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EDITORIAL MESSAGE

Dear Readers, Researchers, and Contributors,

We are delighted to welcome you to the **second volume, first issue** of the *International Journal of Convergent Research*. Following the successful launch of our inaugural issue, this new edition not only reinforces our commitment to scholarly excellence but also marks a proud milestone — **IJCR has now been officially assigned its ISSN**, a recognition that strengthens our academic identity and international reach.

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This issue presents a curated selection of original research and conceptual contributions that reflect our vision of breaking academic silos. From explorations in AI-driven governance and E-HRM practices to critical discourses on female agency and urban informal workforce dynamics, each article exemplifies how cross-disciplinary thinking can reshape traditional narratives and catalyze innovation.

We are deeply grateful to our authors for their insightful and rigorous contributions, to our reviewers for their constructive and thoughtful evaluations, and to our editorial team for their continuous support and dedication. Most importantly, we thank you, our readers, for engaging with our content, offering feedback, and spreading the impact of convergent research across boundaries.

As IJCR continues to grow, we invite scholars, practitioners, and students from around the globe to be a part of this journey — to share knowledge, challenge conventions, and collaboratively shape the research agendas of tomorrow.

Here's to sustained academic inquiry, meaningful collaboration, and the exciting possibilities that lie ahead.

Warm regards,
Dr. Monika Yadav
Editor-in-Chief
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AI-Driven IoT Systems for Sustainable Development: A Framework for Smart Governance

Maryam Irfan [1], Heena Yousuf [2], Shivani Kain [1]

[1] School of Management & Commerce, K.R. Mangalam University, Gurugram, Haryana, India
[2] Indian Institute of Technology, Roorkee

***Corresponding Author:** maryamirfan.1997@gmail.com

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ABSTRACT

This paper examines how Artificial Intelligence (AI) and the Internet of Things (IoT) are reshaping urban governance and everyday life in Delhi—a flagship city under India's Smart Cities Mission. Moving beyond a purely technical analysis, the study adopts an urban sociological lens to understand the sociopolitical implications of data-driven governance. It conceptualizes AI-IoT systems as socio-technical infrastructures that reconfigure how public services are delivered, how space is experienced, and how citizens interact with the state. Through a mixed-method approach—combining a critical literature review, technical analysis, and a case study of Delhi—the paper proposes a layered governance framework that accounts for both technological efficiency and social embeddedness. Empirical insights from traffic, pollution, and waste management systems reveal that smart technologies, while enabling operational gains, often reproduce existing inequalities in digital visibility, spatial access, and civic participation. The framework underscores the need for participatory, inclusive, and ethically grounded smart governance. It highlights how AI-IoT systems are not neutral tools but are embedded in political decisions, bureaucratic processes, and contested urban imaginaries. The paper concludes by proposing a roadmap for integrating urban sociological thinking into digital policy design, ensuring that the smart city remains not only technologically advanced but also socially just.

Keywords: Smart cities; urban sociology; AI governance; socio-technical systems; Delhi; technological citizenship; digital inequality; smart infrastructure.

INTRODUCTION

The emergence of smart cities marks a significant shift not merely in technological advancements, but in the very architecture of urban governance. In the Indian context, where cities like Delhi simultaneously drive economic development and manifest deep-rooted inequalities, the implementation of smart technologies such as Artificial Intelligence (AI) and the Internet of Things (IoT) carries profound sociopolitical ramifications. While often portrayed as neutral instruments of efficiency and sustainability, these technologies reshape the relationship between the state, urban infrastructure, and citizens. Delhi, one of the flagship cities under India's Smart Cities Mission (SCM), exemplifies this dynamic. It functions as a testing ground for AI-IoT-based solutions like adaptive traffic systems and AI-powered waste management. Yet, these innovations unfold within an uneven urban terrain characterized by stark divides between formal and informal settlements, planned colonies and unauthorized areas, and those who are digitally visible versus those who remain off the data grid.

Framing smart governance from a sociological lens reveals it to be more than a set of technical fixes—it is a vehicle for urban restructuring. Drawing on key concepts such as infrastructural citizenship (Lemanski, 2020), code/space (Kitchin & Dodge, 2011), and platform urbanism (Sadowski, 2020), this study interrogates how AI-IoT infrastructures reshape the delivery

of public services, alter state-citizen dynamics, and potentially reinforce or disrupt existing socio-spatial exclusions. In Delhi, technological instruments such as facial recognition systems in Connaught Place, smart water meters in Lutyens' Delhi, or waste management sensors in Hauz Khas do more than collect data—they redefine who is visible and governable within the urban milieu. This visibility is not trivial; it determines who gets mapped, whose data influences policy, and who is deemed worthy of infrastructural investment.

