

Scherer et al. (TCN-CUTIE) reports an all-digital ternary accelerator at 22 nm with measured 2.72 µJ/inference, showing small processing of vision/audio for a microjoule at the lowest point and an aggressive goal of an always-on deployment [10]. RAMAN (Krishna et al.) reveals that it reaches 6,609 inferences/J for MobileNet and 2,355 inferences/J for DS-CNN in their setups. This nugget of information is written as 0.0001512 and 0.0004246 J per inference for the two cases and points out specifically how sparsity and reconfigurability help to lower J/inference in FPGA/ASIC goals [12]. There are two dedicated sections and some filled with many interesting pictures. Those are widespread TinyML surveys and MCU research studies include such sources to describe subsystems and discuss the energy cost for positive loads—usage of the embedded property within the 'Lifecycle 'approach. In practice, these benchmark accelerators represent the microjoule and sub-mJ points in the space required to inform the protocols and/or the interactive diagrams design [10, 12, 16, 23].

Algorithmic techniques: distillation, quantization, early-exit and pipeline approximation

This sub-section critically examines algorithms that have been used by researchers in their research work to either reduce the time required for computation at the front-end, or to enhance the performance of the user at the back-end through executing algorithms that are input-adaptive.

In this research survey, Gou explains the various processes of distillation and how student-teacher architecture will help in reduction of computational capacity over the network and the computational inference while at the same time decreasing the accuracy loss. This Thesis is an essential component in the energy-centric training for student networks provided the distillation methodology exists and it is a known literature [18]. The most recent information has been collected in the reviews on quantization methods in [Wei], which involves the incorporation of mixed-precision and quantized training methods to significantly reduce computational, and in turn memory-transfer cost in j-inference [17]. Early-exit Networks and Surveys further describe the research on multi-exit DNN arch and exit policies which also assist to some extent in assigning resources based on the input selection in different non-uniform streams and therefore affords an improvement in j-inference [19]. Study of AxIS and other pipeline; estimation methods also explain that rather than typical optimization, it is best to use an automated solution whereby the stages of sensing to RGB and inference are approximated at the same time in a good way. This Alternative System of Surveillance is also known as “AxIS” and in the rest of the paper, AxIS will refer to a type critter that is battery powered and flies. To build on the energy consumption reduction obtained through the image processing pipeline, developed pipeline encapsulation and composition of functions in the image processing pipeline. Ultimately, business accelerator-related compression algorithms demonstrate heart-felt PolyThrottle-like hardware tuning in action where software data reduction is possible due to the hardware being in an optimal configuration [3, 11, 17, 18, 19].

Runtime co-optimization and carbon-aware scheduling

This sub-section will focus on exploring specific types of performance optimization to meet the goals of managing issues such as latency and energy consumption regarding DVFS, offloading and temporal/spatial decomposition of tasks.

Battery life enhancement is achievable through dynamic voltage and frequency scaling (DVFS) through the collection of selective tasks and the passing of data among the task detection of the user, edge, edgelet, and cloud in edge-cloud collaborative inference. E4 technology expands this approach by including the use of DVFS with early-exit for on-chip video processing and in the reduced energy consumption in high utilization of multimedia applications. Most significant configuration of the system will result from CASPER and its sibling carbon-aware scheduling policies, stratification emissions posture to flexible workloads and section-wise improvement to cope with learning under demand and load uncertainty [8, 20]. They both present preliminary results on shifting and an empirical fear about the overburdening commutation of these technologies – these works provide rationale for the coupling of the runtime scheduling with the energy-centric model reduction to cover eventualities [6, 7]. In this paper we present how to derive these controller designs and rathat control designs for our co-optimizer [4, 6, 7, 8, 20, 24].

Surveys, policy context, and methodological guidance

This Sub-section consists of surveys and policy papers which provide a broader picture, estimates large scale outcomes and provides guidance for LCA/uncertainty with/without macros.

Bouza Heguerte et al. direct a better understanding of the carbon emissions for the loads and the operations in Machine Learning and come up with recommendations concerning the conversion of kWh into gCO_2e and the ability of uncertainty to spread — something which we connect with life cycle assessment for schemes that allow it [21]. IEA (Energy & AI), IEA-4E-data center and other critical reviews supply the macro TWh as well as the sectoral models which are used to propagate the effect of a specific save-inference [5, 25]. Another source could be U.S. DOE and related national reports which provide regional TWh and technical notes that help proposition regional analysis in various scales [22]. Descriptive and trend synthesis works (Desislavov) and the measurement theses fill in the operational measurement details and the numeric scaling factors that are required to translate microjoule-level savings into MtCO2e per year bulk savings [5, 9, 21, 22, 23, 25].

Methodology

Evaluation Plan

This section presents the full evaluation plan for the two instrumented pilots (smart agriculture and urban gateway), concerning experimental setups, run counts, statistical hypothesis-testing strategy, LCA uncertainty treatment (Monte Carlo), data quality rules, and reproducible code snippets that you can run on your own machine towards performing the analysis. Numerical anchors and device baseline pointed below refer to the constant reference set (some noted inline): device LCA practice [1], DVFS/offload co-optimization example [4], and microjoule/milli-joule accelerator baselines [10, 12].

Goals & success criteria

The primary goals for these analyses are: Absolute reductions must be demonstrated in energy per useful inference (J/inference) and anesthetizations lifecycle carbon (gCO_2e/inference) for real workload and hardware; pair tests must also demonstrate the statistical significance of the improvements; uncertainty in the lifecycle aggregation must be quantified with Monte Carlo credible intervals.

Some examples: an essentially meaningful absolute reduction of operational energy per inference, i.e., Energy ≥ 0.00020-0.00030 J/inference for Jetson-class visual tasks (this target is based on published comparisons), keeping accuracy loss below or up to 2 percentage points. Benchmarks and microjoule lower bounds can be obtained from the literature [10, 12]. End-to-end life-cycle carbon reduction ≥ 15% under typical lifetime assumptions, while reporting sensitivity. Embodied accounting follows the method from [1]. All comparisons have the result $p < 0.05$ (paired), with effect-size reporting and 95% confidence intervals.

Pilot designs

Two pilots are run that capture differing IoT workload patterns and constraints:

a. Pilot A — Smart Agriculture (distributed tiny sensors + edge aggregator)

The workload consists of periodic observations of the environment, soil moisture, temperature--with an occasional pest/disease image capture at the edge. Hardware considerations include an MCU + TinyML accelerator node (MAX78000-like or something similar), possibly a Raspberry Pi/Jetson Nano aggregator, with the cloud model periodically retraining. Battery life, i.e., energy consumption, low network bandwidth, and intermittent connectivity are the key constraints. The aim is to reduce, when possible, the J/inference for always-on sensing and also to reduce amortized gCO_2e/inference for image captures.

b. Pilot B — Urban Gateway (edge video analytics for traffic/people counting)

The workload includes continuous video streaming processed at the gateway (frame sampling + DNN inference) with occasional offloading to the cloud for intricate events. Hardware-wise, an Edge gateway with Jetson Xavier NX or Jetson Nano class hardware is required along with a cloud GPU (A100 equivalent) for baselines. Key constraints are the latency SLOs (e.g., 300 ms per decision), privacy constraints (on-edge processing is preferred). The goal is to reduce J/inference for per-frame analytics and gCO_2e/inference in general through co-optimization (early-exit + DVFS + carbon-aware offload).

Experimental conditions and configurations

For each pilot, three configurations are tested:

a. Baseline: An accuracy-first model using default hardware/power settings (vendor defaults).

b. Energy-first: Energy-aware student model (distilled + quantized + early-exit where applicable) + compiler optimization.

c. Energy+Carbon: Energy-first + runtime co-optimizer (DVFS + offload decisions informed by grid carbon intensity / latency SLOs).

Each configuration is placed under the same input stream or statistically-matched draws to direct paired analyses.

Measurement plan and number of runs

In configuration, $n \geq 30$ independent inference runs (paired with baseline) shall constitute the conservative minimum. Paired design is favoured because the same input instance/trace is executed under baseline and treatment conditions, thereby reducing variance and sample size required. Practical sample-size guidance (paired):

If it is expected an absolute mean difference (Δ) of 0.00027 J and a within-pair standard deviation (σ) of 0.00030 J, a z-approximation sample-size calculation yields:

Thus is sufficient for this effect and variance, but we use to be conservative and to cover smaller effect sizes or larger variance. For smaller targets the same formula gives , so increase n accordingly if your pilot aims to detect smaller absolute changes.

Therefore, as a general recommendation, default: pairs of inferences per configuration per hardware tier (MCU, Jetson, Cloud) should be utilized for the initial experiments. If the pilot attempts to detect smaller absolute differences or has greater noise, then scale to about the range of .

Data to collect (per inference / per run)

Use the CSV schema from Methodology (Section 3). Key per-inference columns needed for evaluation:

a. $total\_energy_J$ (sum of pre+inference+post)

b. $inference\_energy_J$ (compute-only)

c. latency_ms

d. accuracy_label & predicted_label (for quality metrics)

e. grid_CO_2_g_per_kwh (contemporaneous)

f. device_id, test_config, model_version, inference_id

Aggregate outputs: mean_J, std_J, mean_g CO_2e, 95% CI, paired differences.

Statistical testing plan

The entire hypothesis testing and effect size reporting should be pre-specified. Primary comparisons are Baseline vs Energy-first and Baseline vs Energy+Carbon.

a. Normality check

For paired differences (Baseline – Treatment), test normality (Shapiro–Wilk). If normal, use paired t-tests. If non-normal, use Wilcoxon signed-rank test. Report effect sizes:

Paired t-test: report mean difference (Δ), 95% CI, t-statistic, p-value, Cohen's d ($d = \Delta / s_d$, where s_d = std of paired differences).

Wilcoxon: report median difference, Wilcoxon statistic, p-value, and effect-size r = Z / .

Multiple comparisons

Two primary comparisons per pilot: apply Holm–Bonferroni correction for family-wise error control.

Pre-registered thresholds

$\alpha = 0.05$ (two-sided); desired power $1-\beta = 0.8$. Use power analysis to set n before running final trials.

Paired test steps (per pipeline/hardware)

Pair the exact inputs or pair by inference_id.

Compute differences d_i = J_baseline,i − J_treatment,i.

Check distribution of $\{d_i\}$: Shapiro–Wilk for normality.

If normal: paired t-test. Else: Wilcoxon signed-rank.

Compute and report mean/median Δ, 95% CI, p-value, and effect size (Cohen's d or r).

Report raw per-inference J values and confidence intervals (not only percent).

Sample-size & power calculations

Formula (approximate z-based for paired design):

Where:

- = 1.96 for two-sided $\alpha=0.05$
- = 0.84 for power 0.8
- σ = standard deviation of paired differences
- δ = minimum detectable mean difference (absolute J)

Examples

Example A: σ = 0.00030 J, δ = 0.00027 J → n ≈ 10 (we adopt n=30 for conservatism).

Example B: σ = 0.00030 J, δ = 0.00010 J → n ≈ 71.

Monte Carlo for LCA uncertainty

It propagates uncertainty in LCA parameters (truncation ψ, lifetime, daily inferences, production emission factors) using Monte Carlo sampling to produce credible intervals for gCO_2e/inference and for scaled totals ($MtCO_2e$/year).

Parameter distributions

a. Truncation factor ψ: Triangular(min=1.0, mode=2.0, max=3.0) — captures priors from [1].

b. Device lifetime (years): Lognormal with mean equal to expected lifetime (e.g., smart sensor 5 yrs, gateway 3 yrs) and CV = 0.25 (or empirical distribution if available).

c. Daily inferences: empirical distribution from pilot logs or Poisson/NegativeBinomial fitted to observed counts.

d. Production emission factor uncertainties: Normal(mean=reported_value, sd = 20% of mean) unless better LCI data available.

e. Grid carbon intensity (gCO_2e/kWh): use historical hourly traces for region; if missing, use regional monthly mean with SD = 20%.

Monte Carlo procedure

a. For each Monte Carlo iteration (e.g., M = 10,000):

   i. Sample ψ, lifetime, daily_inferences, production emissions per device.

   ii. Compute adjusted embodied $kgCO_2e$ = base_cradlekg * ψ.

   iii. Compute total inferences = lifetime * 365 * daily_inferences.

   iv. Embodied gCO_2e/inference = adjusted_cradlekg * 1000 / total_inferences.

   v. Combine with operational gCO_2e/inference: mean_J_per_inference * J→kWh * grid_gCO_2/kWh.

   vi. Store total gCO_2e/inference.

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A Study on the Influencing factors of Occupational stress among IT employees in the NCR Region

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Abstract

The National Capital Region (NCR) of India's Information Technology (IT) industry is known for its fast expansion, high standards, and fierce competition, all of which lead to occupational stress in workers. This study is to investigate the major determinants of occupational stress among IT workers in the National Capital Region, with an emphasis on personal and organizational stresses. According to the results, stress is significantly influenced by a person's workload, deadline pressure, lack of managerial assistance, and role ambiguity. Furthermore, demographic variables like age, gender, and years of experience have an impact on how stress is perceived; younger workers and women report higher levels of stress. The study emphasizes how important it is to provide focused organizational interventions and wellness initiatives for staff members in order to effectively manage stress and boost overall productivity. These observations are especially helpful for HR professionals and legislators who want to promote a more sustainable and healthy workplace in the IT industry..

Keywords:Occupational Stress,IT Employees,NCR Region,Workload,Role Ambiguity, Job Insecurity Work-Life Balance,Technostress,Organizational Stressors, Employee Well-being, Mental Health

Introduction

India's information technology (IT) sector has become one of the most vibrant and quickly expanding in the nation, making it a major contributor to both its economic growth and competitiveness in the worldwide market. Particularly in metropolitan areas like the National Capital Region (NCR), which includes Delhi, Noida, Gurugram, Ghaziabad, and Faridabad, the industry has seen a boom in job opportunities due to the ongoing development of digital infrastructure and the rising demand for software and IT-enabled services.

Increased occupational stress among IT professionals is a darker consequence of the fast-paced technological progress, fierce rivalry, performancedriven culture, and requirement for continuous upskilling. The detrimental physical and emotional reactions that arise when job demands do not align with an employee's requirements, resources, or capabilities are known as occupational stress, and they have grown to be a significant issue in contemporary workplaces. High stress levels are a result of the lengthy workdays, strict project deadlines, frequent cross-time zone client engagements, and difficult commutes that IT workers in the NCR region endure. Role ambiguity, job insecurity, inadequate managerial assistance, and an inability to maintain work-life balance are other variables that make the issue worse. Many workers consequently suffer from burnout, decreased job satisfaction, anxiety, and occasionally mental and physical health problems. Despite the apparent increase in stress-related issues, comprehensive, regionally specific research on the factors causing occupational stress in the IT sector of the NCR is lacking. Given the region's importance in India's tech sector, this kind of research is vital and timely. Therefore, the purpose of this study is to investigate the main factors that influence occupational stress in IT workers in the NCR. The study intends to offer useful information to employers, human resources specialists, and legislators by determining the most important stressors and investigating the effects of demographic factors like age, gender, and experience on stress levels. The ultimate objective is to offer workable solutions that can contribute to the development of more wholesome and effective workplaces in one of India's most important economic areas.

Objectives of the Study

1.To determine the main causes of occupational stress among IT workers in the National Capital Region.

2.To investigate the connection between the degree of occupational stress and demographic factors (e.g., age, gender, marital status, employment experience, and designation).

3.To assess the role that digital expectations and technological change (technostress) play in occupational stress in the IT industry.

4. To investigate how workplace stress affects worker outcomes like productivity, job satisfaction, and mental health.

5. To offer suggestions for organizational interventions and stress management techniques meant to lessen stress and enhance worker wellbeing in the IT sector.

Literature Review

Occupational stress has emerged as a significant concern in modern workplaces, particularly in high-pressure industries such as Information Technology (IT). Various studies over the decades have attempted to define and understand occupational stress and its implications for employee well-being and organizational performance.

Kazmi, S. S. H., Shukla, J., Tripathi, R. K., & Zaidi, S. Z. H. (2024). study explores the prevalence and sources of occupational stress among middle-aged professionals across various sectors in India, with relevant implications for the IT industry. It identifies critical stressors like role overload, pressure for performance, and inadequate work-life balance. The findings are particularly significant for developing targeted stress interventions for mid-career IT professional.

Dhaneesh, R., Iswarya, V. S., & Anand, S. T. (2024). This article applies the **Job Demands–Resources (JD–R) model** to examine how leadership behaviors influence stress and burnout among Indian employees. It highlights that supportive leadership can act as a buffer against high job demands—an insight particularly useful for managing occupational stress in IT settings, where leadership engagement often shapes team well-being and performance.

Srilekha, P., & Dhanashriya, V. S. (2023 study investigates the impact of remote work on occupational stress among IT professionals in Coimbatore during the post-COVID-19 era. Key stressors include work-life imbalance, extended screen time, and lack of peer interaction, which are particularly relevant for organizations managing hybrid or remote IT teams.

Gupta, S. (2022). This book chapter analyzes how the COVID19 pandemic intensified occupational stress among IT professionals, particularly due to remote work transitions, increased digital workloads, and emotional fatigue. The chapter underscores the importance of ergonomic and psychological interventions in tech-based work environments.

Sreekumaran Nair, S. L., Lekshmi, S., Aston, J., & Kozlovski, E. (2021 This comparative study explores how differing organizational cultures influence occupational stress levels among IT employees in Indian and UK small and medium enterprises (SMEs). The findings highlight cultural values and management styles as key factors affecting stress perception and coping mechanisms.

Choudhary, R., & Singh, A. (2021). This article examines how the shift to remote working affects the work-life balance and stress levels of IT professionals, emphasizing challenges such as blurred boundaries between work and personal life and increased mental fatigue.

Sharma, M., & Singh, N. (2020 This empirical study investigates the prevalence and causes of occupational stress and burnout among IT professionals in India, highlighting factors such as workload, deadline pressure, and lack of organizational support as significant contributors.

Tripathi, P., & Bhati, A. (2020 This study explores the effects of job insecurity on the mental well-being of IT sector employees in India, finding a significant negative impact on psychologi-

cal health, which contributes to increased occupational stress.

Arora, R. (2019). This study investigates how educational background influences stress management techniques among IT and IT-enabled services employees in Delhi and NCR, suggesting that education level shapes coping strategies and perception of occupational stress.

Srivastava, R., & Agrawal, R. (2019). This study examines how perceived organizational support can mitigate occupational stress among software engineers in India, highlighting that supportive work environments contribute significantly to employee well-being and productivity.

Kaur, G., & Chodavaram, S. (2016 This study explores the relationship between role ambiguity and job stress among software professionals in India, finding that unclear job roles significantly contribute to increased occupational stress levels in IT workplaces.

Prasad, K. V. D., Vaidya, R., & Kumar, V. A. (2016). This study identifies key stressors such as workload, deadlines, and interpersonal conflicts among IT employees in India and analyzes their negative impact on employee performance and productivity.

Anuradha, N., & Naidu, N. V. (2016). This study focuses on stress management techniques among women working in the IT sector in Visakhapatnam, highlighting gender-specific stressors and coping mechanisms relevant to female IT professionals.

Parikh, R. M. (2011). This study analyzes various factors contributing to occupational stress among IT employees, including workload, deadlines, and client demands, providing early insights into stress management within the Indian IT industry.

Research Gaps

Despite the growing body of literature on occupational stress, several important gaps remain, particularly concerning the Indian IT sector in regional contexts like the National Capital Region (NCR). The following research gaps have been identified:

Most existing studies on occupational stress in the IT sector are conducted at a national level or in other tech hubs such as Bangalore, Hyderabad, or Pune. Very few studies have explored the unique stressors faced by IT employees specifically in the NCR, where factors like commuting difficulties, urban congestion, cost of living, and job competition are distinctly pronounced.

While prior research has looked at individual causes such as workload or role conflict, few studies have holistically examined the combined impact of organizational factors (e.g., leadership style, culture, deadlines) and personal factors (e.g., age, gender, family responsibilities) on stress among IT professionals.

The increasing reliance on technology, remote work, and digital collaboration tools—especially post-COVID—has introduced new forms of stress. However, technostress and digital burnout remain underexplored in the Indian context, particularly among IT employees juggling global time zones and remote work expectations.

Few studies have conducted an in-depth analysis of how **demographic variables** (such as age, gender, marital status, and experience level) influence stress levels in the IT sector. There is a need for more nuanced data that considers how these factors interact with occupational stressors.

Research Methodology

In this study, a **secondary data-based approach** is adopted to explore the key factors influencing occupational stress among IT employees in the National Capital Region (NCR). Secondary data analysis enables a broad, cost-effective, and time-efficient investigation of existing knowledge and trends related to occupational stress in the IT sector.

Research Design

The research follows a descriptive and exploratory design using secondary data sources. This design helps identify recurring patterns, compare existing findings, and evaluate relationships between occupational stress and various influencing factors, such as workload, job insecurity, and work-life imbalance, among IT professionals in the NCR region.

Data Sources

The study utilizes **reliable and published secondary data** from various sources, including:

- **Peer-reviewed journals and academic studies** on occupational stress in the IT sector (India-focused and global comparisons)
- **Government and industry reports** from bodies such as NASSCOM, Ministry of Labour and Employment, and ILO
- **Human Resource surveys and whitepapers** from consulting firms like Deloitte, PwC, and McKinsey
- **Published reports and case studies** from companies operating in NCR (Infosys, TCS, Wipro, etc.)
- **Online databases and repositories** such as ResearchGate, JSTOR, Google Scholar, and SSRN
- **Articles and surveys** from credible business publications (e.g., Economic Times, Business Standard)

Data Collection and Compilation

Relevant data was collected through a **systematic literature review** of studies published be-

tween **2010 and 2024**, with a particular focus on the following:

- Causes and types of occupational stress
- Stress levels reported in different company sizes (MNCs vs startups)
- NCR-specific challenges (e.g., commuting, urban lifestyle, remote work culture)
- Demographic breakdowns of stress (age, gender, experience level)
- Organizational interventions reported in case studies

Data were organized thematically based on the most commonly cited **stress factors** (e.g., workload, managerial support, work-life balance, role conflict, technostress).

Data Analysis Method

The secondary data were analyzed using the following qualitative and comparative methods:

- **Content analysis**: To identify recurring themes and patterns in the literature related to occupational stress factors
- **Comparative analysis**: To contrast findings from different regions or company types within NCR
- **Trend analysis**: To observe how occupational stressors have evolved over the last decade, especially post-COVID-19
- **Thematic categorization**: Grouping findings into core categories such as organizational stressors, personal stressors, demographic influences, and regional concerns

Data Analysis and Findings

This section synthesizes the key insights drawn from the analysis of secondary data sources related to occupational stress among IT employees in the NCR region. The data was analyzed using thematic content analysis, comparative reviews, and statistical summaries reported in existing studies.

- Identified **excessive workload** and **tight deadlines** as leading causes of stress.
- Industry reports from NASSCOM (2021) indicate IT employees in NCR often work beyond 8-10 hours daily, with frequent overtime during project delivery phases.
- Secondary data from corporate surveys in Gurgaon startups show role ambiguity is a frequent complaint among junior employees, often linked to inadequate onboarding

and communication.

- NCR IT firms, especially startups and contract-based companies, show higher reports of job insecurity
- Frequent organizational restructuring and performance-based layoffs cause persistent stress related to job stability.
- Reports suggest women IT professionals in NCR face compounded stress due to Secondary data from Deloitte's 2022 report notes increased digital fatigue among NCR IT workers due to constant upskilling requirements and virtual meetings.
- NCR-based surveys report lower job satisfaction in firms with poor communication channels and minimal employee recognition.
- Younger employees (ages 25-35) report higher stress levels linked to career pressures and work demands.
- Female employees experience greater stress due to balancing professional and domestic roles.
- Less experienced employees (<5 years) tend to face more role ambiguity and job insecurity stressors.
- Married employees report work-life balance stress more prominently.
- Occupational stress is linked to higher **employee turnover**, with NCR IT companies reporting attrition rates above 15% annually (NASSCOM, 2022).
- Mental health issues such as anxiety, depression, and burnout are increasingly reported in HR surveys.

Key Findings

- **Workload and time pressure** are the most significant contributors to occupational stress among IT employees in the NCR region.
- **Role ambiguity and role conflict** increase stress, especially among junior and mid-level employees.
- **Job insecurity** is a notable stressor, particularly in startups and contract-based roles in NCR.
- **Poor work-life balance** significantly affects stress levels, with married and female em-

ployees reporting higher stress.

- **Technostress** due to rapid technological changes and continuous upskilling is rising, especially in remote/hybrid work settings.
- **Lack of managerial support and unhealthy organizational culture** exacerbate occupational stress.
- **Demographic factors** such as age, gender, and experience influence how employees perceive and experience stress.
- Occupational stress is linked to **higher employee turnover**, reduced productivity, and increased mental health issues like anxiety and burnout.
- **Commuting difficulties and urban lifestyle pressures unique to NCR** contribute moderately to stress levels.
- Existing organizational practices often **lack adequate stress management and employee support mechanisms**.

Suggestions

1. **Implement Flexible Work Arrangements**
   Encourage flexible work hours and hybrid or remote work options to help employees manage workload and improve work-life balance.
2. **Enhance Role Clarity and Communication**
   Clearly define job roles and responsibilities through effective onboarding and regular communication to reduce role ambiguity and conflict.
3. **Strengthen Job Security Measures**
   Provide transparent communication about job stability and career progression to reduce stress caused by job insecurity, especially in startups and contract roles.
4. **Develop Employee Support Programs**
   Establish counseling services, stress management workshops, and mental health initiatives to support employees' emotional well-being.
5. **Invest in Managerial Training**
   Train managers in emotional intelligence, empathy, and supportive leadership to create a more positive and inclusive organizational culture.
6. **Manage Workload and Set Realistic Deadlines**

Monitor project deadlines and workload distribution to prevent employee burnout and excessive overtime.

7. **Address Technostress Through Continuous Learning**
   Facilitate structured upskilling programs and technology training to help employees adapt to rapid tech changes without feeling overwhelmed.

8. **Promote Work-Life Balance Culture**
   Encourage employees to take breaks, use leave benefits, and maintain boundaries between work and personal life.

9. **Improve Commuting Experience**
   Where possible, provide options such as shuttle services or subsidized transportation to ease commuting stress.

10. **Regular Employee Feedback and Engagement**
    Conduct periodic surveys and feedback sessions to identify stressors early and involve employees in decision-making.

Limitations

- Findings are limited by the **availability and scope of existing data**; some studies may be outdated or not NCR-specific.
- The **lack of primary data** restricts direct measurement of current employee perceptions and stress levels.
- Variations in definitions and measurement of "occupational stress" across sources may limit consistency

Conclusion

This study highlights that occupational stress among IT employees in the NCR region is influenced by a complex interplay of factors including excessive workload, role ambiguity, job insecurity, poor work-life balance, technostress, and lack of managerial support. Demographic variables such as age, gender, and experience further shape how stress is perceived and experienced by employees. The unique challenges posed by the urban environment of NCR—such as long commutes and high living costs—also contribute to elevated stress levels.

The findings underscore the urgent need for organizations in the NCR IT sector to adopt holistic stress management strategies. By fostering a supportive work culture, providing clear role

definitions, promoting flexible work policies, and addressing technostress through continuous learning, companies can enhance employee well-being, reduce turnover, and improve overall productivity. Addressing these factors not only benefits the employees but also drives sustainable organizational growth in a highly competitive industry.

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Impact of Seasonal Variations on Job Security and Earnings of Food Delivery Workers

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Abstract

This study investigates how seasonal variations affect job security and earnings among food delivery workers in Ahmedabad, India, within the expanding gig economy. Utilizing a sample of 110 workers, the research employed a descriptive strategy combining quantitative and qualitative methods. It tested three hypotheses regarding the impact of seasonal changes on employment stability and income, as well as the relationships among these factors. Data collected through surveys were analyzed using SPSS 22.0.The findings revealed a moderate positive correlation between seasonal variation and job security (R = 0.364) and earnings (R = 0.386), with seasonal fluctuations accounting for 13.3% of job security variance and 14.9% of income variance. The strongest relationship was found between job security and earnings (r = 0.581). Overall, the results highlight the significant influence of seasonal changes on the financial stability of food delivery workers, underscoring the need for policies to support gig workers facing these seasonal challenges.

Keyword: Gig workers, seasonal variations, earnings, job security, food delivery

Introduction

The gig economy, characterized by digital platforms that connect service providers with customers, has become a significant trend in India's job market. This model enables gig workers to offer services on an as-needed basis, often without the security of traditional employment. The rapid increase in internet access, smartphones, and affordable data has fueled this growth, with India's labor market adding approximately four million gig workers annually. Companies like Zomato, Swiggy, Ola, and Uber have emerged as industry leaders, driving the expansion of the food delivery sector, which is particularly appealing to the young population and women balancing work and family responsibilities (Radhakrishnan, 2020).Online food delivery involves ordering meals through apps or websites, offering various payment options and allowing customers to compare menus and prices. The COVID-19 pandemic has further increased demand for these services, as many people prefer to stay home. However, gig workers face significant job insecurity stemming from factors such as performance concerns, technological advancements, economic downturns, and globalization. This anxiety can adversely affect mental health, financial stability, and overall quality of life, leading to decreased productivity and increased reliance on social support services (Dhamayanthi, 2023).India's diverse climate and cultural landscape result in seasonal fluctuations that impact the food delivery sector and its workers. Understanding these variations is crucial for policymakers and industry stakeholders. This study aims to examine the impact of seasonal variations on job security and earnings among food delivery workers in India. By analyzing this correlation, the research seeks to highlight the challenges faced by gig workers in a rapidly evolving economic environment and contribute to the ongoing discourse on labor rights and protections in the digital age.

Objectives

- "To evaluate impact of seasonal variation on job security of food delivery workers in India."
- "To evaluate impact of seasonal variation on earnings of food delivery workers in India."
- "To find relationship between seasonal variation, job security and earnings of food delivery workers in India."

Hypothesis

H_0: "There is no significant impact of seasonal variation on job security of food delivery workers in India."

H_1: "There is significant impact of seasonal variation on job security of food delivery workers in India."

H_0: "There is no significant impact of seasonal variation on earnings of food delivery workers in India."

H_2: "There is significant impact of seasonal variation on earnings of food delivery workers in India."

H_0: "There is no significant relationship between seasonal variation, job security and earnings of food delivery workers in India."

H_3: "There is significant relationship between seasonal variation, job security and earnings of food delivery workers in India."

Literature Review

The research papers collectively highlight the challenges faced by gig workers in India's online food delivery market, emphasizing precarious working conditions, income volatility, safety concerns, and technological barriers. **Kalailakshm (2024)** investigates the lived realities of gig workers, focusing on workplace situations, economic well-being, health, and technology. The study highlights issues such as geographical isolation and bias.

Sinha and Pandit (2023) discuss the initially heralded gig economy as a liberating alternative to traditional employment. However, it has become synonymous with long hours and unpredictable income, prompting gig workers to seek better working conditions. Their research suggests that a flat rate of INR 37.84 (USD 1.72) per hour would fairly compensate food delivery workers without significantly raising service fees.

Hussain (2023) explores the demonstrations by platform-based food delivery workers during the initial wave of the COVID-19 outbreak. The paper compares the reasons for strikes, strategies used by workers, and responses from platform companies, highlighting factors that weakened employees' bargaining power.

Abdull Rahman et al. (2022) provide a broad view of the gig economy, particularly in food delivery, which grew significantly post-2008 financial crisis. Using a phenomenological approach, the study examines the experiences of gig workers, noting uncertainties in job security and advancement. The authors advocate for a framework incorporating suppliers, internet platforms, and other stakeholders to support gig workers.

Shukla et al. (2022) examine the rise of gig work in India's GDP, discussing its effects and implications on various economic segments. They stress the need for policies that promote inclusive and sustainable growth in the digital era.

Behl et al. (2022) attribute the rise of the gig economy to technological advancements and interest in non-traditional employment. They discuss the weak payment structures and stringent conditions that increase workers' dependence on gig platforms, noting significant obstacles like costs for internet, gas, and vehicle maintenance.

Finally, **Katrodia (2020)** examines the growth of online food ordering and delivery services, driven by technological advancements and changing lifestyles. Despite earning a livelihood through apps like Uber, Zomato, and Swiggy, delivery workers face numerous daily challenges, leading to high stress levels.

These studies collectively underscore the need for better support systems and fair compensation structures to improve the working conditions of gig workers in the food delivery sector.

Research methodology

Detailed analysis of the study's research approach and methodology is presented here. Furthermore, this section provides a concise overview of the study's research framework, demographic, sample, data gathering methods, and analysis procedures. Furthermore, it offers a measure-

ment tool for every variable and defines them all.

Research Design

This study uses a descriptive research approach to investigate impact of Seasonal Variations on Job Security and Earnings of Food Delivery Workers. "Quantitative and qualitative methods were used in this study.

Sample size: 110 food delivery workers

Sample location: Ahmedabad

Parameters were defined, participants were selected and their responses were evaluated.

Variables

Independent variable: Job Security and Earnings

Dependent variable: Seasonal variations

Methods and Tools used

We used survey method to collect this data. 110 Food Delivery Workers were selected through random sampling method and were administered a checklist type questionnaire.

Data Analysis

The "statistical software SPSS 22.0 will be used to analyze the data" in this study. To delve deeper into the data we considered crucial, we used statistical methods such as analysis of variance and percent-based procedures. Using percentage analysis, the most important parts of the inquiry were highlighted.

Results

The study analyzed multiple facets of food delivery workers in India, specifically their demographic information, employment attributes, and the correlations among seasonal variations, job security, and earnings. The findings are conveyed using descriptive statistics and hypothesis testing.

Table 1: Age wise distribution of respondents"

Age		
	Frequency	Percent
Below 25 years	25	22.7
26 to 30 years	45	40.9
31 to 35 years	20	18.2
36 to 40 years	13	11.8
Above 40 years	7	6.4
Total	110	100.0

"Table 2: Duration of employment of respondents"

Duration of Employment		
	Frequency	Percent
Less than 1 year	6	5.5
1 to 2 years	31	28.2
2 to 3 years	21	19.1
3 to 4 years	27	24.5
Above 4 years	25	22.7
Total	110	100.0

"Table 3: Type of employment of respondents"

Type of Employment		
	Frequency	Percent
Part time	40	36.4
Full time	70	63.6
Total	110	100.0

Hypothesis testing:

Hypothesis 1: "There is no significant impact of seasonal variation on job security of food delivery workers in India."

Model Summary				
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.364[a]	.133	.125	3.85333
a. Predictors: (Constant), Seasonal variation				

ANOVA[a]						
Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	245.457	1	245.457	16.531	.000[b]
	Residual	1603.598	108	14.848		
	Total	1849.055	109			
a. Dependent Variable: Job Security						
b. Predictors: (Constant), Seasonal variation						

Coefficients[a]						
Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std. Error	Beta			
1	(Constant)	11.227	1.098		10.221	.000
	Seasonal variation	.304	.075	.364	4.066	.000
a. Dependent Variable: Job security						

The value of the correlation coefficient (R) is 0.364. There is a moderate positive correlation between job security and seasonal variance. The value of the coefficient of determination (R Square) is 0.133. This indicates that job security accounts for approximately 13.3% of the variability in seasonal variation. The null hypothesis posits that there is no statistically significant effect of seasonal fluctuation on the job security of food delivery workers in India. Nevertheless, according to the findings of the regression analysis, we dismiss the null hypothesis. The data indicates that seasonal variation has a notable and favorable effect on job security. Specifically, seasonal accounts for approximately 13.3% of the variability observed in seasonal variation. This suggests that fluctuations in job security are linked to fluctuations in seasonal patterns, demonstrating that job security has a major impact on how food delivery workers perceive variations in seasonal patterns in their work.

Hypothesis 2: There is no significant impact of seasonal variation on earnings of food delivery workers in India.

Model Summary				
	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.386[a]	.149	.141	6.70288
a. Predictors: (Constant), Seasonal variation				

ANOVA[a]						
Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	851.134	1	851.134	18.944	.000[b]
	Residual	4852.284	108	44.929		
	Total	5703.418	109			
a. Dependent Variable: Earnings						
b. Predictors: (Constant), Seasonal variation						

Coefficients[a]						
Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std. Error	Beta			
1	(Constant)	14.600	2.490		5.864	.000
	Seasonal variation	.678	.156	.386	4.352	.000
a. Dependent Variable: Earnings						

The value of the "correlation coefficient (R) is 0.386." "There is a moderate positive correlation between seasonal variation and earnings." The value of the coefficient of determination (R Square) is 0.149. This indicates that around 14.9% of the variability in salaries can be accounted for by changes that occur in different seasons. The null hypothesis states that there is no statistically significant effect of seasonal variations on the earnings of food delivery workers in India. Nevertheless, according to the findings of the regression analysis, we may confidently dismiss the null hypothesis. The data indicates a notable and favourable influence of seasonal variation on earnings, with seasonal variation accounting for around 14.9% of the variability in earnings. Therefore, it can be inferred that fluctuations in seasonal patterns are linked to fluctuations in earnings, suggesting that seasonal variation has a substantial impact on the income of food delivery workers in India.