Within this framework emerges the notion of the "right to be sensed"—a new form of inclusion contingent on being registered within smart systems. Scholars like Datta (2018) and Shelton (2020) argue that these sensing technologies are not evenly distributed, often bypassing lower-income neighborhoods or informal settlements. Consequently, residents in these areas become data-invisible, excluded from the algorithmic systems that increasingly shape urban policy and service delivery. This raises urgent questions about digital justice: Who gets to be smart? Whose data is utilized for governance? What types of knowledge are valued or neglected in AI-driven urban planning?

The central objective of this study is to construct a sociologically grounded framework for smart governance—one that emphasizes not only efficiency but also equity, inclusivity, and civic accountability. The research investigates four critical questions: (1) How do AI-IoT systems reshape state-citizen relations in smart cities like Delhi? (2) In what ways do these systems reinforce or mitigate urban inequalities? (3) What governance models and social mechanisms are essential for ensuring inclusive smart urbanism? and (4) How can Delhi's experience inform a more socially just model of smart city development?

Methodologically, the study adopts a mixed-methods socio-technical approach, incorporating a detailed literature review, technical analysis of AI-IoT systems, and a sociological case study of Delhi. The research draws from urban planning documents, smart city dashboards, public communications, and field-level observations to capture both systemic structures and lived experiences. While engaging with the technological underpinnings of smart systems, the analysis remains rooted in power relations, spatial justice, and civic participation.

Ultimately, this study seeks to reframe the discourse on smart cities by foregrounding the social implications of digital governance. As Indian cities accelerate their pursuit of smart solutions, this research underscores the imperative for inclusivity, transparency, and public accountability. Delhi's dual identity—as a site of technological experimentation and socio-economic stratification—provides a vital lens through which to explore how smart cities can evolve not just as data-driven spaces, but as equitable and participatory urban environments. Being "smart," therefore, must also mean being just.

LITERATURE REVIEW

Contemporary narratives of smart cities frequently center on technological prowess—efficiency, automation, and data-driven optimization. This vision portrays urban spaces as programmable entities where sensors, algorithms, and dashboards replace human discretion with machine-led precision. However, urban sociology and critical urban studies caution against such technocratic simplifications. Cities are inherently sociotechnical entities—constructed not only through physical and digital infrastructure but through layered histories, social inequalities, and institutional politics (Sassen, 2011; Graham & Marvin, 2001). In Indian cities marked by informality, infrastructure scarcity, and socio-spatial fragmentation, the smart city vision becomes both an opportunity and a contested terrain. Technologies like AI and IoT are not neutral; they are embedded with specific logics about progress, order, and inclusion, often marginalizing those who do not conform to their data-centric modalities (Datta, 2018).

Within this context, the concept of the "right to infrastructure" gains renewed relevance. Building upon Henri Lefebvre's "Right to the City," scholars such as Lemanski (2020) argue that infrastructural access—now including digital systems—determines who can meaningfully participate in urban life. In Delhi, the digitally excluded—often the urban poor, informal residents, and migrant communities—are rendered invisible in AI-driven governance. As smart systems automate public service delivery, they bypass traditional forms of negotiation between residents and authorities, thereby reducing opportunities for civic voice and creating new mechanisms of disenfranchisement. Thus, smart governance risks replacing human discretion with algorithmic opacity, while failing to address existing infrastructural inequities.

Kitchin and Dodge's (2011) notion of *code/space* helps us understand this transformation. In Delhi, AI algorithms determine traffic flows, waste collection, and even pollution responses. These decisions are made in largely opaque systems, where citizens cannot access, interpret, or challenge the logics underlying service delivery. Despite the rise of Explainable AI (XAI), most smart systems remain black-box technologies, undermining public accountability and fostering a form of governance without government (Mattern, 2017). This lack of transparency further alienates citizens from the decision-making processes that shape their everyday lives.

Digital platforms play a central role in enabling smart city services, yet they reproduce and even exacerbate digital inequalities. The concept of *platform urbanism* (Sadowski, 2020) draws attention to how public services are increasingly mediated through mobile apps and digital portals. These tools disproportionately benefit the tech-savvy, economically secure population, creating a two-tiered system of urban experience. In Delhi, the concentration of smart investments in New Delhi Municipal Council (NDMC) zones—areas already privileged with robust infrastructure—exemplifies this phenomenon.