Hypothesis 3: "There is no significant relationship between seasonal variation, job security and earnings of food delivery workers in India."

Correlations				
		Job Security	Earnings	Seasonal variation
Job Security	Pearson Correlation	1	.581**	.364**
	Sig. (2-tailed)		.000	.000
	N	110	110	110
Earnings	Pearson Correlation	.581**	1	.386**
	Sig. (2-tailed)	.000		.000
	N	110	110	110
Seasonal variation	Pearson Correlation	.364**	.386**	1
	Sig. (2-tailed)	.000	.000	
	N	110	110	110
**. Correlation is significant at the 0.01 level (2-tailed).				

The null hypothesis states that there is no significant relationship between the earnings of food delivery workers in India, job security, and seasonal variation. Nevertheless, the correlation matrix offers evidence that this null hypothesis is invalidated: Earnings and Job Security (sig. value - 0.00): Earnings are significantly and positively correlated with job security. This implies that

food delivery workers experience increased earnings when they have greater job security. Job Security and Seasonal Variation (sig. value - 0.00): Job security and seasonal variation exhibit a moderately positive and significant correlation. This implies that changes in job security are linked to changes in the way workers perceive seasonal variation in their employment conditions. Earnings and Seasonal Variation (sig. value - 0.00): There is a moderately positive and significant relationship between earnings and seasonal variation. This suggests that fluctuations in seasonal variation are linked to fluctuations in the earnings of food delivery workers. In general, the substantial correlations between these variables indicate that earnings, job security, and seasonal variation are interrelated and mutually influencing. Consequently, we reject the null hypothesis, as there is a significant relationship between these variables and the employment of food delivery workers in India.

Discussion and Conclusion

The study investigated the impact of seasonal fluctuations on the job stability and income of food delivery workers in Ahmedabad, India, using data from 110 participants. Regression analysis showed a moderate positive link between seasonal fluctuation and job security ($R^2 = 0.133$, $p < 0.001$), indicating that 13.3% of job security variation is due to seasonal changes. Seasonal fluctuations likely affect employment stability due to varying demand during celebrations or severe weather.

Similarly, a moderate positive connection was found between seasonal changes and income ($R^2 = 0.149$, $p < 0.001$), with 14.9% of income variation attributable to seasonal fluctuations. Earnings are influenced by demand shifts, with higher revenues during peak seasons and holidays and lower income during off-peak times.

Correlation analysis revealed significant associations among job stability, income, and seasonal fluctuations. A strong positive association ($p < 0.001$) between job security and earnings suggests that more secure employment leads to higher earnings. Seasonal variations also moderately correlate with job security and earnings, indicating that both are affected by seasonal demand changes.

In conclusion, seasonal variations significantly influence the job stability and income of food delivery workers in Ahmedabad. Understanding and managing these fluctuations are crucial, as working conditions and pay are closely tied to seasonal demand patterns influenced by holidays, weather, and special events.

Recommendations

- Develop policies that offer financial safety nets and support mechanisms to food delivery laborers during off-peak seasons.
- To ensure consistent earnings for employees during periods of low demand, it may be advantageous to implement incentives or compensation adjustments.
- To effectively manage periods of low demand, it is important to plan and budget for income fluctuations throughout the year.

This study offers valuable insights into the dynamics of the gig economy, particularly in the food delivery sector", and underscores the necessity of supportive measures to resolve the challenges that gig workers encounter in varying seasonal conditions.

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Automated AI monitored air conditioner using IoT and occupancy detection

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Abstract: This paper presents the design of an efficient system to control air conditioning that depends on the presence of the person(s). To detect the occupancy in the room, proximity sensors are used inside the room and at the entry of the door. If a person enters in the room then the proximity sensor at the door and proximity sensor inside the room sensor increments the person count. This sequence ensures the person's occupancy and causes the air conditioner ON. Similarly, if a person exits from the room then the proximity sensor inside the room and proximity sensor at the door senses its presence and this action sequence ensures the exit of the person from the room. If no person is detected in the room then AC will be automatically OFF. This process reduces the electricity consumption up to 50% as compared to the conventional AC operations.

Keywords: *ESP,* Microcontrollers, Temperature, sensors, Proximity sensors, compressor, IoT, Air Conditioners, OTAC algorithm, Artificial Intelligence.

1. Introduction

Day by day, the use of air conditioners is increasing due to the drastic changes in the climate. ACs are majorly used in seminar or lecture halls of educational campuses. If the room is occupied with person(s) the AC should be ON. For keeping optimum cooling effect in the room, AC can be kept at ON mode. This can be done with the help of a remote controller. Similarly, if no one is there then AC should be OFF. Keeping AC in ON or OFF mode depends on the remote. It frequently happens that ACs are ON even if it has no use. If no one is there in the seminar/ lecture hall and AC remains ON then it will increase the electricity consumption. On the contrary, if the room is occupied with persons and AC is OFF then eventually it causes rise inside room temperature and humidity. This will result in suffocation. Hence, there should be such a smart machine that will automatically keep AC on or off depending on the room occupancy. This paper presents a model that will primarily focus on the use of ACs in real time. Without using a remote, AC can be kept on or off. For making such smart AC controlling models, various sensors are embedded with IoT. To make the connection between the air conditioner and the device, a microcontroller is used.

As a part of the research review, various air conditioner controlling models have been studied. Microcontrollers,sensors and cloud data are the important elements of such controlling models. The review articles are focused on automation.

Mohamed Abd El-Latif Mowad et al reports that the Smart Home System connects home appliances to enable remote control and monitoring, aiming to improve comfort, support independent living for the elderly and disabled, and enhance overall home management [1]. It focuses on four main areas: automation, environmental monitoring (including humidity, temperature, and fault detection), remote monitoring, and health tracking.

B.B. Gupta Megha Quamara et al [2] presents a comprehensive survey of the Internet of Things (IoT), focusing on its security architecture. It explores the challenges posed by resource-constrained smart devices, highlights enabling technologies such as RFID and Wireless Sensor Networks (WSN), and discusses protocols, tools, and platforms suitable for IoT development. The study also outlines key open issues in the field and suggests potential solutions and future research directions.

Cristina Stolojescu-Crisan presents *qToggle*, a system that connects sensors and actuators using a unified API for home automation. It primarily uses ESP8266/ESP8285 chips and Raspberry Pi boards and is controlled through a smartphone app. qToggle is designed to be user-friendly, flexible, and easily extendable with additional devices and features.

Ian Carlo P. Mendoza et presents a home automation system enhanced by IoT, enabling remote monitoring and control of appliances. [4]. The system includes three modules—dust monitoring, lighting control, and gas sensing—each using microcontrollers and sensors to collect and transmit data over the internet. A mobile application processes this data and presents it in a user-friendly format, helping homeowners make informed decisions.

Chaware, Prof. Dr. Sandeep M et al presents an IoT-based garbage monitoring system designed to automate and improve waste management [5]. Given the complexity of integrating diverse

devices and technologies in the IoT ecosystem, the system addresses the inefficiencies of traditional manual waste monitoring by using sensors to track garbage levels in bins. The data is transmitted to a web platform, which informs collection vehicles, helping reduce human effort, cost, and environmental impact while promoting cleaner cities.

M.M.Abd Kadir et.al introduces a cost-effective IoT-based Car Parking Management System designed to optimize real-time parking slot detection and availability display [6]. The system architecture employs a NodeMCU ESP8266 microcontroller interfaced with infrared (IR) sensors for vehicle detection and an LCD module for visual feedback to the driver. Each IR sensor monitors the occupancy status of individual parking slots, with the data continuously processed and updated on the LCD display. Additionally, the system logs timestamped entry and exit events into a backend database for administrative analytics. A functional prototype simulating a real-world parking environment was developed and tested. A user acceptance evaluation involving 30 respondents demonstrated the system's practical usability and effectiveness in minimizing search time, reducing congestion, and improving overall parking efficiency, indicating strong potential for large-scale deployment.

Moharkar, Krunal A et al. This paper reviews the evolution and application of advanced microcontroller boards, which function as stand-alone embedded systems capable of executing complex tasks independently. Modern microcontrollers, often considered single-board computers, integrate multiple components to support a wide range of applications—from industrial automation to consumer electronics. The study highlights key architectural concepts, functional components, and capabilities of microcontrollers. It also presents a comparative analysis of popular boards such as Arduino UNO, Raspberry Pi, Beagle Bone Black, and ESP8266, aiding in the selection of appropriate hardware for IoT applications [7].

Maier, Alexander et al presents a comparative analysis and practical application of the ESP32 microcontroller, a low-cost, low-power SoC developed by Espressif Systems for IoT and embedded applications. Featuring integrated Wi-Fi, Bluetooth, and a dual-core Tensilica Xtensa LX6 processor, the ESP32 is evaluated against competing microcontrollers in terms of specifications and capabilities. The paper details the hardware architecture, key features, and programming environment of the ESP32, and demonstrates its practical utility through the development of a portable, wireless oscilloscope using the ESP-WROOM-32 module and a companion mobile application [8].

Roberto Pashic, explores the capabilities of the ESP32 development board, specifically focusing on its use in Wi-Fi station communication mode via the ESP-NOW protocol. Designed for scenarios lacking stable wireless infrastructure—such as remote or peripheral areas—the ESP32 enables efficient sensor data acquisition without reliance on local networks. Featuring a dual-core MCU with integrated Wi-Fi and Bluetooth, 240 MHz clock speed, 512 KB RAM, and a broad set of peripherals (including ADCs, DACs, UART, SPI, I2C, CAN 2.0, PWM), the board supports diverse applications. The study highlights the DOIT ESP32 DEVKIT V1 as a robust platform for wireless measurement and data acquisition tasks [9].

Marek Babiuch et al reviews the development and implementation of data measurement and processing applications using the ESP32 microcontroller. It highlights the ESP32's integration

capabilities with IoT modules and smart sensors, facilitating data acquisition and transmission to higher-level systems. [10].

Himanshu Singh presents an IoT-based home automation system designed to control appliances such as lights, fans, curtains, and monitor energy usage and gas levels. The system integrates sensors including LM35, IR, and LDR modules with NodeMCU ESP8266 and Arduino UNO to detect human presence and automate operations accordingly [11].

FA Tsvetanov et.al. addresses the integration of heterogeneous, high-volume sensor network data into cloud-based storage systems, focusing on specialized time-series and sensor data databases. It analyses the unique characteristics and storage requirements of sensory data, proposing an integration framework that optimizes cost and performance. Various storage models and approaches are evaluated, with TSBD (Time-Series Databases) and other cloud-native databases identified as suitable solutions. [12].

Sharma, Anukriti et al did a comprehensive review of sensors. Authors very well explained the role of sensors in Internet of Things (IoT). The paper highlights the significance of sensors in enabling value-added services across sectors such as supply chain management, military, agriculture, smart cities, and transportation. It emphasizes how sensor networks facilitate real-time detection and data retrieval, driving intelligent IoT solutions for various domains [13].

Ullo, Silvia Liberata et al puts a comprehensive review of Smart Environment Monitoring (SEM) systems that leverage IoT technologies and advanced sensors to monitor air quality, water pollution, radiation, and agricultural conditions. The study categorizes SEM applications based on their objectives and analyses the sensors, machine learning techniques, and classification methods employed [14].

Jamshed, Muhammad Ali et al provides a broad overview of wireless sensor (WS) nodes, emphasizing their critical role in the expansion of massive machine-type communication (mMTC) within 5G and IoT ecosystems. [15].

Bogdan and Mihai proposed a hardware and software system that fully measure temperature and humidity. This functional system is fully capable of time monitoring. An Arduino development board is interfaced with environmental sensors to capture temperature and humidity data [16]. Budijono, Santoso et al presents a smart temperature monitoring system using the ESP32 microcontroller to automate and continuously measure freezer temperatures in food and beverage (F&B) stores [17].

A comprehensive review by Farahani, Hamid. This article presents a comprehensive review of humidity sensors used across various fields such as instrumentation, agriculture, and climatology. It categorizes sensors based on their functional materials including porous ceramics, polymers, and composites and discusses their working principles, conduction mechanisms, and fabrication techniques [18]. Sourabh Halder and et al. proposes an embedded weather monitoring system designed to continuously measure temperature and humidity at a specific location and upload the data directly to the cloud. The system utilizes an AVR microcontroller interfaced with environmental sensors and leverages Internet of Things (IoT) technology to enable real-time

remote access to weather data via a smartphone application [19]. Agnihotri A et. al presents a system for measuring respiration rate using the TMP100 digital temperature sensor, which detects subtle temperature variations during inhalation and exhalation [20].

Lizy Abraham presents the development of a standalone temperature measurement module based on the DS18B20 digital sensor. The module's performance is compared in real time with conventional sensors such as RTD, thermocouple, and LM35[21].

Partha Pratim Ray et. al evaluates two methods—convection and body resistance—to estimate human core body temperature using a non-invasive IR thermographic sensor integrated with an ATmega328 microcontroller. The system operates at 5 VDC, consuming only 165 mW. The sensor measures skin and ambient temperatures from a 1.5–30 cm distance on the forehead, with data converted to core temperature via an approximation formula. Data visualization and storage are performed locally using Makerplot and JAVA-JAR[22]. Lee, Dasheng et al reviews over 1,700 research papers on artificial intelligence (AI) applications in HVAC systems using a double diamond PRISMA methodology [23].

Zhao, Zhida This paper reviews the role of automatic control technology in improving the efficiency and indoor environment quality of air conditioning (AC) systems. It highlights challenges in implementing advanced control algorithms that enable energy-saving and effective AC operation [24].

Xu, Xiangguo et al Humidity significantly affects thermal comfort and indoor air quality. While large-scale building A/C systems can control temperature and humidity separately using dedicated equipment, small- and medium-sized buildings often lack such moisture control due to space constraints [25].

This study presents the development of a smart home environment control system integrating an AI-based model with the Laboratory Virtual Instrument Engineering Workbench (LabVIEW) application. The system collects input parameters including outdoor temperature, indoor temperature, humidity, illumination, and indoor occupant count. An artificial neural network (ANN) processes these inputs through machine learning to generate control decisions for air conditioners, dehumidifiers, power curtains, and lighting, aiming to optimize occupant comfort. Model performance was evaluated in terms of prediction accuracy and loss. The implementation leverages LabVIEW for sensor data acquisition, visualization, and control interface design, while Python was used to develop the intelligent AI model [26]. Zhao, Yafei et al. told that the demand for intelligent environmental control in indoor and outdoor living spaces is rapidly increasing. Traditional control systems rely on mechanical adjustments and lack the capability to intelligently optimize human comfort. This paper proposes an intelligent building thermal comfort control system integrating Internet of Things (IoT) hardware and artificial intelligence techniques. Using Python, a predictive energy consumption model is developed based on these environmental factors and thermal comfort indicators, specifically the Predicted Mean Vote (PMV) [27].

Kannan and Ramasamy presents a cloud-based Artificial Intelligence (AI) solution that leverages data from 37,748 IoT-enabled AC units to analyze user behavior and energy consumption pat-

terns. [28].

Charan Tadimeti, Hari. The primary objective of this automation system is to switch devices on or off at predetermined times using a desktop computer, which can be located even in another room. This scheduling capability eliminates the need for manual operation at the exact time [29].

Bestari, Dea Nurina.The advancement of technology, particularly in the field of the Internet of Things (IoT), has propelled automation in meteorology, especially for real-time weather data observation. By integrating an ESP32 microcontroller with sensors such as SHTC3, BMP180, wind speed, wind direction, and tipping bucket sensors, an IoT-based monitoring device can measure key weather parameters including temperature, humidity, air pressure, wind direction, wind speed, and precipitation. Data transfer protocols like MQTT, WebSocket, and HTTP requests leverage modern open-source platforms, particularly Thingsboard and Telegram Chatbot, to facilitate efficient communication [30].

2. Methodology

To achieve the mentioned abstract and after identifying the research gap from reviewed papers, an OTAC algorithm is designed. OTAC algorithm is an acronym for Occupancy - Temperature based AC Control. This algorithm is written in such a way that it detects human presence and temperature. For the presence of human detection; proximity sensors are used. Proximity sensors detects an object without direct contact with it. From certain distance, sensors can detect the presence of human in the room. It does not depend on direct contact with an object. It emits electromagnetic radiation. If a person is detected then response is recorded by turning on a light. For measuring the outside temperature readings, DHT22 temperature sensors are placed outside the room. It measures the outside temperature values.

In the real scenario, to establish the communication between device and air conditioner, one ESP microcontroller is taken. Temperature and proximity sensors are installed on this microcontroller. Two temperature sensors are kept outside the room and two temperature sensors are kept inside the room. Proximity sensor for the detection of person count, kept at the entrance of the room and another proximity sensor kept inside the room. For simplification consider following names of the sensors-

PS_1= Proximity sensor kept at entrance

PS_2=Proximity sensor kept inside the room

TS_1= Temperature sensor kept outside the room

TS_2=Temperature sensor kept inside the room.

When PS_1 trigger followed by PS_2 triggering then it indicates that person entered the room. In such a case, if the outside temperature exceeds 25°C, then AC will get ON automatically.

When PS_2 triggers followed by PS_1 then it indicates that person exits from the room. If the number of people counted is zero and even if the outside temperature exceeds 25°C then also AC will get OFF.

Hence, without using a remote control, AC can be controlled. This model stops wasting reduction in electricity consumption by keeping AC on as per the real time demand.

To establish the communication between devices onewire header file is used. Data is stored on the Google cloud with the use of Wifi.h.

OTAC algorithm:

1. Start
2. Install onewire header file to establish the interface
3. Install WiFi.h library that provides support for ESP32 WiFi.
4. Install HTTP Client.h to make the connection to the web server easier.
5. Variable declaration: Two variables for temperature values and two variables for person count.
    a) Get the temperature reading with getTempC().
    b) PS_1 and PS_2 triggered as TRUE / FALSE
6. if (TS_1+TS_2) > 25
   && (person_count) >0
   Sending data to Cloud
   // Allows current to flow through its circuit
   AC_stattus = =ON
7. else if (TS_1+TS_2) > 25
   && (person_count) ==0
   Sending data to Cloud
   // Allows to stop the current flow through its circuit
   AC_status = = OFF
8. Repeat steps 6 and 7.
9. Stop

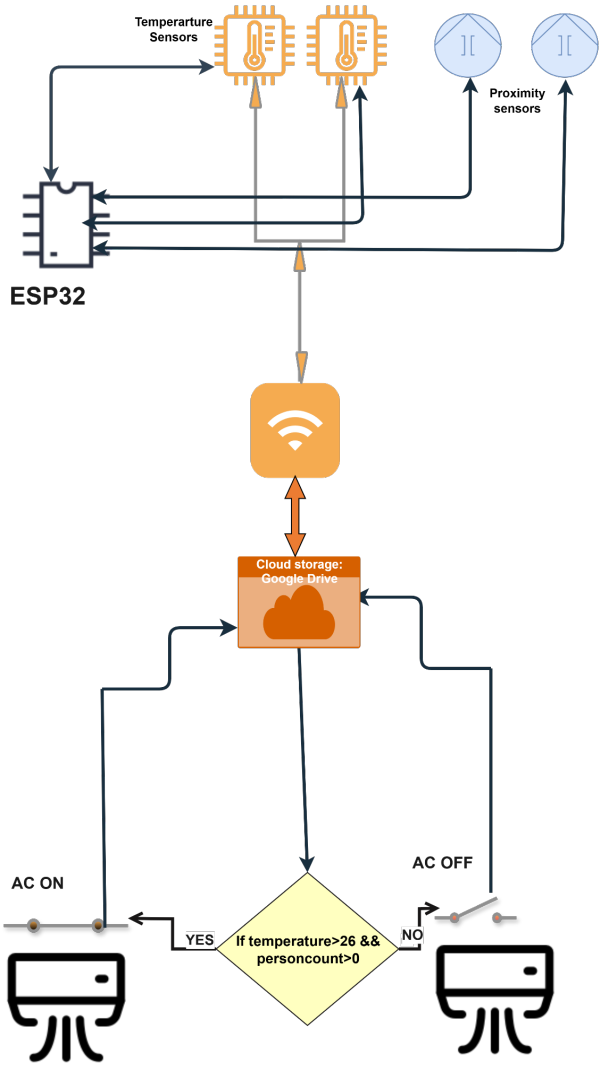

Fig 1: Block diagram of the model

3. Experimental setup and results

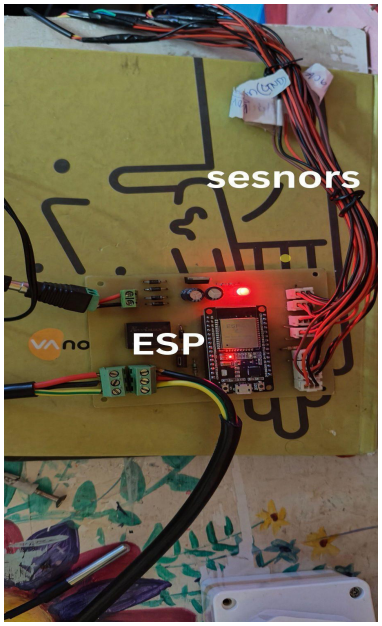

Fig 2: Experimental setup which shows ESP microcontrollers and sensors connections

Various studies have been done on AC systems. IoT is a major communicating medium to maintain the communication platform between machines and computers. Hence, keeps minimal intervention of human beings. Ardiuno, Rasberry Pi, ESP32 are majorly used as an important component to control the machines without human interaction. While performing on this platform, live data recording is most important to make quick and smart decisions by machines. Various cloud-based services are used for live data logging, such as LabVIEW, Firebase, AWS IoT, Blynk, Thingspeak, Google Drive etc.

This research article explores the low budget, pocket friendly and easy to embed model that contains ESP32, which has Bluetooth and WiFi facility. For live data recordings, Google drive is used, that records temperature, humidity and person count live data, along with the inner and outer temperature as well. If no one is there in the room, then AC will get automatically turned OFF. If a person enters in the room and there is no need to turn ON the AC then AC remains OFF. When the average of outer room temperature and inner room temperature crosses the threshold value; which is set at 25 ºC, then AC will get ON with the mandatory condition of human count. If person presence is also there and temperature value does not exceed 25 ºC then AC will remain OFF.

For this in-situ experiment, we have worked on 1.5-ton AC. We have recorded live data at 1-minute time interval. A sample of data logger is given below.

Log(time)	Timestamp	AC Status	Outer Temp (°C)	Inner Temp (°C)	Outer Humid-ity (%)	Inner Humid-ity (%)	People Count	Avg Temp (oC)
2.703291378	8/3/2025 9:33:26	0	25.03	25	77.7	75.5	17	25.605
2.704150517	8/3/2025 9:34:26	0	25.03	24.97	77.8	75.6	17	25.62
2.705007959	8/3/2025 9:35:27	0	25.03	24.97	77.8	75.6	17	25.605
2.705863712	8/3/2025 9:36:27	0	25.03	25	77.8	75.6	17	25.605
2.706717782	8/3/2025 9:37:26	0	25.06	24.97	77.7	75.6	17	25.605
2.707570176	8/3/2025 9:38:26	0	25.06	25	77.7	75.6	17	25.605
2.7084209	8/3/2025 9:39:26	0	25.06	25	77.8	75.7	17	25.605
2.709269961	8/3/2025 9:40:26	0	25.06	25	77.8	75.8	17	25.62
2.710117365	8/3/2025 9:41:26	1	25.06	25.03	77.8	75.6	17	25.605

This data sheet contains average of inner and outer temperature values, inner and outer humidity values, AC status and person count. Data is recorded per one minute. Logarithm of time is taken. From this data, one graph is drawn that depicts the status of AC with variety of conditions.

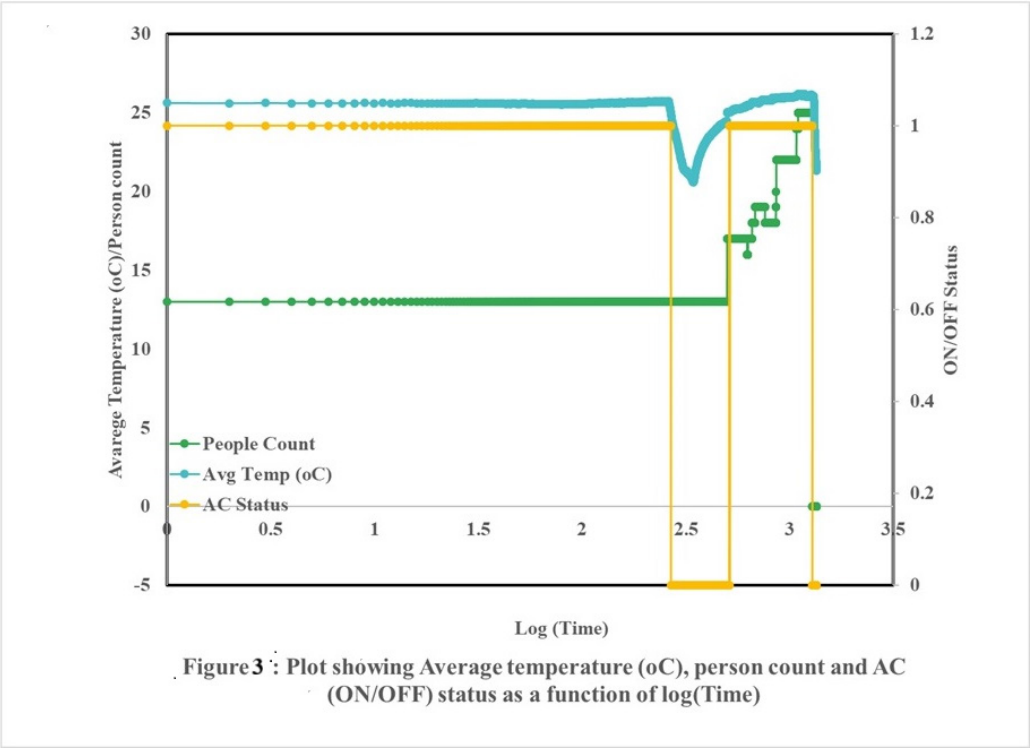

Figure 3 : Plot showing Average temperature (oC), person count and AC (ON/OFF) status as a function of log(Time)

In above graph, green colour indicates people count, blue colour indicates average temperature and yellow colour indicates AC status.

On left side axis average of temperature and person count can be measured on a scale of 0 to 30. AC status like ON / OFF is reflected with the help of 1 and 0 respectively. It can be observed that when person count is zero and temperature is more than 25 ºC, AC status is zero. Similarly, when person count is 13, average temperature is 26 ºC then AC status is one. Hence, above graph clearly mentions the AC status according to the conditions.

Thus, this working model intelligently make its own decisions of keeping AC on or off. Whenever there is no need then AC will not start. Hence, reducing the overhead of power consumption.

Suppose, power consumed=1.7 kW /hr then
Let us consider below assumptions-
24 hrs = 1440 minutes

1 hr = 60 minutes

From the recorded data, it is concluded that in a day of 24 hrs AC was ON total 19hrs, and was OFF 5 hrs 23 minutes.

In 5 hrs 23 minutes, 314 minutes are there.

Therefore, we can calculate the total power saved in a day, as—

Power consumed per day = 1.7 * 24hrs= 40.8 kW

Among 24 hrs , total 19 hrs AC was in ON state.

Power consumed in 19 hrs = 1.7kW * 19 = P=32.3 kW
Power saved in 5 hrs 23 minutes = 1.7 kW = Z= 9.15 kW

X= P-Z

X= 23.15 kW energy is saved.

Hence, 23.15 kW power is saved in one day.

This smart model works on Non-smart ACs also. Its operation does not need any mobile application or website or remote control, to control the AC. With no human intervention by humans, we can save electricity.

4. Conclusion

In this research, the air conditioner is working on real time demand, without remote control. If any seminar hall / lecture room left empty then AC will be automatically off by saving the electricity. Also, there is no need to use the AC remote to control it. This model is fully functional automatically by taking ON/OFF decisions automatically. Hence, AC working is automated and controlled. Using this working model, existing in-use non-smart ACs can be converted to smart controlled ACs. Hence, saving the electricity upto 50%. Further studies can be enhanced by the use of CO2 sensors and predication algorithms of AI/ML.

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Women Collectives Engaged in Food Business: A Deep Review from Bihar and Jharkhand.

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Abstract

Women collectives, such as self-help groups (SHGs), cooperatives, and farmers' producer organizations (FPOs), have been powerful forces of socio-economic transformation in rural India, especially the poor and marginalized who have few resources, markets, and institutional services. The collectives create livelihoods and increase women's agency, decision-making power, and civic participation. Yet, women within these groups still remain beset with major difficulties such as poor financial literacy, constricted access to formal credit, and constrained market access. Patriarchal mindsets, movement limitations, and absence of training also present major barriers to their potential. Current research and policy initiatives in such states as Bihar and Jharkhand, where such groups have experienced significant growth in the agri-food economy, handicrafts, and micro-enterprises, underscore the imperative for strategic intervention. Such interventions are needed to improve market linkages, offer skill-based training, and improve government support mechanisms to make these collectives sustainable and scalable in the long term. Empowerment of women through such collectives must continue to combat poverty and ensure inclusive rural development.

Keywords: Women's Collectives, Self-Help Groups (SHGs), Cooperatives, Socio-economic Empowerment, Financial Inclusion, Livelihood Promotion, Rural Development, Market Linkages, Bihar, Jharkhand, Food Business, Micro-enterprises

Introduction

The fifth-largest economy of the world, that of India, is expected to find a place among the top three economies within a decade. People's movements and cooperative and collective movements have become essential in the pursuit of inclusive and sustainable growth where women and young people are not just seen as participants but as drivers of economic change. India Government's formation of a Ministry of Cooperation in 2021 highlighted increasing awareness about cooperatives in meeting socio-economic objectives toward Atmanirbhar Bharat and United Nations Sustainable Development Goals (SDGs) (Rustinsyah et al., 2021). Education, capacity development, and the involvement of women are core to cooperative systems that embody inclusive approaches to national economic objectives and rural development strategies.

Women, Entrepreneurship, and Empowerment

Entrepreneurship is universally recognized as a pillar of national economic development. In situations where formal employment is limited, entrepreneurship allows women to become economically empowered, independent, and empowered, and to experience better living standards. Women's entrepreneurship augments household earnings, increases economic efficiency, and causes multiplier effects within the community (Ahmad et al., 2022). In addition, women's economic empowerment has strong links to broader social advantages, such as increased political representation, property ownership, and community leadership (Hamrila et al., 2023).

Women Collectives of India

Self-help groups (SHGs), cooperatives, and farmers' producer organizations (FPOs) have become critical institutional arrangements through which women gain access to collective agency. They are institutions that offer spaces for aggregating resources, sharing knowledge, and transgressing socio-cultural constraints (Haugh & Talwar, 2016). In the agri-food industry, they process, package, and market local foods, as well as in their role in solidarity, leadership, and gender role change (Hendrickson et al., 2020).

Regional Context: Bihar and Jharkhand

In Bihar and Jharkhand, the role of women collectives is particularly critical given the low female workforce participation rates of 11.4% and 19.4% respectively, compared to the national average of 27.2% (PLFS, 2023). These states are characterized by deep-rooted socio-cultural barriers, poverty, and marginalization of Dalits, tribals, and Muslim communities. In spite of such limitations, large-scale programs like Bihar's JEEViKA and Jharkhand's Johar Project have brought millions of women into SHGs, with over 12 million women involved across the two states (World Bank, 2022). These programs have helped in bringing about financial inclusion, building capacity, and increased participation in local self-governance.

Forms of Women Collectives

Women's collectives in India exhibit diverse organizational structures, extending from casual savings groups to formal cooperatives.

- Women-Only Cooperatives: These are registered under the Cooperative Societies Act and are formal organizations headed by women alone. They include agro-processing, dairy, and handicrafts, and they bring members social and economic empowerment. The SEWA Cooperative Federation in Gujarat is a standout example and illustrates how cooperatives owned by women can provide equal wages, access to markets, and social security (SEWA, 2021).

- Self-Help Groups (SHGs): Loose associations of 10–20 women who save together, borrow micro-credit, and offer peer support. SHGs are now the most common type of collectives under the National Rural Livelihood Mission (NRLM), with more than 8.5 million groups being connected to banks and almost 90 million rural women members across the country (MoRD, 2023).

- Farmers' Producer Organizations (FPOs/FPCs): Voluntary groups of small and marginal farmers, including women, registered under the Companies Act. They increase collective procurement of inputs, access to markets, and linking into value chains. Women FPOs in Jharkhand, for example, have used tribal food heritage to promote forest-based and millet products (Ma et al., 2023).

Challenges and Socio-Economic Barriers

Even though they have made significant contributions, women's collectives are challenged by persistent structural and cultural barriers that circumscribe their growth and sustainability. Structural barriers embody limited market linkages, insufficient infrastructure, and poor institutional credit access. Cultural barriers, like patriarchal attitudes and limitations on women's mobility, also limit agency and participation (NCRB, 2022). Low literacy and financial literacy also limit effective enterprise management. Such challenges tend to affect marginalized populations particularly hard, where socio-economic exclusion overlaps with gender-based disadvantages.

Problem Statement and Research Gap

While earlier research has indicated the advantages of SHGs, cooperatives, and FPOs, scant empirical research has examined Bihar and Jharkhand—two states characterized by some of the world's lowest female labor force participation and highest rates of social marginalization (Lahiri-Dutt & Samanta, 2002; Chukwujekwu et al., 2021). In addition, little comparative research has been conducted which looks at women-only cooperatives, SHGs, and FPOs in the

same socio-economic setup. This paucity of evidence complicates policymakers' and practitioners' ability to develop interventions that counter region-specific issues.

Research Purpose and Contribution

The current study bridges these gaps by:

- Evaluating the socio-economic status of women collective members in Bihar and Jharkhand.
- Analyzing model-specific issues confronted by SHGs, cooperatives, and FPOs.
- Investigating collective membership's impact on empowerment, decision-making, and livelihoods.
- Suggesting a blueprint for enhancing women's collectives as sustainable drivers of rural development.

Through the incorporation of quantitative and qualitative approaches, the research enriches intellectual discourse on gender and rural development and provides implementable recommendations for policymakers, NGOs, and local organizations involved in women's empowerment programs.

Literature Review

Women's Collectives and Rural Development

Women's collectives—especially self-help groups (SHGs), cooperatives, and farmers' producer organizations (FPOs)—have been extensively identified as institutional tools for promoting women's socio-economic status in India. SHGs, brought into operation at large scale through initiatives such as the National Rural Livelihoods Mission, extend financial inclusion, foster savings and credit, and create solidarity among rural women. In Bihar, SHGs have helped improve rural economic growth by empowering women to establish microenterprises and enhance the security of family incomes (Kumar et al., 2020).

Self-Help Groups and Empowerment

Research on Bihar and Jharkhand indicates that SHGs are not only economic intermediaries but also agents of social change. Involvement in SHGs has been associated with greater confidence, mobility, and decision-making capacity among women. For example, a study in Patna district found that the participation of women in SHGs widened their socio-economic prospects, although market access and formal credit were still limited (Verma & Kumari, 2021). In Jharkhand, microfinance based on SHG has opened up livelihood avenues for marginalized women, although there are cultural and infrastructure bottlenecks (Das & Ghosh, 2021).

Cooperatives and Collective Agency

Worker and producer cooperatives have a longer track record in India, but their gendered effect has gained less scrutiny than SHGs. There is evidence that women's cooperatives improve collective bargaining leverage and provide job opportunities in agro-processing, handicrafts, and dairy industries (Singh & Bhowmik, 2019). Yet the contribution of cooperatives in Bihar and Jharkhand is oftentimes eclipsed by SHGs because of lesser policy and financial support mechanisms (Kandpal, 2022).

Farmer Producer Organizations (FPOs) and Market Integration

FPOs are a more recent type of collective, intended to enhance farmers' access to inputs, markets, and institutional credit. Their ability to empower women has been progressively acknowledged, especially in tribal and poor areas such as Jharkhand. For instance, the Lakhpati Kisan program proved that FPOs led by women could significantly boost household incomes and resilience (World Bank, 2022). Comparative research indicates that although FPOs enhance market linkages and productivity, women members are hindered by mobility, literacy, and leadership issues (Ma et al., 2023; Steven & Msosa, 2022).

Challenges and Research Gaps

- While positive results are reported, a number of challenges preclude the full potential of women's collectives in Bihar and Jharkhand. These are:
- Socio-economic limitations: low literacy levels, poor financial literacy, and poverty-based dependence on male family members (Chakraborty & Chaturvedi, 2021).
- Cultural barriers: patriarchal attitudes and restrictive gender norms that constrain women's mobility and leadership (Haugh & Talwar, 2016).
- Structural and policy gaps: inadequate infrastructure, inadequate credit linkages, and institutional support for women-owned FPOs being fragmented (Rustinsyah et al., 2021).
- They also observe that the literature that is currently available is program-specific and rarely carries out comparative analysis of different types of collectives. Overall integrated studies are necessary to analyze the combined contribution of SHGs, cooperatives, and FPOs towards women's empowerment in the distinct socio-economic scenarios of Bihar and Jharkhand (Swapna, Thomas, & Mercykutty, 2023; Ekta & Singh, 2022).