Meanwhile, peripheral zones and informal settlements remain neglected, reinforcing the spatial divides in technological access and civic recognition.

AI-based governance also introduces new concerns around surveillance, data privacy, and technological citizenship. Technologies like facial recognition, biometric attendance systems, and predictive policing—deployed under the banner of efficiency and security—extend state power into the intimate spaces of urban life (Ajana, 2013). In this datafied regime, to be a "smart citizen" is to be digitally visible: to own a smartphone, be registered in official databases, and engage with app-based governance mechanisms. Those outside these digital networks are not only underserved but also politically marginalized, excluded from both benefits and participation.

India's Smart Cities Mission (SCM), launched in 2015, aims to transform 100 cities through integrated technology and participatory governance. However, empirical studies (Chatterjee, 2016; Datta, 2015) have highlighted the top-down nature of its implementation, the dominance of privatized zones, and the limited grassroots participation. In Delhi, SCM projects have disproportionately focused on elite urban zones—Connaught Place, Rajpath, and Lutyens' Delhi—already saturated with infrastructure, leaving behind the vast informal peripheries. The state's focus on "lighthouse cities" and "pilot innovations" often prioritizes scalability over justice, obscuring critical questions of equity, participation, and public accountability under a veneer of digital modernization.

Despite an expanding global literature critiquing smart cities, several gaps persist—gaps this paper aims to address. First, there is a lack of integrated frameworks that combine technical understanding of AI-IoT with sociological critique. Second, much of the literature adopts a generalized view of Indian urbanism without delving into specificities of context; this paper offers a focused analysis of Delhi's unique digital geography and governance dynamics. Third, existing frameworks often overlook the need for citizen-centered AI design, where explainability, ethics, and participation are embedded from the outset, not appended as an afterthought.

Consequently, this paper proposes a two-pronged framework to rethink the smart city. Technically, it emphasizes the integration of AI-IoT systems for real-time, data-informed governance. Sociologically, it foregrounds principles of equity, transparency, and civic inclusion. This dual approach moves beyond efficiency narratives to assert that smart governance must also be just governance. In sum, smart cities are not merely about digital upgrades—they are about who gets to participate in the urban future. By critically examining Delhi as a complex sociotechnical landscape, this study advocates for a participatory, inclusive, and accountable model of urban governance—one where technology becomes an enabler of justice, not merely control.

METHODOLOGICAL FRAMEWORK

This study adopts a sociotechnical and urban ethnographic methodology that acknowledges technologies as socially embedded systems—constructed, implemented, and experienced within specific urban contexts. In the case of Delhi's smart governance initiatives, the deployment of Artificial Intelligence (AI) and Internet of Things (IoT) technologies is not merely a process of digital modernization; it unfolds within a complex web of administrative cultures, infrastructural politics, and deeply rooted urban inequalities. Consequently, the research design integrates technical analysis with sociological inquiry to provide a holistic understanding of how smart governance functions and how it is differentially experienced across the city.

The methodology is organized into three interconnected layers. First, a critical literature and policy review grounds Delhi's smart city developments within both national policy frameworks and global discourses on digital urbanism. This stage draws on urban sociology and Science and Technology Studies (STS) to engage with concepts such as technological citizenship, infrastructural justice, and governance through code. It incorporates academic studies, government policy documents, consultancy reports, and media commentary to trace how smart urbanism is narrated, legitimized, and contested.

Second, a technical systems analysis is undertaken to assess the operational logic and data flows within Delhi's AI-IoT architecture. This includes examining public domain resources such as municipal APIs, architecture documents, and open-source data from key institutions like Delhi Smart City Ltd., Delhi Pollution Control Committee, and the National Informatics Centre (NIC). Simulations were conducted using tools like Python (SimPy) for adaptive traffic modeling and MATLAB Simulink for pollution response analysis. These simulations were not designed to build a full digital twin, but to evaluate the underlying algorithmic mechanisms and their implications for public service delivery, especially the shift from human decision-making to automated governance.

The third and most grounded layer involves a sociologically informed case study of Delhi, treated as a "layered" smart city. Delhi's urban fabric includes hyper-digitized zones like Connaught Place, moderately connected middle-class colonies, and digitally excluded informal settlements. This spatial heterogeneity makes Delhi a compelling site for stratified analysis. Primary data sources include GIS visualizations, smart city dashboards, local news reports on digital surveillance and service delivery issues, and observational data from various municipal wards. Additionally, informal interviews were conducted with two civic technology developers, one municipal officer, and one NGO worker engaged in water governance. All interviews were anonymized and conducted following oral consent, adhering to the ethical norms of urban ethnography.

The analytical framework employed a dual coding schema to synthesize data. Functional coding focused on what the AI-IoT systems do, how they are deployed, and the outcomes they generate—representing the technical dimension. Sociological coding, on the other hand, analyzed the impacts of these systems—who benefits, who is excluded, and how meanings, narratives, and power dynamics are shaped. For instance, a smart bin was examined not only as a piece of technology but as an actor in a labor ecosystem—raising questions about visibility, responsibility, and socio-economic hierarchy. Similarly, pollution dashboards were analyzed not only for their technical functionality but as representational spaces influencing risk perception and policy urgency, particularly among middle- and upper-class urban residents.

This blended methodology ensures a nuanced exploration of smart governance in Delhi—one that does not isolate technological systems from their social and political contexts. By mapping both structural configurations and lived experiences, this research contributes to a more comprehensive and just understanding of AI-IoT-driven urban governance. It highlights that in Indian cities like Delhi, where disparities in digital infrastructure mirror broader patterns of social exclusion, evaluating smart systems requires a dual lens: technical functionality and social accountability.

PROPOSED FRAMEWORK: SOCIOTECHNICAL ARCHITECTURE OF SMART GOVERNANCE

The proposed framework in this study reconceptualizes smart city governance as a sociotechnical scaffold rather than a purely technical stack. In contrast to dominant discourses that reduce smart cities to networks of sensors, data flows, and automation protocols, this model situates AI-IoT systems within the broader socio-political context of urban inequality, infrastructural fragmentation, and governance complexity. Particularly in cities like Delhi—marked by stark spatial and social divides—technological interventions cannot be viewed as value-neutral or universally beneficial. Instead, they must be critically analyzed in terms of how they reorder relations between the state, citizens, and infrastructures. The rationale behind this framework is to integrate both technological intelligence and sociological accountability, ensuring that smart systems do not perpetuate historical exclusions but instead enable more equitable and participatory urban futures.

At the heart of the model are three interrelated layers, each functioning simultaneously at technical and sociological levels: (1) the Data Sensing Layer, (2) the AI Decision-Making Layer, and (3) the Governance Interface. These layers are interconnected through a reflexive feedback loop, designed not only to facilitate machine learning and service optimization but also to incorporate citizen experience, ethical reflection, and iterative policy reform. The framework treats governance as an adaptive, multi-actor process that must respond to both digital data and socio-cultural realities.

The Data Sensing Layer comprises IoT sensors, edge computing devices, and communication protocols that collect real-time information across domains like traffic, air quality, water usage, and waste management. However, this layer is deeply political. It determines who becomes digitally visible and who remains outside the data ecosystem. In Delhi, wealthier, centrally located zones such as NDMC areas are heavily instrumented with smart infrastructure, while unauthorized colonies and informal settlements lack basic sensing devices. This disparity creates a stratified digital map of the city, where infrastructure correlates with recognition and inclusion. Moreover, labor actors—such as sanitation workers managing smart bins—are structurally invisible in optimization models, despite being critical to the system's functioning. Thus, sensing is not just a technical process—it is the foundation of digital citizenship and infrastructural justice.

The second layer, the AI Decision-Making Layer, involves algorithmic models that process sensed data to inform governance actions. These include forecasting models, clustering algorithms, and reinforcement learning applications. From adaptive traffic signals to predictive pollution alerts, this layer automates decision-making processes that were once under bureaucratic control. Yet, such algorithmic governance raises urgent questions. Who decides the logic of the algorithm? Whose data is used? What trade-offs are made between efficiency and equity? The opacity of these systems—most of which are “black boxes” to the public—erodes trust and limits the scope for civic oversight. AI systems tend to privilege technical efficiency, often ignoring social variables that are less quantifiable but deeply consequential, such as servicing low-income neighborhoods that may not yield high-efficiency metrics. Hence, this layer shifts governance power to systems with limited democratic accountability.