Research Questions

Women collectives, such as self-help groups (SHGs), women-only cooperatives, and farmers' producer organizations (FPOs), have emerged as key institutional platforms for promoting financial inclusion, entrepreneurism, and social empowerment of rural women (Ekta & Singh, 2022). Although their potential has been well recognized, ongoing gaps continue to exist in

women's participation, enterprise viability, and access to institutional support (Steven & Msosa, 2022; Swapna et al., 2023). In this context, the current study was informed by the following research questions:

RQ1: What is the socio-economic status of women collective members in Bihar and Jharkhand?

This question examines the degree to which membership in a collective has an impact on education, earnings, ownership of assets, access to credit, decision-making participation, and social mobility. The existing research indicates that SHG members tend to have higher earnings, more involvement in local government, and better access to healthcare and education than non-members (Minaxi et al., 2022; Vinay, 2022). Results are not equal among marginalized groups like Dalits, tribals, and Muslim women (Lahiri-Dutt & Samanta, 2002).

RQ2: What are the core issues confronted by women collective members?

This question looks at economic, cultural, and institutional obstacles such as limited institutional credit access, poor market linkages, infrastructural shortfalls, low digital literacy, and patriarchal constraints (Chukwujekwu et al., 2021; Ahmad et al., 2022). Organizational weaknesses like absenteeism, record-keeping, and price volatility in women's cooperatives are also pointed out by studies (Swapna et al., 2023). Also, cultural obstacles—particularly gender discrimination and mobility restraints—still restrict women's agency (Haugh & Talwar, 2016).

RQ3: What strategic plan can be put forth to consolidate women's collectives as durable instruments for socio-economic transformation?

This question involves finding policy and programmatic interventions that advance sustainability, scalability, and empowerment results. Previous studies highlight the need for capacity building, digitalization, leadership development, and supportive institutional environments (Hamrila & Latip, 2023; Rustinsyah et al., 2021). Drawing from field observations and secondary information, this study suggests a roadmap based on inclusive financing, e-commerce-enabled market access, gender-sensitive training, and leadership promotion among women-headed collectives.

Comprehensive review of work already done on the subject:

Women Collectives and Socio-Economic Development

The socio-economic empowerment of women through collective efforts has long been recognized as a critical entry point for poverty reduction and empowerment. Self-help groups (SHGs), microfinance institutions (MFIs), and cooperatives have contributed immensely to financial inclusion and vulnerability reduction among rural women (Ekta & Singh, 2022; Kandpal, 2022). Research across SHG and non-SHG members has invariably identified greater education, family

involvement, and income levels among SHG members, pointing to collective membership enhancing socio-economic traits (Dang et al., 2022; Minaxi et al., 2022).

In Indonesia, Suseno and Nataliningsih (2023) reported that women's cooperatives improved entrepreneurial skills and facilitated equal access to welfare resources. Analogously, in India, SHGs have been linked to increased household savings, ownership of assets, and decision-making (Vinay, 2022). These reports affirm that collectives have beneficial impacts on socio-economic conditions, yet outcomes tend to differ across caste, religion, and geographical locations (Lahiri-Dutt & Samanta, 2002).

Empowerment, Entrepreneurship, and Women's Agency

Women collectives also play a crucial role in broadening the scope of entrepreneurship and leadership. Entrepreneurial collective models have been demonstrated to improve women's human capabilities at family, individual, and community levels (Hamrila & Latip, 2023). Social network connections within collectives have a positive effect on entrepreneurial persistence even in situations where financial resources are scarce (Ahmad et al., 2022). In addition, cooperatives and producer organizations enhance access to inputs, markets, and value chains, hence enhancing food security and poverty reduction outcomes (McInerney, 2014).

Yet, empowerment outcomes are often mediated by institutional and cultural factors. For instance, Iris et al. (2008) noted that interpersonal compatibility and trust were key success determinants in Swiss farming collectives. In rural India, where patriarchal culture prevails, SHGs assist women in challenging limiting social structures and exercising increased agency (Haugh & Talwar, 2016).

Women Collectives' Challenges

Despite the benefits, women collectives continue to experience entrenched challenges. Research points out that SHGs and women cooperatives are typically limited by poor financial knowledge, weak bookkeeping, absenteeism, and market price volatility (Swapna et al., 2023). Steven and Msosa (2022) contend that a lack of knowledge about the markets, transportation challenges, and structural constraints impede the scaling of women cooperatives. Chukwujekwu et al. (2021) also highlight that institutional dimensions accentuate women's disproportionate access to training and technologies, with younger women encountering more challenges than older members.

These observations have implications within Indian contexts, as gender-based limitations on mobility, low literacy rates, and socio-cultural discrimination still prevail among women belonging to marginalized groups like Dalits, Muslims, and tribals (NCRB, 2022). Therefore, although collectives offer a protective atmosphere, they cannot remain isolated from larger structural

inequalities.

Institutional and Policy Dimensions

At the policy level, governments and international organizations increasingly acknowledge the contribution of collectives to the attainment of Sustainable Development Goals (SDGs). For instance, FAO (McInerney, 2014) identifies cooperatives as important allies in sustainable agricultural development. Rustinsyah et al. (2021) also establish that cooperatives among women are successful in promoting SDG-corresponding outcomes like gender equality and poverty reduction.

Recent research also emphasizes the need for organizational and leadership considerations. Leadership, training, and organizational culture are key success factors in collective sustainability, according to Onyia et al. (2023). Sinarti and Churiyah (2023) postulate a strength-based approach in order to leverage women entrepreneurs' potential to the fullest, if only governments provide stable institutional support.

Emerging Areas of Research

New directions for SHG and collective research are in the areas of digital transformation, peer-support mechanisms, and online forums. Garu and Dash (2023) identify computer-mediated communication, e-health, and social media as new fields which can be expanded to take collectives further. This is also in line with India's efforts at digital inclusion in rural development initiatives.

Research Gap

While research supports the socio-economic advantages and empowerment potential of women collectives, region-specific challenges to women's collectives are not well understood. The majority of studies encompass SHGs for India as a whole with limited attention paid to Bihar and Jharkhand, where women's participation in the workforce is the lowest in the country (PLFS, 2023). Additionally, there is a dearth of empirical literature that compares different forms of collectives—SHGs, FPOs, and women-exclusive cooperatives—in terms of challenges and empowerment. Plugging this void is important in coming up with policies that suit marginalized women in these states.

Research Methodology

Research Design

The research is a review paper that brings together available literature to investigate the effect of soft skills on business school teaching performance. Since no primary data was gathered, the study is based completely on secondary sources. The research uses a systematic literature

review strategy whereby identification, analysis, and synthesis of studies are made to arrive at a holistic understanding of the subject matter (Creswell & Creswell, 2018).

Sources of Data

The research utilizes secondary sources, including:

- Peer-reviewed journal papers from Scopus, Web of Science, and Google Scholar databases.
- Books and book chapters on soft skills, faculty development, and business education pedagogy.
- Educational authorities and international organizations (e.g., UNESCO, World Bank) reports highlighting teacher performance and soft skill development.
- Online academic materials, conference proceedings, and institutional literature pertinent to teaching effectiveness in higher education.

Selection Criteria

The literature was selected based on the following criteria:

- Published in the last 15 years (2008–2023) to ensure relevance.
- Written in English.
- Focused on soft skills in higher education or business schools.
- Studies that examine teaching performance, faculty development, or student learning outcomes.
- Studies focusing solely on technical skills or outside the higher education context were excluded.

Data Collection and Extraction

Literature relevant to the question was found by searching with keywords including "soft skills in teaching," "teacher performance," "business schools," "faculty development," and "emotional intelligence in education." For every study selected, data were collected on:

- Study aims and areas of focus.
- Nature of soft skills under investigation.
- Findings about teacher effectiveness.
- Recommendations and challenges found.

Data Analysis

Data were thematically analyzed from the information extracted. Some of the most important themes identified are:

- Influence of communication and interpersonal skills in teaching performance.
- Impact of leadership, team work, and emotional intelligence.
- Barriers to the development of soft skills for teachers.
- Best practices and recommendations for faculty development programs.

Thematic synthesis permits cross-study comparison and points out research gaps for future study (Kitchenham, 2004).

Presentation of Findings

Results are summarized under thematic titles related to the soft skills under discussion, with tables synthesizing studies, their purpose, methodology, and key conclusions. This format gives a clear description of the literature and shows trends, gaps, and implications for business school faculty development.

Findings and Expected Contributions

The research yielded findings that are theoretically meaningful as well as pragmatic for policy-makers, practitioners, and members of collectives. The major contributions include:

- Thorough understanding of Bihar and Jharkhand women collectives

The research gave empirical facts regarding the socio-economic status of the women collective members, such as income levels, education, decision-making status, and resources access. These facts enlighten policymakers, NGOs, and development organizations regarding both the potential and limitation of women's collectives in the agri-food system, especially in terms of contributing to Sustainable Development Goals (SDG-1: No Poverty, SDG-5: Gender Equality, and SDG-8: Decent Work and Economic Growth) (Rustinsyah et al., 2021; PLFS, 2023).

- Identification of challenges and coping strategies

The research underscored key issues that face women collectives, including scarce resources, weak market connectivity, infrastructural vulnerabilities, and socio-cultural barriers. Concurrently, it identified coping mechanisms established by women, including new business models, solidarity groups, and informal networks. The findings add to the body of academic literature on collective entrepreneurship and yield practical implications for community-based problem-solving (Steven & Msosa, 2022; Swapna et al., 2023).

- Design of a structural business model for women collectives

Based on field evidence and best practice, the research suggested a structural business model combining capacity development, digital inclusion, and market linkages. This model supports increased long-term financial, social, and environmental sustainability of women collectives and

provides a replicable model for other contexts in India and elsewhere (Hamrila & Latip, 2023).

- Roadmap and strategic recommendations

The study ended with a roadmap for building strong women's collectives in Bihar and Jharkhand. Key recommendations are:

- Streamlining credit access for women entrepreneurs.
- Scaling up digital and e-commerce connectivity for local food items.
- Improving leadership and governance structures for collectives.
- Mainstreaming gender-responsive capacity-building efforts.

These policies will make women's collectives transform into effective, sustainable institutions that can scale up as drivers of rural transformation and women's empowerment (World Bank, 2022).

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Classroom Behavioural Challenges among Adolescents: Causes, Implications, and Interventions

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ABSTRACT

Behavioral challenges among adolescents in schools are an increasing concern, as they disrupt the learning environment and impact students' academic and social development. This study explores the common behavioral issues displayed by adolescents, their underlying causes, and the consequences on academic and social life. A total of 75 secondary school teachers from Bengaluru district were surveyed using a structured questionnaire. Data were analyzed through percentage analysis. Results revealed that adolescents often display behaviors such as aggression, violation of school rules, frequent absenteeism, disinterest in group activities, and unnecessary arguments in class. Teachers identified broken family relationships, lack of parental supervision, exposure to negative peer groups, and parental substance abuse as significant contributing factors. Consequences included poor academic performance, low self-esteem, strained teacher-student relationships, and social withdrawal. The study highlights the need for early identification, teacher-parent collaboration, and targeted interventions to manage behav-

ioral challenges effectively.

Key Terms: Adolescents, Classroom Behavior, Disruptive Conduct, Academic Outcomes, Teacher Perceptions

INTRODUCTION

Adolescence is a critical stage of human development characterized by rapid physical, cognitive, and emotional changes. During this stage, adolescents often exhibit behaviors that challenge authority, social norms, and classroom discipline. These behavioral issues, while sometimes transient, can escalate into persistent patterns that hinder not only academic progress but also social development. In schools, disruptive classroom behaviors such as aggression, rule violations, absenteeism, and disrespect toward teachers create barriers to effective learning and teaching.

The prevalence of behavioral challenges among students has been widely acknowledged by educators and psychologists. Such behaviors often stem from complex interactions of family background, peer influence, and socio-economic conditions. Teachers, being primary observers of students' day-to-day conduct, play a crucial role in identifying and addressing these challenges before they escalate. Left unaddressed, persistent behavioral problems can result in academic failure, low self-esteem, strained peer relationships, and in extreme cases, long-term social maladjustment. This study therefore aims to explore behavioral challenges in secondary school students, their causes, and their consequences from the perspectives of teachers.

NEED AND SIGNIFICANCE OF THE STUDY

With increasing reports of aggression, disrespect, and disengagement among adolescents in schools, understanding classroom behavioral challenges has become essential. Teachers frequently encounter students who display disinterest in studies, disregard school norms, and exhibit disruptive conduct, which affects not only their own academic performance but also that of their peers. The significance of this study lies in highlighting the urgent need for timely identification and intervention. By understanding the root causes of adolescent behavioral issues, teachers, parents, and policymakers can develop effective support systems that promote healthier academic and social development.

STATEMENT OF THE PROBLEM

Adolescents in secondary schools often display behavioral challenges that disrupt classroom functioning and violate social and academic norms. These issues impact not only their personal and academic growth but also the learning environment of others. In this context, the present study is entitled: *Classroom Behavioral Challenges among Secondary School Students: Causes, Implications, and Interventions*.

OBJECTIVES OF THE STUDY

1. To identify the common behavioral challenges displayed by adolescents in secondary schools.

2. To analyze the causes behind these behavioral challenges.
3. To examine the consequences of these behavioral issues on academic and social outcomes.

HYPOTHESIS OF THE STUDY

Adolescents in secondary schools often display disruptive behavioral patterns that negatively influence academic performance and classroom climate.

MATERIALS AND METHODS

Method Adopted for the Study

A descriptive survey method was adopted to collect data on adolescent behavioral challenges from secondary school teachers.

Sample Selection

The sample comprised 75 secondary school teachers from selected schools in Bengaluru district. Teachers were selected using a simple random sampling technique, as they directly observe and experience students' behavioral patterns in classrooms.

Tool Used for the Study

A structured questionnaire with 40 closed-ended items was administered to the teachers. The items were categorized to identify behavioral issues, their causes, and their consequences. Responses were recorded in a standardized format for analysis.

Statistical Technique Used

Percentage analysis was employed to interpret the data and draw meaningful conclusions.

ANALYSIS AND INTERPRETATION

The analysis revealed the following key findings:

1. **Common Behavioral Challenges:**
    - Violation of school rules (65%)
    - Aggression and hostility toward peers or teachers (62%)
    - Frequent absenteeism or skipping classes (58%)
    - Persistent lying and excuses (55%)
    - Disinterest in group activities (70%)
    - Unnecessary arguments in classrooms (60%)
2. **Causes of Behavioral Challenges:**
    - Broken family relationships (72%)
    - Lack of parental supervision (68%)

- Negative peer influence (61%)
- Parental substance abuse (54%)
- Exposure to traumatic life events (50%)
- Ineffective school discipline policies (47%)

Consequences of Behavioral Challenges:

- Poor academic performance (74%)
- Low self-esteem (65%)
- Social withdrawal and lack of peer acceptance (59%)
- Strained teacher-student relationships (62%)
- Negative influence on classmates (57%)
- Increased risk of school dropout (48%)

MAJOR FINDINGS OF THE STUDY

- Behavioral challenges such as aggression, absenteeism, disinterest in group activities, and violation of school rules are common among adolescents.
- Key contributing factors include broken family relationships, poor parental supervision, peer influence, and parental substance abuse.
- These challenges result in academic underachievement, low self-confidence, strained relationships, and increased risk of long-term maladjustment.

SUGGESTIONS

For Teachers:

- Monitor behavioral changes and engage in early identification of at-risk students.
- Build positive teacher-student relationships to encourage open communication.
- Incorporate collaborative and experiential learning methods to engage students.
- Collaborate with school counselors to provide timely interventions.

For Parents:

- Create a supportive and nurturing home environment.
- Avoid substance abuse and ensure parental involvement in children's education.
- Attend school awareness programs to understand adolescent behavior better.
- Seek professional help when children show persistent behavioral challenges.

For Policymakers and Schools:

- Introduce school-based counseling and mental health programs.
- Develop clear disciplinary policies with a focus on rehabilitation rather than punishment.
- Organize workshops for teachers on managing adolescent behavioral issues.
- Promote extracurricular activities to channel adolescent energy positively.

CONCLUSION

The study concludes that behavioral challenges among adolescents are widespread in secondary schools and significantly affect both academic performance and classroom climate. Broken family relationships, inadequate parental supervision, and peer influences were identified as major causes. These challenges often lead to academic failures, low self-esteem, strained teacher-student interactions, and social withdrawal. Addressing adolescent behavioral challenges requires early identification, strong collaboration between teachers and parents, and supportive school policies. By implementing structured interventions, schools can create a more positive and inclusive environment that supports adolescents in their academic and personal growth.

DIMENSIONS OF HUMAN RIGHTS IN 21ST CENTURY – AN ANALYTICAL STUDY OF EMERGING ISSUES.

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Abstract

The idea of human rights starts at the center of the recognition of the presence of a personhood – the notion of a character or a personality that fits to be a human, and worth a rational, dignified life. Since the dawn of civilisation, human beings have been looking for stability in their way of life – or food or land or wars, but at the heart of it all has been the pursuit of living a dignified life and fulfilling the bare essentials first and then a gradual evolution of a paraphernalia that was associated with living in dignity. Expections form the core of the discourse of human rights. The concept of human rights is the outcome of widespread debate. Numerous scholars have upheld that rational thinking forms the core of the idea of human rights.

Keywords –Rights, Constitution, Philosophy, Development, State, Protection

Introduction – The Expanding Meaning of Human Rights

The principles of the Universal Declaration of Human Rights UDHR) were formulated in *1948*serve as a background for maintaining unity among people of diverse cultures and religion. Universal, timeless, for people of all colour, sex, orientation and faith – the UDHR is a people's document. Particularly *Art.1 and Art.18* of the UDHR state that 'All human beings are born free and equal in dignity and rights, emphasising shared humanity that unites people across differences.' And Art.18 guarantees the freedom of
thought, conscience, and religion, ensuring that individual can practice their faith without fear or discrimination.'[1] It's not just the language and text of UDHR that assumes so much importance, but rather the experiences from the bloody wars and aggression that led to global consciousness on the subject of peace. The concept of human rights has been profoundly shaped by Enlightenment philosophy. Numerous foundational concepts derived from the Western past, including democracy, Justice, freedom, equality, and human dignity, are frequently utilised in political discourse. We cannot dismiss the significance of these phrases just due to their connections with Western Enlightenment thought. It would restrict or render the political discourse in contemporary society barren.[2] Consequently, these concepts must be rendered more dynamic and inclusive to embrace the ambitions of diverse cultures and traditions rather than solely Western interpretations. The Enlightenment has instigated substantial changes in dogmatic and traditional traditions, while it has occasionally adopted the rhetoric of materialism and self-indulgence. The universality of human rights should not be misconstrued as immutable; instead, it ought to be informed by individual subjective experiences. The articulation of universal principles requires participation in discourse, contemplation, and the exchange of ideas.

Any social or religious reformation, as historically evident, has been through phases of realisation and moral accomplishment that have led to legal reforms as well. Human rights are a cornerstone of contemporary political and legal thought. They have become a central component of international relations, domestic governance, and moral philosophy. Despite their ubiquity in discourse and policy, the concept of human rights remains complex and contested. Their definition must account for legal, philosophical, political, and socio-cultural dimensions.

Human rights are intrinsic, inalienable, and universal privileges that every individual possesses by their humanity, regardless of nationality, ethnicity, gender, religion, or any other status. These rights are rooted in the dignity and value of the human individual and are vital for the comprehensive development of human potential in both individual and collective spheres.

1 UDHR https://www.un.org/en/about-us/universal-declaration-of-human-rights

2 Steven Pinker, ENLIGHTENMENT NOW THE CASE FOR REASON, SCIENCE, HUMANISM, AND PROGRESS 1-7 (2018)

From a legal and philosophical perspective, human rights constitute a normative framework that specifies the essential norms required for individuals to exist with freedom, equality, justice, and peace. They are enshrined in international documents such as the Universal Declaration of Human Rights (1948), the International Covenant on Civil and Political Rights (1966), and the International Covenant on Economic, Social and Cultural Rights (1966), among others. These rights span a wide range, encompassing civil and political rights (e.g., right to life, freedom of expression, right to a fair trial), as well as economic, social, and cultural rights (e.g., right to education, right to employment, right to health).[3]

Human rights constitute not only legal assertions against the state but also moral assertions grounded in diverse ethical traditions. They establish a foundation for responsibility, empowerment, and social justice, necessitating both negative obligations (to abstain from interference) and positive obligations (to proactively protect and fulfil) by states and, increasingly,

non-state actors. In modern discussions, human rights are viewed through a multi-faceted perspective, intersecting with development, gender, environmental justice, and postcolonial analysis, thus transcending a Western-centric legal framework to adopt pluralistic and context-specific interpretations. Human rights are a cornerstone of contemporary political and legal thought. They have become a central component of international relations, domestic governance, and moral philosophy. Despite their ubiquity in discourse and policy, the concept of human rights remains complex and contested. Their definition must account for legal, philosophical, political, and socio-cultural dimensions. This essay offers a comprehensive and analytical exploration of human rights, grounded in normative theory, international law, and critical thought.[4]

Jurisprudential foundations of human rights have helped their evolution over the years, charting their own unique territory. At its core, human rights refer to entitlements and freedoms inherently possessed by all human beings, simply by virtue of being human. They are not earned, granted, or conditional; they are inherent (born with the person), inalienable (cannot be taken away), and universal (applicable to all people without discrimination). These attributes distinguish human rights from other rights, such as legal rights or privileges, which are contingent on laws or social status.

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3 ICCPR , https://www.ohchr.org/en/instruments-mechanisms/instruments/international-covenant-civil-and-political-rights

4 Human Rights and Development –
An International Political Economy Perspective
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Philosophically, the idea of human rights is rooted in natural law theory, which posits that certain rights exist independent of written laws and derive from human nature and reason. Thinkers such as John Locke, Immanuel Kant, and later Thomas Paine developed the idea that every individual possesses inalienable rights that must be respected by the state. For Locke, rights to life, liberty, and property were pre-political and derived from natural law. Kant, on the other hand, emphasised the intrinsic dignity of the individual as the moral foundation for rights, framing them as expressions of autonomy and rationality. While early scholars and thinkers heavily relied on morality as an aspect of dignity, the birth of democracies and rationality in political thinking diverted this course in a different direction altogether.[5]

Though human rights have centuries-old intellectual roots, their legal articulation became well-known following World War II. Adopted in 1948 by the United Nations General Assembly, the Universal Declaration of Human Rights (UDHR) is the first thorough statement of internationally acknowledged human rights norms. The UDHR has been the normative basis

for other international treaties and national constitutions even though it is not a legally enforceable treaty. Later, both the International Covenant on Economic, Social and Cultural Rights (ICESCR) and the International Covenant on Civil and Political Rights (ICCPR), enacted in 1966, operationalised the UDHR's ideas into legally enforceable responsibilities. These devices, taken together, create what is sometimes known as the International Bill of Human Rights. These records outline a wide spectrum of rights, including Civil and political rights, including those to life, freedom of expression, torture avoidance, and a fair trial. Rights in economics, social life, and culture: those including those to labour, housing, healthcare, and education. Numerous other conventions, including the *Convention on the Elimination of All Forms of Discrimination Against Women* (CEDAW)[6], the *Convention on the Rights of the Child* (CRC), and the *Convention on the Rights of Persons with Disabilities* (CRPD), have also supplemented the legal codification of these rights.[7]

The emergence of the concept of codification in the human rights regime began with the numerous conventions, as guided by the global forces. The codification of human rights is crucial for guaranteeing the recognition, respect, and protection of the inherent dignity and freedoms

5 "Human Rights and Natural Law," UNESCO Courier, 9 October 2018 (last updated 4 May 2023).

6 The Convention on the Elimination of All Forms of Discrimination against Women (CEDAW), adopted in 1979 by the UN General Assembly, is often described as an international bill of rights for women. Consisting of a preamble and 30 articles, it defines what constitutes discrimination against women and sets up an agenda for national action to end such discrimination.

7 https://social.desa.un.org/issues/disability/crpd/convention-on-the-rights-of-persons-with-disabilities-crpd

of all individuals under the law. Codification denotes the official documentation of rights inside legal writings, including constitutions, legislation, treaties, and declarations. In the absence of precise articulation and legal enforceability, human rights may persist as abstract concepts rather than tangible assurances. One of the principal justifications for codifying human rights is to ensure clarity and uniformity.[8] Clearly stated rights facilitate citizens' comprehension of their entitlements and enhance the accountability of governments and institutions. Legal codification guarantees the enforceability of these rights. Individuals whose rights have been infringed may seek redress through the judiciary, and courts can invoke statutory legislation to safeguard those rights. In addition, codifying human rights fosters public awareness and education, encouraging citizens to stand up for their rights and the rights of others. It helps embed values of equality, justice, and dignity into the fabric of societies. Therefore, codification is not only a legal necessity but also a moral and practical imperative for building fair and just societies where the rights of all are safeguarded.[9]

Although the codification of human rights is absolutely important, it presents several major difficulties. The diversity in cultural, political, and religious beliefs among different civilisations is one of the key issues since it can cause conflicts on what defines a universal human right. For instance, in some areas rights pertaining to gender equality[10] or freedom of expression could contradict religious or conventional wisdom. This makes it difficult to reach world agreement and produce really universal human rights treaties. Absence of enforcement systems is another main problem. Even when national or international law codifies rights, enforcement usually relies on the political will of nations, many of which might overlook or implement these rules only selectively. Human rights regulations may exist on paper in authoritarian governments, but they are often disregarded in fact. Some human rights documents also suffer from ambiguity and wide language since they could result in different interpretations and gaps, therefore undermining their efficacy.[11] Furthermore, there are tensions between certain rights, such protection from hate speech against freedom of expression, which call for careful balance and might not be readily settled by codification by itself.. Furthermore, socioeconomic inequalities might hinder the realisation of rights since underprivileged groups could not have access to legal rem-

8 Polak, Jan Tobias, Lea Smidt and Lena Taube (2021), Human Rights in German Development Policy. Part 1: The Human Rights Strategy and its Implementation, German Institute for Development Evaluation (DEval), Bonn.

9 https://www.ohchr.org/en/development/development-and-human-rights

10 Daniel Kaufmann, "Human Rights and Governance: The Empirical Challenge," in Human Rights and Development: Towards Mutual Reinforcement, Oxford University Press, 2004.

11 Id

edies or encounter systematic obstacles even with established protections. At last, the politicisation of human rights—where strong countries employ rights discourse to further their own goals or attack rivals—may compromise the credibility and neutrality of human rights systems. Therefore, even if codification is a first step towards justice and protection, it must be really fulfilled by efficient implementation, political dedication, and sensitivity to different environments.

There is another growing perspective in the area of human rights – the *local versus global* angle to it. Do we need a global lens to view human rights in a particular setting, or should the analysis be guided by local customs and practices as cardinal to civilisations marked with diversity? One of the most ongoing arguments in human rights research revolves on its universality. According to the universalist view, everyone has human rights in every society at every moment.

This stance stems from the conviction in the moral value and common dignity among all human beings. Cultural relativists[12] contend, however, that human rights have to be understood within historical, religious, and cultural setting. They contend that Western liberal principles, which might not appeal to non-Western traditions, often define the mainstream discourse of human rights. Critics of communitarian civilisations in Asia or Africa, for instance, have pointed out that they can put family or communal obligations above personal autonomy, therefore subverting the priority of individual rights. This conflict has resulted in initiatives at localising human rights, in which case universal norms are modified to meet particular political and cultural settings. Issued by Asian governments, the Bangkok Declaration (1993) underlined the need of including national and regional particularities into the application of human rights. Most international human rights instruments remain universalistic in spite of such calls.[13]

Human development and Human Rights- Diversity, Inclusivity, Equality.

Deeply entwined and reflecting both theoretical and pragmatic aspects formed over decades of international debate, human development and human rights are intimately related. Fundamentally, human development stresses the increase of people's capacities and options so allowing them to lead lives they value. By virtue of their humanity, human rights are normative entitlements unique to every person. Though their philosophical roots—human development in economics and development theory, and human rights in legal and moral philosophy—the

12 U.N. DEP'T OF ECONOMIC AND SOCIAL AFFAIRS, TRANSNATIONAL CORPORATIONS IN WORLD DEVELOPMENT: A RE-EXAMINATION 158-61, Annex 1, U.N. Doc. E/C 10/38 (1978); see
also U.N. DEPARTMENT OF ECONOMIC AND SOCIAL AFFAIRS, TRANSNATIONAL CORPORATIONS IN WORLD DEVELOPMENT 4-6, Annex 2, U.N. Sales No. E.73.II.A.11 (1973)

13 A/CONF.157/PC/83,
Bangkok NGO Declaration on Human Rights

two concepts are increasingly acknowledged as mutually reinforcing.

Particularly via the Human Development Index (HDI), human development as stated by the United Nations Development Program (UNDP)[14] gives health, education, and standard of living top priority. Early versions of development language, however, sometimes saw people as passive beneficiaries of aid rather than active change agents. By contrast, human rights debate stresses agency, dignity, and justice. Comprising a thorough legal and moral framework guaranteeing individuals' civil, political, economic, social, and cultural rights, the 1948 Universal Declaration of Human Rights and later international treaties have created

The *2000 UNDP Human Development Report*[15], which maintained that human rights and human development had a same goal: guaranteeing the freedom and well-being of people, arguably most aptly illustrates the junction of both ideologies.

Rights including political involvement, healthcare, and education are not only tools for progress; they are rather the essence of it. Moreover, underdevelopment can be both a cause and a result in the denial of rights. For example, systematic gender discrimination not only violates women's rights but also limits the possible contributions of half the population, therefore hindering more general progress.

Normatively, including human rights into development models answers important ethical concerns about inequity, responsibility, and involvement. Development projects without including human rights run the danger of either aggravating or extending already existing power disparities. On the other hand, rights-based models of development guarantee that underprivileged groups participate in decision-making procedures and gain from results. This change from charity to entitlement redefines development not as a nice deed but rather as a moral and legal obligation. Moreover, embraced in 2015, the Sustainable Development Goals (SDGs) highlight this connection. Human rights norms closely relate goals like reducing poverty, guaranteeing decent education, attaining gender equality, and supporting inclusive institutions to the dedication of the SDGs to "leave no one behind" reflects the universal human rights idea devoid of prejudice.

In essence, human rights and human development have a symbiotic and necessary relationship. Human rights give the ethical basis and legal means to guarantee dignity, justice, and equality; human development offers the empirical methods and policy frameworks to increase well-being. Development has to start in respect, protection, and fulfilment of human rights if we are to

14 The United Nations Development Programme is a United Nations agency tasked with helping countries eliminate poverty and achieve sustainable economic growth and human development. The UNDP emphasizes on developing local capacity towards long-term self-sufficiency and prosperity.

15 https://hdr.undp.org/content/human-development-report-2000

achieve sustainable and fair progress. The realisation of human rights then advances through the social and material achievements made possible by human development. Combining these perspectives not only reflects an ethical need but also a sensible road to a fair world.

Generally speaking, economic development is the improvement in income, employment, infrastructure, and service access. Ideally, it should give everyone—including women and underprivileged groups—the tools they need to lead safe and respectable life. Human developmentally speaking, economic empowerment can improve women's agency, lower reliance on abusive spouses, and increase chances for involvement in decision-making. Access to financial resources and jobs, for instance, can help women to exercise their rights, exit abusive relationships, and acquire social capital. Still, economic prosperity does not immediately eradicate gender-based violence. Indeed, in some situations women's higher economic involvement could cause reaction from males who believe their traditional positions as heads of households or providers to be under danger. Often referred to as a "male backlash," this phenomenon has been seen in developed as well as developing nations. In patriarchal countries, in which male dominance is ingrained in societal systems, economic growth may change economic power without always changing fundamental gender roles. These changes may thus cause some males to react with violence in an attempt to regain control.

Moreover, if fast economic growth is not inclusive, it might aggravate already existing inequality. Women, for example, are disproportionately represented in low-paying, unstable, informal labour sectors, which not only limit their financial autonomy but also expose them to harassment and exploitation. Particularly vulnerable to sexual harassment and coercion are migrant women, domestic workers, and those in the apparel or service sectors; sometimes lacking legal rights and channels for redress, these groups. While in many ways positive, economic progress can also lead to urbanisation and social mobility, which could upset established communal institutions that historically provided unofficial support systems. In the lack of sufficient institutional protections, such as easily available court systems, gender-sensitive police, and shelters, women may find themselves more isolated and at danger of assault in urban or transitional settings.

On the other hand, there is transforming power when economic development is clearly gender-responsive. Together, investments in girls' education, fair employment rules, loan availability for women entrepreneurs, and social security systems will help to lower the GBV prevalence and influence. Programmes for conditional cash transfers linked to the results of women's health and education have also showed promise in improving women's negotiating power inside homes and lowering domestic violence. In essence, economic growth can be a very effective weapon in the battle against gender-based violence; but, only when it is included into more general plans of gender equality and social justice will it be able to be a weapon. Economic development by itself may not be able to shield women from violence—and in certain situations

may rather aggravate their vulnerability—without deliberate attempts to destroy patriarchal norms and create inclusive institutions. Therefore, not only desirable but also necessary for really sustainable and fair development is the inclusion of gender points of view into economic policymaking.

CONTEXTS AND CONTENTS – INTERDISCIPLINARY ANGLES

Much like the historic crusades, gender equality is a constant battle which, even though it is not fought on the battlefield, still has the potential of being named so. Rising against patriarchal domination and discrimination, the road to equality has been a long and tiresome struggle that has rewarded the world globally with positive connotations and consequences. Oppressive patriarchal notions have been continuously challenged to change the course of history. The dogmatic conceptualisation of a bygone era has indeed given way to more liberal understandings, in a widely dynamic and evolving socio-economic context that has brought gender diversity to the workforce, but has however not solved the problems identified.

The context of Human Development, when viewed through the lens of economic progress viability, sustainable growth, indulges us in a variety of theories, most of which tend to prescribe parameters or certain objective criteria for measurement. This is arithmetically significant as a deals with numbers but at the same time, it is subjectively vague as it clearly does not taken into account inter related and multi-disciplinary factors around the same.

The empowerment of women and economic possibilities are intricately connected, serving as a formidable catalyst for social and economic advancement. Empowering women entails providing them with the autonomy, resources, and options essential for self-determination. When women receive equal access to economic opportunities, including employment, entrepreneurship, and financial services, entire communities see enhanced productivity, innovation, and development.

Women development and economics of well being

Historically, women globally have encountered systematic obstacles to their full participation in economic activities. These encompass legal constraints, gender bias, inequitable access to education, and restricted asset ownership. As countries challenge these traditions and offer equal possibilities, the transformative potential of women's economic engagement becomes apparent. An excellent method to economically empower women is by education and skill enhancement. When females obtain quality education, they are more equipped to join the workforce, initiate enterprises, and make informed choices. Education also serves to contest cultural and social norms that confine women's roles to household duties. Furthermore, proficient women are more inclined to attain higher-paying positions and substantially contribute to economic development. Access to capital is a vital component of economic empowerment. Women en-

trepreneurs frequently encounter difficulties in securing finance due to insufficient collateral, biassed lending policies, or inadequate financial awareness. Governments and financial institutions can facilitate women's entrepreneurship and business expansion by endorsing microfinance institutions, digital banking, and inclusive lending laws, thereby generating employment and invigorating local economies.

Workplace inclusion and equality are essential factors. Guaranteeing equitable compensation for identical labour, offering maternity and childcare assistance, and advancing women into leadership positions can substantially improve their economic involvement. Inclusive workplaces enhance organisational performance while benefiting women, as diverse teams tend to exhibit greater creativity and effectiveness.The economic empowerment of women is crucial for alleviating poverty. In numerous households, particularly in low-income nations, women serve as the principal carers and administrators of family resources. Women who generate their own money are more inclined than men to allocate resources towards their children's health, education, and general welfare. This generates a ripple effect that enhances the prospects of the subsequent generation and fosters long-term development.

Moreover, the economic empowerment of women fosters more resilient communities. In times of emergencies, whether pandemics or economic recessions, women frequently assume a vital role in preserving household earnings and fostering social solidarity. Policies that assist female workers and entrepreneurs during these times contribute to the preservation of livelihoods and the enhancement of recovery initiatives. In conclusion, economic possibilities constitute a vital component of women's empowerment. Eliminating obstacles, investing in education, guaranteeing financial inclusion, and advancing gender equality in the workforce are crucial measures for establishing a more equitable and successful society. Empowered women not only revolutionise their own lives but also propel sustainable economic advancement for all. Enhanced economic opportunities dramatically elevate women's living standards by facilitating access to income-generating activities, augmenting agency and autonomy, and enabling intergenerational advancements in well-being. From a development economics perspective, the correlation between economic empowerment and improved living standards is both direct—via increased income and consumption—and indirect—through alterations in household dynamics, investment in human capital, and reductions in vulnerability.