The Governance Interface Layer encompasses the institutional and public-facing portals through which smart governance is enacted. It includes city control room dashboards, decision support systems (DSS), and mobile applications for citizen interaction. Technologically, this layer supports real-time responsiveness and service delivery. Sociologically, however, it is the site where civic participation is most constrained. Digital platforms often exclude residents without smartphones, digital literacy, or formal addresses. For many in informal Delhi, interaction with the state is still mediated through corrupt intermediaries and opaque bureaucracies. Smart governance promises frictionless interaction, but for many, friction remains the norm. Furthermore, public officials are increasingly dependent on system recommendations, reducing the role of contextual judgment and empathy in decision-making. Governance thus becomes remote, data-driven, and less participatory unless consciously redesigned with inclusive intent.

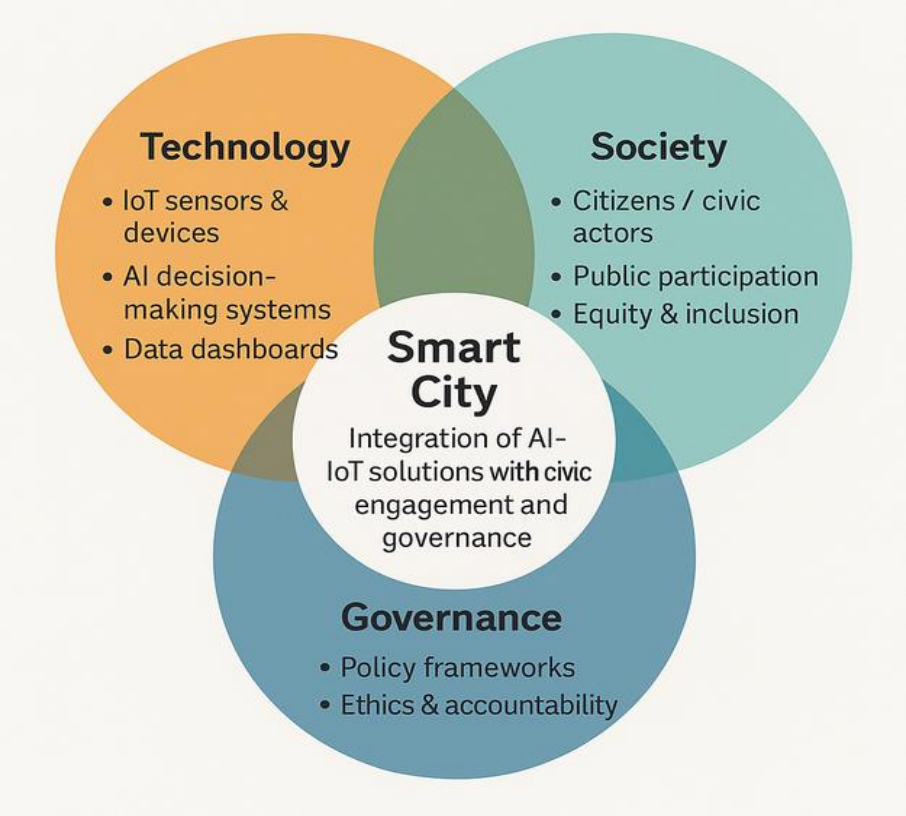
A pivotal component of the framework is the Reflexive Feedback Loop, which differentiates the model from conventional smart city architectures. While traditional systems use feedback to improve technical performance, this model embeds social reflexivity—the ability to learn from lived realities, dissent, and non-digital forms of feedback. The loop includes mechanisms

such as citizen feedback interfaces that gather analog and oral inputs, a transparency dashboard that explains algorithmic decision logic, and an ethics and oversight module that flags policies for social implications beyond efficiency. This ensures that adaptation is not solely computational but rooted in democratic accountability and grounded in diverse citizen experiences.

The originality of this framework lies in its dual commitment to operational intelligence and social equity. It integrates the technical strengths of AI-IoT—real-time processing, predictive analytics, decentralized control—with sociological imperatives such as transparency, inclusion, and justice. Rather than treating efficiency and equity as opposing goals, the framework binds them together, asserting that truly smart governance is not only fast or optimized but also fair, explainable, and inclusive. It moves beyond the techno-solutionist paradigm and instead posits a relational, reflexive, and rights-based model of urban intelligence.