Essentially, women's access to increased economic opportunities enables them to produce independent incomes. This currency serves as a means of empowerment rather than only a commodity for consumption. Empirical research has demonstrated that women who manage their financial resources generally allocate their funds in ways that improve household welfare, notably in domains such as nutrition, healthcare, and children's education. This tendency aligns

with models of intra-household bargaining; wherein relative economic contributions partially delineate the allocation of power inside households. The negotiation position of women improves as their share of household income increases, hence fostering more equitable decisions and superior outcomes for the family. Employment and entrepreneurship enable women to accumulate savings, acquire possessions, and reduce dependence on informal or precarious income sources. In the informal economy, where women are particularly vulnerable to economic shocks and social protection is insufficient, financial resilience is essential. Enhanced housing, healthcare, and the opportunity to engage in lifelong learning and skill acquisition are contingent upon increased economic stability. These investments subsequently exert multiplicative effects on the well-being of women and their families.

In addition to mere cash opportunities, economic factors exert significant psychological and societal impacts. Consistent employment or profitable self-employment enhances self-esteem, fosters social inclusion, and diminishes the incidence of gender-based violence by increasing women's visibility and worth in both public and private spheres. According to the capabilities perspective, advocated by Amartya Sen and Martha Nussbaum, economic engagement expands the spectrum of functionings that women can achieve, including adequate nutrition, education, participation in community life, and the exercise of political agency.This dynamic also encompasses macroeconomic factors. Potential productivity is constrained, and income inequality endures when several women are economically marginalised, thus diminishing overall demand and social mobility. Conversely, the economy benefits from a more diversified and inclusive growth trajectory when women are integrated into the workforce, particularly in high-productivity sectors. Incorporating women into structural transformation promotes gender equity and fosters a more sustainable development pathway. Significantly, sustained developmental outcomes and demographic shifts are associated with enhanced economic opportunities for women. Women with access to income and education generally have fewer children, allocate greater resources to the health and education of each child, and exhibit increased participation in political and civic activities. By augmenting human capital and social cohesion, these developments yield long-term benefits for both individual households and society at large.

Fundamentally, enhancing economic opportunities for women is a strategic imperative for elevating living standards at both local and macro levels, transcending mere considerations of equity. Women are better positioned to lead lives of dignity and autonomy through increased income, agency, and resource accessibility. This alteration has significant implications for development strategy and necessitates a gender-responsive approach to labour markets, educational systems, and institutional reform. One interesting idea as highlighted by the Scholar,s is the causal relationship between human development and the degree of economic growth which emphasises a particular reciprocal rainforcement connection. These two factors are largely subjective and grounded in social forces, hence policy planning at the macro and the micro

level can help in analysing how these two factors reinforce one another and play a crucial role in regulating the same. Insofar as the interconnection between needs to domains are concerned, there is also a dedicated theory called the economic theory of human rights that deliberate specifically on this topic. According to this theory[16] people's actual ability to understand and enforce their human rights depends on there economic and political power that works as an enabling force. This also in turn is a parameter of their ability to provide benefits to others and a demarcation of there position in the social hierarchy of respect. This theory is starkly in contrast to the natural laws or contractual rights theory as it sets the nodal point with the particular person who is supposed to be enjoying or having the rights. Gustav Ranis explores the intricate relationship between human development (HD) and economic growth (EG), emphasizing their mutual reinforcement. He posits that while economic growth can provide the resources necessary for human development, the enhancement of human capabilities and freedoms—central to HD—can, in turn, stimulate and sustain economic growth.

THE ENVIRONMENTAL IMPACT ON HUMAN RIGHTS –

The human rights framework offers a compelling ethical and legal foundation for prompt and decisive action to safeguard the environment in the interest of all individuals. The objectives of environmental protection and the realisation of human rights are mutually reinforcing and lie at the heart of the sustainable development agenda. Ecological systems, and the vital services they provide, are integral to the exercise and enjoyment of a broad array of human rights. In this context, states are under explicit human rights obligations to prevent environmental harm that could undermine these rights, as well as to ensure the protection of environmental human rights defenders who are often at the frontlines of advocacy efforts. Furthermore, the corporate sector bears a corresponding duty to respect human rights, to avoid contributing to environmental harm, and to undertake rigorous due diligence in their operational and supply chain activities. In circumstances where environmental degradation results in violations of human rights, both state and corporate actors have an obligation to provide effective access to remedies for affected individuals and communities.[17]

There exists an expanding body of jurisprudence, constitutional provisions, legislative enactments, and international instruments that underscore the interdependence between environmental law and human rights law. This convergence is especially evident in legal measures and judicial decisions concerning the rights of Indigenous peoples—particularly in relation to their cultural practices, livelihoods, and stewardship of ancestral lands and natural resources. Addi-

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17 United Nations, Human Rights, the Environment and Sustainable Development, United Nations Human Rights Office of the High Commissioner, available at: https://www.ohchr.org (last visited May 29, 2025).

tionally, environmental legal principles have addressed the safeguarding of collective intellectual property through equitable benefit-sharing mechanisms, notably in relation to the utilization of genetic materials.

The United Nations has been instrumental in advancing and institutionalising the recognition of the interconnection between human rights and environmental protection. Nevertheless, a universally recognised and clearly defined right to a healthy environment has not yet been codified in binding international law. Nor have the associated obligations of states been comprehensively articulated. Human rights bodies at the international level have increasingly incorporated environmental considerations into their analyses of a range of rights, including the rights to life, health, water, food, property, religion, and culture. While references to the right to a healthy environment have occasionally appeared in their findings, more often these mechanisms have approached environmental concerns as components or determinants of pre-existing, well-established rights.[18]

In the case of *Tapas Guha & Ors vs. Union of India & Ors*. –

In this case[19], the court raised serious concerns regarding violations of environmental regulations linked to the Silchar Greenfield Airport Project, which had advanced without securing the necessary Environmental Clearance. The bench criticised the National Green Tribunal (NGT) for failing to fulfil its responsibilities by not intervening in the project's continuation. Consequently, the court reversed the NGT's decision and issued a directive halting all construction activities at the proposed airport site on the Doloo Tea Estate until the appropriate environmental clearance was obtained. The judgment underscored that environmental laws are established specifically to ensure that infrastructure initiatives, such as airport construction, are carried out in an ecologically responsible manner. These regulations aim to mitigate environmental harm and protect the interests of surrounding communities. While the bench recognised the value of infrastructure for broader development goals, it emphasised that such progress must align with environmental legal standards to avoid causing irreversible damage to ecosystems and biodiversity.

The Environmental Clearance process was described as an essential mechanism to prevent the unregulated use of natural resources, reinforcing the concept of sustainable development. This approach prioritises not only present needs but also those of future generations. Thus, even when large-scale development projects align with national policy objectives, they must be implemented within the bounds of environmental law. Ignoring these legal requirements jeopardises both environmental governance and long-term ecological balance, potentially leading

18 GERALD M. MEIER, LEADING ISSUES IN ECONOMIC DEVELOPMENT 364 (3d ed. 1976)

19 2024 INSC 399; reported at [2024] 6 S.C.R. 75; 2024 LawText (SC) (5) 61

to social unrest and lasting environmental harm.The intersectionality of human rights with the environment does not restrict itself to mere deliberations over clearances, projects and their environmental impacts. The cause is pervasive and universal, which has also taken into account the climate-based impact on the population. In the case of *M.K. Ranjitsinh and Others v. Union of India –*

The present matter[20] involves a writ petition filed before the Supreme Court of India, invoking its extraordinary jurisdiction to issue directions for the protection of two critically endangered bird species—the Great Indian Bustard (GIB) and the Lesser Florican. This plea stems from the Supreme Court's earlier judgment dated 19 April 2021, in which the Court had prohibited the use of overhead transmission lines across significant territories identified as critical habitats for the GIB. The Court had further directed that these overhead lines be converted to underground cables within a year, and established a committee to evaluate the feasibility of laying high-voltage underground power lines.

Subsequently, key ministries, including the Ministry of Environment, Forest and Climate Change, the Ministry of Power, and the Ministry of New and Renewable Energy (MNRE), sought modifications to the 2021 judgment. Their argument rested on the premise that enforcing the judgment in full would severely disrupt the functioning of the energy sector and hinder India's international commitments under the Paris Agreement (2015) made within the framework of the UNFCCC, particularly those related to energy transition from fossil fuels to renewables. In adjudicating this case, the Supreme Court was tasked with addressing two significant issues: (1) whether the directives issued in the 2021 judgment should be revised, and (2) how to balance the imperative of conserving the GIB with India's urgent need to mitigate climate change through a just and equitable energy transition. The Court examined the existential threats faced by the GIB, reviewed governmental efforts such as the "Habitat Improvement and Conservation Breeding of Great Indian Bustard" programme initiated in 2016, and considered broader conservation strategies.

The Court also engaged with the larger context of climate change, emphasizing the vital role of renewable energy in promoting environmental justice and inclusive development. It highlighted the constitutional responsibilities enshrined in Article 48A (directive principles regarding environmental protection) and the fundamental duties of citizens under Article 51A(g), which mandate compassion for living beings and the protection of the environment. These were linked with the fundamental rights under Article 21 (right to life) and Article 14 (right to equality), grounding the right to a clean environment and protection against climate change in constitutional doctrine.

20 M. K. Ranjitsinh & Ors. v. Union of India & Ors., (2024) INSC 273, Supreme Court of India, judgment delivered on 21 March 2024 by D. Y. Chandrachud C.J., J. B. Pardiwala & Manoj Misra JJ.

Recognising the complex intersection of biodiversity conservation and climate mitigation, the Court ruled that the rights of endangered species and the necessity of transitioning to clean energy must be harmonised. On 21 March 2024, the Supreme Court modified its 2021 ruling. It restricted the requirement to lay underground transmission lines to only the designated "priority areas" for GIB conservation, covering roughly 13,163 square kilometres, subject to feasibility, which was to be assessed by an expanded expert committee of seven members. Additionally, the Court relaxed the limitations originally placed on "potential GIB areas," thereby accommodating the energy sector's operational concerns while upholding the constitutional imperative of ecological preservation.

FREE SPEECH ISSUES – DEMOCRACY AND HUMAN RIGHTS

Freedom of speech and expression forms the cornerstone of a democratic society. In the Indian constitutional framework, this freedom is not merely a civil liberty but a foundational value that underpins participatory governance, social critique, and the pursuit of truth. Article 19(1)(a) of the Constitution of India guarantees to all citizens the right to freedom of speech and expression. This essay offers a critical, jurisprudential analysis of this right, situating it within India's democratic ethos, constitutional philosophy, and evolving judicial interpretations. The philosophy of human rights in Constitution is a tenet – a guarantee for the basic right to express itself. Article 19(1)(a) enshrines the freedom of speech and expression as a fundamental right available to Indian citizens. It encompasses a wide range of expressive freedoms, including spoken and written words, visual representations, symbolic speech, the right to information, and even the right to silence. It reflects the framers' commitment to liberal democratic ideals and the influence of international human rights instruments, particularly Article 19 of the Universal Declaration of Human Rights, 1948.[21]

No right can work in absolutism and hence even in the Constitutional framework there are restrictions – or rather limitations on the ambit of the rights, its scope and application. However, the right under Article 19(1)(a) is not absolute. Article 19(2) provides the grounds on which the State may impose "reasonable restrictions" in the interests of sovereignty and integrity of India, the security of the state, public order, decency or morality, contempt of court, defamation, and incitement to an offence. The juxtaposition of rights and restrictions introduces a dynamic tension that the Indian judiciary has often been called upon to resolve.

In the case of *Kaushal Kishore v State Of Uttar Pradesh*[22]

21 Article 19 of the Universal Declaration of Human Rights (UDHR) protects the right to freedom of opinion and expression. This includes the freedom to hold opinions without interference and to seek, receive, and impart information and ideas through any media and regardless of frontiers.

22 Kaushal Kishor v. State of Uttar Pradesh & Ors., Writ Petition (Criminal) No. 113 of 2016, Supreme Court of India (Dipak Misra & A.M. Khanwilkar JJ.), judgment dated 29 March 2017, reported as (2017) 1 SCC 409 .

In 2016, Azam Khan, a Member of Parliament from the Samajwadi Party, referred to the gang rape allegations made by a minor girl and her mother as a "political conspiracy" aimed at tarnishing the reputation of the Uttar Pradesh government. Feeling aggrieved by this remark, the victims filed a petition before the Supreme Court, contending that Khan's statement infringed upon their fundamental right to life and personal liberty under Article 21 of the Constitution and also obstructed the ongoing criminal investigation.

On 3 January 2023, a five-judge Constitution Bench of the Supreme Court, headed by Justice S. Abdul Nazeer, delivered a significant verdict. The Bench ruled that restrictions on freedom of speech and expression, guaranteed under Article 19(1)(a), can only be imposed based on the specific grounds enumerated in Article 19(2). The Court categorically stated that the mere infringement of other fundamental rights, such as the right to dignity or privacy, does not justify curtailing free speech unless it falls within the limitations expressly provided in Article 19(2). Nonetheless, the Court acknowledged the influential role of public officials and observed that they should exercise restraint and caution in their public remarks, especially on sensitive matters. It emphasised the importance of establishing a code of conduct to govern such statements, underscoring the potential implications for public confidence and the administration of justice.

The importance of restrictions lies in a fine and delicate balance of allowing the expression and curtailing certain aspects of it, both of which should go hand in hand for a sustainable democracy.

In the case of *Kunal Kamra v. Union of India*[23]

In a significant ruling, the Bombay High Court, by a 2:1 majority, struck down Rule 3(1)(b)(v) of the Information Technology (Intermediary Guidelines and Digital Media Ethics Code) Rules, 2024, declaring it unconstitutional. The matter arose from a public interest litigation filed by comedian Kunal Kamra alongside various journalists, editors, media organisations, and publications. They challenged the rule, which granted a government-constituted fact-checking unit (FCU) the authority to flag, label, or compel the removal of online content concerning government affairs as "fake," "false," or "misleading" under Rule 7 of the Ethics Code. The petitioners contended that this rule infringes on the fundamental right to freedom of speech and expression protected under Article 19(1)(a) of the Constitution. They argued that the rule was vague, lacked objective criteria, and risked arbitrary enforcement, thereby creating a chilling effect on free speech and open dialogue in the digital space.

Justice Gautam Patel held the rule to be unconstitutional, stating that it violated Articles 14, 19(1)(a), and 19(1)(g). He emphasised that the rule imposed excessive compliance burdens on online intermediaries, incentivizing self-censorship and undermining democratic discourse. Jus-

23 Writ Petition (L) No. 9792 of 2023

tice Patel was particularly critical of the lack of procedural checks on the FCU, observing that it effectively rendered the government both the accuser and adjudicator, which is incompatible with constitutional norms. In contrast, Justice Neela Gokhale upheld the rule, maintaining that it represented a reasonable and proportionate restriction within the ambit of Article 19(2). She asserted that the measure was aimed at combating the growing problem of misinformation and included adequate safeguards. According to her, intermediaries still had options such as attaching disclaimers rather than outright content removal, thereby preserving a degree of editorial freedom.

The final word came through a tie-breaker judgment by Justice A.S. Chandurkar, who concurred with Justice Patel. He concluded that the rule exceeded the regulatory scope provided by the Information Technology Act, 2000, and was constitutionally invalid. Justice Chandurkar pointed out that the rule's ambiguous language, absence of robust procedural mechanisms, and discriminatory application to online platforms created an unjustifiable burden on freedom of expression and contributed to an overall chilling effect on speech.

Majoritarianism, Minority and Human Rights in India –

A. **Refugee Crisis –**

The Rohingya community from Myanmar constitutes the world's largest stateless group, numbering approximately 2.8 million individuals. Stripped of citizenship and subjected to systemic persecution by Myanmar's military regime, most of the Rohingya have been forcibly displaced due to acts amounting to genocide. While considerable attention has been given to the plight of Rohingya refugees in nations such as Bangladesh, Malaysia, Thailand, and Indonesia, far less scrutiny has been applied to the roughly 22,500 Rohingya registered with the UNHCR and residing in India. More alarmingly, the condition of those Rohingya who face indefinite and arbitrary detention within India remains largely overlooked, despite persistent threats of incarceration and deportation to Myanmar.[24]

Between May and November 2024, Refugees International and The Azadi Project conducted fieldwork, including interviews with Rohingya detainees, their families, and legal representatives, along with visits to detention centers. Their findings expose severe breaches of fundamental rights enshrined in both India's Constitution and international human rights instruments. Among the most egregious violations are the separation of spouses, and the forcible removal of children from their parents—contravening India's own model detention code which mandates

24 A Lifetime in Detention: Rohingya Refugees in India (Refugees International & The Azadi Project, investigative report May–Nov 2024, published 2025).

that families should be kept together. These gaps in policy enforcement reflect broader systemic failings across the country's detention infrastructure.

In many instances, detainees remain imprisoned even after completing their sentences. Children lack access to education and recreational facilities, and elderly individuals with mobility impairments are often dependent on fellow detainees for basic needs. Some detainees have been confined since infancy, never having experienced life beyond detention walls. Overcrowded conditions, inadequate sanitation, and insufficient ventilation have led to a range of health problems, including psychological distress and physical ailments such as temporary paralysis. Access to medical care is minimal and closely monitored by law enforcement, while mental health services are absent. Legal support and channels for engagement with international bodies such as UNHCR remain largely inaccessible, leaving many Rohingya to languish in detention for years, often over a decade, without formal charges or trial. Among the incarcerated are pregnant women, nursing mothers, minors, the elderly, and people with disabilities.[25]

India's treatment of the Rohingya, a group already traumatized by ethnic cleansing, raises serious ethical and legal concerns. The Government of India must immediately release those most vulnerable and end the practice of arbitrary detention. Structural reform is also essential: the Rohingya's legal status should be clearly defined, the archaic Foreigners Act of 1946 must be revised, and refugee policy brought into alignment with global human rights norms. In the interim, international actors—including the United States and UNHCR—should engage constructively with India to facilitate the release of detainees, expand refugee registration, and support local civil society initiatives aimed at enhancing the dignity and well-being of Rohingya refugees.[26]

The refugee crisis needs a humanitarian approach, albeit not compromising with sovereignty and well well-being of the population first. With no international help or infrastructure in India to deal with often large influxes of population in the nature of a refugee crisis. Recent steps like the CAA is a step in that direction.

B. DIGITAL RIGHTS AS FUNDAMENTAL RIGHTS –

The judicial approach towards the misinformation within the Indian digital ecology is becoming an issue of critical concern with regard to the dissolution of the constitutional rights, particularly the right to free speech and expression in Article 19(1)(a). Though restrictions are allowed by the Constitution in the Article 19(2), the increased use of criminal prosecution and preventive

25 India, UNHCR India, profile page on UNHCR website, accessed 14 July 2025

26 Refugees International and The Azadi Project, A Lifetime in Detention: Rohingya Refugees in India, (Refugees International, 22 May 2024), available at https://www.refugeesinternational.org/reports-briefs/a-lifetime-in-detention-rohingya-refugees-in-india/ (last visited Jun. 6, 2025)

detention even in situations where there is no immediate danger of disrupting the order threatens to limit the democratic discourse and dissent. This may be seen through a recent case in the Madras High Court where the arrest of a person as a "Goonda" on the grounds of sharing fake documents online raised the judicial concern.[27] The Court ruled that misinformation should be punishable by proportional prosecution and only reserved to cases that can prove to endanger safety in the society.

This Arresting people who publish alleged false or politically charged information on social media is a worrying re-interpretation of powers by the state on what should be deemed as misinformation. In many cases, these arrests are made without any apparent signs of a malafides and where the statutory definitions are not fulfilled, people are charged with broad laws such as the UAPA or the IT Act. This ambiguity allows arbitrary application and limitations to the exercise of lawful expression.

One of the problems that lie at the root of this legal encroachment is the vague definition of the term, public order. Although, the Supreme Court has explained in *Ramji Lal Modi v. State of U.P. and another v. Ram Manohar Lohia. State of Bihar* that only those disturbances which have a close and substantial effect on the community could be considered as disruption of public order, the problem lies in the disparity of the application of these criteria. Irrespective of the jurisprudential protection such as the test of "close proximity" and the test of a "calculated tendency" to offend the feelings of a group of persons, the courts have repeatedly affirmed speech prohibitions on subjective grounds of taking offence to the sentiments of a group of persons.[28]

A more rights-based, balanced approach that adheres to democratic principles; that protects individual freedom; and that combats misinformation with narrowly tailored legal regimes that are proportionate is what the true need of the hour.

C. TRIBAL RIGHTS IN THE CONSTITUTIONAL FRAMEWORK

The Indian Constitution affords significant protection to tribal communities, particularly in relation to their land and cultural autonomy. Schedules V and VI, along with Article 342 and Part X, establish a framework for safeguarding tribal rights, including their right to self-determination. Scheduled Tribes, who constitute approximately 8.6% of the population (Census 2011), are

27 A. Kamala vs The State, specifically Habeas Corpus Petition (HCP) No. 1163 of 2024, decided on August 9, 2024,. This case challenged the detention of YouTuber Savukku Shankar under the Tamil Nadu Prevention of Dangerous Activities of Bootleggers, Drug Offenders, Goondas, Immoral Traffic Offenders, Forest Offenders, Sand Offenders, Sexual Offenders, Slum Grabbers and Video Pirates Act, 1982, also known as the Goondas Act

28 Curbing Misinformation or Chilling Free Speech? Navigating India's Legal Response to Online Content, Internet Freedom Foundation (Aug. 2024) https://internetfreedom.in/curbing-misinformation-or-chilling-free-speech/.

among India's most marginalized groups and heavily depend on forest land for their livelihoods. To address historical injustices and provide legal recognition to forest-dwelling communities, the Scheduled Tribes and Other Traditional Forest Dwellers (Recognition of Forest Rights) Act, 2006 (FRA) was enacted. The Act confers both individual and community rights to forest land and resources. These include the right to reside on and cultivate forest land, access to minor forest produce, and recognition of community tenures and traditional usage rights such as fishing and grazing. It also mandates the conversion of forest villages into revenue villages and allows for the protection and regeneration of community forest resources.

The Act defines Other Traditional Forest Dwellers as individuals or communities who have resided in forest land for at least three generations (75 years) prior to December 13, 2005, and depend on the forest for their livelihood. Such individuals must substantiate their claims through documentary or oral evidence as prescribed under the FRA Rules. Furthermore, the Act recognises biodiversity-related rights and community intellectual property, while explicitly prohibiting hunting rights. It also ensures rehabilitation for forest dwellers displaced before 13 December 2005, provided they did not receive legal redress.[29]

A critical role under the FRA is assigned to the Gram Sabha, which is responsible for initiating and verifying claims through a Forest Rights Committee. Verified claims are mapped and forwarded to higher-level committees—Sub-Divisional, District, and State—for final adjudication. The Gram Sabha must complete the process within three months, failing which it must provide justification in writing. Importantly, the law prohibits the eviction of claimants until their claims are resolved. Once rights are granted, they are heritable but non-transferable. Tribal communities also bear a duty to preserve biodiversity, wildlife, and the ecological balance of their habitats, reinforcing a sustainable relationship between indigenous populations and their traditional environments.[30]

CONCLUSION

The Indian modern narrative of human rights has transformed over the centuries because of the constitutional provisions, judicial interpretations, international commitments and socio-political processes. In the Indian Constitution, a very strong system of safeguarding civil, political, economic, and cultural liberties has been codified in the Preamble, the Fundamental Rights, and the Directive Principles. Imperative judicial statements have successively increased the practice of rights under Article 21 and they have included the right to privacy, health, clean environment and digital access in it. Nonetheless, notwithstanding this progressive jurisprudence, issues still

29 Ministry of Tribal Affairs, Government of India, The Scheduled Tribes and Other Traditional Forest Dwellers (Recognition of Forest Rights) Act, 2006, https://tribal.nic.in/FRA/data/FAQ.pdf (last accessed 10 June 2025).

30 Id

persist. Structural barriers to the actualization of their rights still exist among the marginalized groups like Scheduled Tribes, Dalits, religious minority groups, women, LGBTQ+ communities, and persons with disabilities. The cases of custodial violence, caste-based crime, gender discrimination, and digital and press freedom curbs reveal the possibilities of disparities between the constitutional ideals and reality on the ground. During the era of digital governance and algorithmic decision-making, new threats to human rights also appear in form of digital surveillance, misinformation, and data privacy. Besides, the policies like the Unlawful Activities (Prevention) Act (UAPA) and the misuse of the sedition laws are also raising concerns of reducing the civic space in India and stifling the dissent. However, the proactive civil society and media and the interest litigation also remain central in ensuring accountability and promotion of inclusive development. In the present reality when India has to walk the thin line between economic development, social justice, and technology, the necessity to introduce a human rights approach into policy, governance, and societal outlook has never been so acute. This is not just the problem of identification of the right, but of their successful implementation and lack of discrimination. Thus, human rights in the modern India should be regarded as a perpetual promise that has a living and evolving character and is based on constitutional morality as well as reacts to the changing parameters of a globalized and digitalized world.

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समकालीन युग में अरुण कमल एवं रामशंकर वद्रिोही की कवतिाओं का प्रभाव

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प्रस्तावना:

अरुण कमल समकालीन साहत्यि जगत में अद्वतिीय हैं। समकालीन समय की कई सच्ची घटनाएँ इन्हें उन्होंने अपनी कवतिाओं में इस्तेमाल करने की कोशशि की है। अरुण कमल अन्याय और बुराई के खलिाफ आवाज उठाने वाले व्यक्त हैं। अरुण कमल अपने समय के ज्वलंत मुद्दों को हमारे सामने प्रस्तुत करते हैं। वास्तव में उनकी कवतिाएँ, पूँजीवाद, उपभोक्तावाद, बहुराष्ट्रीय कम्पनयिों, भ्रष्टाचार और अन्याय के वरिुद्ध प्रतरिोध की कहानयिाँ बन जाती हैं। कहा जा सकता है कि अरुण जी की कवतिाएँ पूंजीवादी व्यवस्था के खलिाफ आवाज़ उठाती हैं। अपनी सरल और सहज भाषा के माध्यम से वे पूंजीवादी व्यवस्था की भयावहता को स्पष्ट रूप से पहचानते हैं। साथ ही वे अपने कवतिाओं के माध्यम से पूंजीवादी और उपभोक्तावादी नीतयिों के चंगुल में फंसने से बचने की अपील भी करते हैं। सही मायनों में अरुण जी व्यंग्य के हथयिार के माध्यम से समसामयकि मुद्दों को उजागर करते हैं। इसमें वे सक्षम भी साबति हुए हैं। अरुण कमल का मानना है कि एक घर से इस धरती से पाखंडयिों और मूर्खों का राज खत्म हो जाएगा। एक दनि इस धरती से सभी तरह के अत्याचार और असमानता भी खत्म हो जाएगी। एक दनि इस धरती पर व्याप्त नरिाशा और उदासी भी खत्म हो जाएगी।

वहीं देखा जाए तो रामशंकर वद्रिोही मुख्यतः प्रगतशिील चेतना के कवि हैं। उनकी कवतिाएँ लंबे समय तक अप्रकाशति रहीं और उनकी स्मृति में सुरक्षति रहीं। अपनी कवता-कहने की शैली के कारण वे बहुत लोकप्रयि थे। वद्रिोही की अवधी कवतिाएँ उनकी काव्य चेतना के वकिास की कवतिाएँ हैं। ये एक कवि की अपनी मातृभाषा में आँखें खोलने और वशि्व-दृष्टि गढ़ने की कवतिाएँ हैं और उस प्रखर राजनीतकि चेतना की ओर बढ़ते कदम हैं जसिका वकिास वद्रिोही ने बाद में कयिा। वद्रिोही को स्वयं अहीर होने पर शर्म नहीं आती, बल्कि वह कहता है कि 'मैं अहीर हूं और यह दुनयिा मेरी भैंस है'।

मूल शब्द: पूंजीवादी, उपभोक्तावादी, काव्य चेतना, वंचति, शोषति, बहष्कृि त, लोकतंत्र

समकालीन युग में अरुण कमल की कवतिाओं का प्रभाव:

अरुण कमल की रचनाएँ अपने समय के सही मायने को दर्शाती हैं। आगे वह लखिते है कि आज पूरी दुनयिा में पूंजीवाद हावी है। हर दनि दुनयिा भर में भूख से मरने वालों की संख्या बढ़ती जा रही है। पैसे वाले लोग आम लोगों का शोषण कर रहे हैं। दरअसल भूख और अकाल पूंजीवादी व्यवस्था का ही नतीजा है। शोषति, वंचति, मजदूर पूंजीपतयिों के खेतों में मेहनत करते हैं, जबकि मैन्युफ़ैक्चरगि पूंजीपति सत्ता हथयिा लेते हैं। इन लोगों को खाने के लिए भी पर्याप्त भोजन नहीं मलि रहा है। इस पर प्रतक्रियिा देते हुए अरुण कमल लखिते हैं:

"पहले खेत बकि
फरि घर फरि जेवर
फरि बर्तन
और वह सब कयिा जो गरीब और अभागे
तब से करते आ रहे हैं जब से यह दुनयिा बनी
इस तरह एक-एक कर घर उजड़े गाँव उजड़े

और नगर महानगर बने
पर कोई नहीं बोलता ऐसा हुआ क्यों
अब कोई नहीं पूछता यह दुनिया ऐसी क्यों है
बेबस कंगालों और बर्बर अमीरों में बंटी हुई है।"

अरुण कमल हरियाली और खुशहाल दुनिया की कामना कौन करता है। दुनिया की मौजूदा स्थिति में यह एक तरह की आपदा है। कौन अपनी आंखों के सामने ऐसी दुनिया देख सकता है जहां धरती पेड़-पौधों से ढकी हो और सड़कें इसी वजह से अवरुद्ध हो जाएं। अरुण कमल का मानना है कि हमारे जीवन जगत में जो कुछ भी है, वह सब कविता का विषय बन सकता है। अरुण कमल की दृष्टि 'हमारे युग के नायक' कविता में व्यक्त हुई है, जिसमें वे लिखते हैं कि

' एक दिन खत्म हो जाएगा मूर्खों का राज
पकवानों का भोग छकता महंत
हथगोले बारूद का ढेर गिनता महंत
और माफिया गिरोहों के डॉन
नष्ट हो जायेंगे एक दिन
तब , जिनकी आत्मा सबसे पवित्र है
तब , जो जगे हैं , रात भर बेचैन ओस से भरे
वे ही आंएगे आगे
और ले चलेंगें सबको प्रकाश की ओर |"

इस तरह अरुण कमल अपनी छोटी-छोटी कविताओं में यह दिखाते हैं कि कैसे बिम्बों के ज़रिए प्रभाव पैदा होता है। बिम्बों की शक्ति ने उनकी कविताओं में एक चतुराईपूर्ण सरलता ला दी है। बिम्बों के ज़रिए घटनाओं की कहानी मेरी आँखों के सामने पेश होती है। यह उदियारन की कविता 'एक रात की ठंडक' की प्रस्तुति है -

``कुटपथों के दकनारे
दुकानों के आगे
तीखी हवा कोड़ रही है
काँपते शरीरों को
आवारा कुत्ते बिलकुल गठरियों से
पड़े हैं कोने – दरबों में
हवा के पैर खुल गए हैं आज |

अरुण कमल की जड़ें उनके लोक जीवन से गहराई से जुड़ी हुई हैं, इसीलिए वे अपनी कविताओं में भोजपुरी भाषा के शब्दों का प्रयोग इस तरह करते हैं कि उन शब्दों को बदलने से पूरी कविता का अर्थ ही लुप्त हो जाता है।

समकालीन युग में रामशंकर विद्रोही की कविताओं का प्रभाव:
रामशंकर विद्रोही मुख्यतः प्रगतिशील चेतना के कवि हैं। उनकी कविताएं लंबे समय तक अप्रकाशित और उनकी स्मृति में सुरक्षित रही। रामशंकर विद्रोही ऐसे अहीर हैं जो नूर मियां के पाकिस्तान चले जाने से इसलिए दुखी हैं क्योंकि नूर मियां ने उन्हें अपना नहीं समझा और पाकिस्तान चले गए। रामशंकर विद्रोही उन करोड़ों

अहीरों के प्रतनिधि हैं जो श्रम से अपने जीवन की गाड़ी हांक रहे हैं। रामशंकर वद्रिोही उनके प्रतनिधि हैं जो भूमहिीन कसिान, खेतहिर मजदूर, मस्त्रिी, पल्लेदारी करने वाले और बोझ ढोने वाले, वंचति, शोषति और बहष्कृिृत हैं। असल में वद्रिोही देहाती सौन्दर्य का महान गायक हैं और वस्तुतःवह श्रमजीवयिों और कसिानों की खुशयिों और उन खुशयिों के छोटे-छोटे माध्यमों के गायक हैं। इसीलएि जब वह कवति गाते है तो खुशी उसके शब्दों से छटिककर बखिरती है और वह आपको यथार्थ के ऐसे बीहड़ में ले जाएंगे कि आगे चकति और नरिुत्तर होने के अलावा कोई रास्ता ही नहीं बचता। मैं कसिान हूं, आसमान में धान बो रहा हूँ... इन पंक्तयिों को सुनने के बाद शुरु हुआ रामशंकर यादव से 'वद्रिोही' बने इंसान की यात्रा को जानने और समझने की कोशशि कर सकते हैं -

मैं तुम्हें इसलएि प्यार नहीं करता
कि तुम बहुत सुंदर हो,
और मुझे बहुत अच्छी लगती हो.
मैं तुम्हें इसलएि प्यार करता हूं
कि जब मैं तुम्हें देखता हूं.
तो मुझे लगता है कि क्रांति होगी...

रामशंकर वद्रिोही ऐसे ही कवि थे जहां थक हार के सो जाए वहीं उनका घर हो जाता था। रमाशंकर यादव, एक युवा छात्र थे जो राजनीतकि हस्तयिों के जाल में फंस गए । जे.एन.यू. में अस्सी के दशक के प्रशासनवादी मशिन के द्वारा अपने केंद्र से बेदखल कयिा गया और फरि बनिा हारे माने वही जे.एन.यू में धैर्य की कवतिाएं सुनाई दीं तो लोगों ने उन्हें वद्रिोही समझा दयिा। उनके अंदर लोकतंत्र के लएि गुस्सा, दर्द और ना जाने कतिनों की हारी हुई लड़ाईयों का एक मानवीय दर्द था। उनके जाने के बाद भी जतिने भी लोग जे.एन.यू. आए तो उन्हें 'वद्रिोही' नाम से ही खोजा।

मैं साइमन
न्याय के कटघरे में खड़ा हूं
प्रकृति और मनुष्य मेरी गवाही दें
मैं वहां से बोल रहा हूं
जहां मोहनजोदाड़ो के तालाब की आखरिी सीढ़ी है
जसि पर एक औरत की जली हुई
लाश पड़ी है
और तालाब में इंसानों की हड्डयिां
बखिरी पड़ी हैं.

रामशंकर वद्रिोही अपने बहुत भीतर छपिे कसिी भी वचिार को सतह पर लाने से नहीं डरते थे। उनका सच, उनके भीतर का आईना था। अपनी पछिली और आने वाली पीढ़ियों की औरतों के बारे में कही गई उनकी कवतिा हो या 'भारत भाग्य वधिाता', उन्होंने हमेशा एक संवाद शुरू करने की ही कोशशि की।

कोई खुदा नहीं, खुदा का बच्चा भी नहीं
सवाल आदमी का है, आदमी ही खड़ा होगा.
और मैं मसीहाई में यकीन रखता ही नहीं,
मैं मानता ही नहीं कि कोई मुझसे बड़ा होगा

"मैं तुम्हारा कवि हूं" नाम से 'वदि्रोही' पर डॉक्यूमेंट्री भी बनी है, जो कि काफी प्रसदि्ध है। अपने उपर बनी डॉक्यूमेंट्री में वदि्रोही खुद कहते हैं, 'मैं कसिी से भी ज्यादा शहरी हूं और कसिी से भी ज्यादा ग्रामीण,। कपड़ों से आदमी की पहचान करने वालों के लिए वदि्रोही कसिी पूर्ण वरिाम की तरह थे।

सन्दर्भ सूचि:

1. पुतली में संसार, अरुण कमल
2. कविता और समय, अरुण कमल
3. मैं वो शंख महाशंख, अरुण कमल
4. नये इलाके में, अरुण कमल
5. सबूत, अरुण कमल
6. नयी खेती, रमा शंकर वदि्रोही
7. सुनील चौधरी, प्रतरिोध की कविता रामशंकर वदि्रोही की काव्य चेतना, इंटरनेशनल जर्नल ऑफ़ हदिी रसिर्च, वॉल्यूम १०, इश्यू ४, २०२४, ISSN: 2455-2232.
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