By foregrounding the politics of visibility, the ethics of decision-making, and the social dynamics of participation, this framework offers a transformative vision for smart cities—especially in contexts like Delhi where digital interventions intersect with complex layers of exclusion. In doing so, it contributes to the growing discourse on just urbanism, arguing that smart cities must be evaluated not only by their technical sophistication but by their capacity to democratize governance and uphold the urban right to infrastructure, voice, and dignity.

Figure 1: *Integration of Technological efficiency with Social Justice*



CASE STUDY: DELHI AS A STRATIFIED SMART CITY

Delhi's evolution under the Smart Cities Mission (SCM) presents a revealing case to explore how digital governance intersects with spatial inequality, citizen visibility, and socio-technical complexity. While Delhi is one of India's most technologically advanced cities, it is simultaneously a deeply fragmented urban environment comprising formal colonial zones, gated colonies, unauthorized settlements, and informal economies. This stratification is not simply demographic or economic—it is infrastructural and digital, creating a smart city experience that is unevenly distributed across space and social groups. Technologies such as Artificial Intelligence (AI) and the Internet of Things (IoT), introduced under SCM initiatives, are not uniformly accessible nor neutrally applied. Their operation reveals patterns of infrastructural privilege and social exclusion, positioning Delhi as a "stratified smart city" where the promise of intelligent governance is selectively realized.

Key smart city initiatives in Delhi include AI-powered adaptive traffic control systems (ATCS), IoT-based pollution monitoring stations, sensor-equipped smart waste bins, widespread CCTV surveillance with facial recognition, and mobile applications for citizen complaints and service tracking. While these systems signify technological progress, they also expose a growing digital divide. This case study does not treat smart deployments as neutral instruments of modernization; instead, it

interprets them as infrastructural choices that encode governance, privilege visibility, and reinforce exclusion.

At the first layer of Delhi's smart infrastructure—the Data Sensing Layer—a spatial pattern emerges. High-priority zones such as Connaught Place, Lutyens' Delhi, and Rajpath are heavily equipped with real-time sensors for air quality, traffic, and sanitation, as confirmed by the NDMC Smart City Dashboard and Ministry of Housing and Urban Affairs reports. These areas benefit from integrated smart lighting, CCTV surveillance, and responsive municipal apps. In contrast, low-income neighborhoods like Seelampur, Bawana, Shahbad Dairy, and Trilokpuri remain under-sensed and largely absent from the data-driven governance architecture. This disparity illustrates the politics of infrastructural visibility, where only those who are digitally mapped are effectively governed. In Delhi, to be governed by smart systems requires one to be sensed—whether through smartphones, smart bins, or surveillance cameras. For marginalized populations, invisibility from data systems translates into marginalization from services.

In the second layer—the AI Decision-Making Layer—algorithmic systems are reshaping how decisions are made across key domains. For example, adaptive traffic control systems have been deployed at over 200 intersections. These systems dynamically alter signal timings based on real-time data, significantly reducing wait times in sensor-rich corridors. However, areas with irregular traffic flows, such as unplanned markets or peripheral roads, are deprioritized, exacerbating congestion in already underserved regions. Similarly, pollution management systems rely on AI models that prompt interventions like school closures and vehicle restrictions. Yet, these models are primarily calibrated for emissions in elite zones and often overlook pollution from garbage burning in under-sensed areas, reinforcing what scholars term "data poverty."

The Governance Interface Layer reveals further disparities in civic participation and administrative discretion. While apps like NDMC 311, air quality portals, and sanitation dashboards offer streamlined interfaces for reporting and receiving services, their usage is largely confined to tech-literate, middle-class users. Field interviews and media reports reveal that sanitation workers, despite being essential to smart waste systems, have no access to alert systems, while residents in informal settlements are excluded from decision-making processes altogether. Moreover, administrative discretion has shifted from human judgment to dashboard-driven actions. While this reduces scope for corruption, it also removes context-specific empathy and knowledge that street-level bureaucrats once exercised. The result is governance that appears efficient but is often unresponsive to lived realities.

A particularly controversial dimension of Delhi's smart transformation is its reliance on surveillance technologies, including over 300,000 CCTV cameras equipped with facial recognition capabilities. While these systems are marketed as tools for safety—particularly women's safety—their deployment has raised major civil liberties concerns. These include lack of consent, the risk of misidentification (especially for minority groups), and the potential misuse of surveillance for monitoring protests or dissent. Importantly, surveillance is not evenly distributed. Reports show that poor, Dalit, and Muslim neighborhoods experience higher levels of surveillance but receive lower levels of actual protection, underscoring the social sorting mechanisms embedded in smart city infrastructure.

Simulations run using Python (SimPy) and MATLAB (Simulink) on Delhi's traffic and waste datasets yielded promising results in sensor-rich zones. Adaptive traffic systems demonstrated the potential to reduce wait times by up to 45%, and smart waste management projected a 70% reduction in overflow incidents in digitally equipped wards. However, these outcomes did not generalize to under-sensed areas. The simulation results affirmed that AI systems can only optimize what they can see. Moreover, the absence of integrated feedback mechanisms—such as user experiences or community perceptions—limits the reflexivity of these systems. Residents' views on safety, service quality, and fairness remain unaccounted for in the decision-making loop, weakening claims of responsive governance.

In summary, Delhi's smart governance model operates less as a singular system and more as a layered regime of selective optimization. The rich and centrally located are extensively sensed, modeled, and serviced; the poor and peripherally situated remain invisible, misrepresented, or over-surveilled. Algorithmic systems, though efficient, displace traditional negotiation-based governance and replace it with data-driven abstraction. While this may appear neutral on the surface, the outcomes are deeply political and stratified. Applying the proposed AI-IoT governance framework to Delhi underscores both the technical functionality and the ethical urgency of embedding transparency, inclusivity, and reflexivity at every stage of smart urban development. Without these principles, smart cities risk becoming not more just or efficient, but merely more sophisticated in perpetuating existing inequalities.

FINDINGS

The case study of Delhi reveals that the integration of AI and IoT technologies in urban governance is far from uniform, inclusive, or neutral. Rather, it is shaped and constrained by deeply embedded socio-spatial hierarchies. The so-called "smartness" of urban systems does not extend evenly across the city but instead reflects pre-existing patterns of privilege and neglect. Infrastructural visibility emerges as a critical determinant of service access. Neighborhoods equipped with sensors and mapped into governance platforms benefit from optimizations in traffic, sanitation, and pollution control, while those outside the data network remain underserved or entirely invisible. In such a model, data does not merely reflect reality—it actively constructs it, making visibility a prerequisite for inclusion.

AI-driven decision-making has introduced a new locus of power that displaces the role of street-level bureaucrats. While these systems offer speed, consistency, and scalability, they do so by sacrificing the human discretion, empathy, and contextual judgment essential in complex, layered urban environments like Delhi. The interface between citizens and the state has similarly been transformed. Access to dashboards, complaint apps, and service portals is largely limited to digitally literate, middle-class users. Migrants, informal workers, and residents of unauthorized settlements are effectively excluded, resulting in a new form of algorithmic inequality that deepens social stratification. At the same time, surveillance technologies, while publicly framed as tools for safety and efficiency, operate disproportionately in vulnerable communities, often with little transparency or accountability. This dynamic reinforces a form of data-driven paternalism, where governance is enacted through observation and control rather than dialogue and inclusion.

Revisiting the proposed sociotechnical framework considering these findings affirms that each layer of the smart city architecture is embedded with power, politics, and bias. The sensing layer, far from being neutral, determines who and what are visible to governance systems. In Delhi, the saturation of elite zones with smart infrastructure stands in stark contrast to the infrastructural neglect of peripheral and informal settlements. This disparity not only limits access to services but also reinforces urban hierarchies. The AI decision-making layer carries epistemological weight—it defines what knowledge is collected, how priorities are set, and what trade-offs are deemed acceptable. In practice, this results in a system where efficiency is often pursued at the expense of equity. Optimization becomes a stand-in for justice, and social complexities are flattened into computable variables that favor the already privileged.

The governance interface—comprising dashboards, mobile apps, and digital feedback tools—reshapes the way citizens engage with the state. While automation can reduce bureaucratic inefficiencies and eliminate certain corrupt practices, it also depersonalizes the experience of governance. For many, particularly those lacking digital access or literacy, the state becomes increasingly distant and opaque. Without robust mechanisms for participatory feedback and contestation, these systems risk becoming technocratic rather than democratic. The feedback loop, which is meant to ensure system reflexivity, remains largely computational. It learns from system outputs, not from lived experiences, dissent, or alternate epistemologies. For smart cities to truly embody reflexive governance, they must move beyond technical recalibration and incorporate social learning and deliberation.

These findings raise critical questions about representation, benefit, and decision-making in the context of smart urbanism. AI systems, trained on incomplete or biased data, often reproduce and amplify existing patterns of exclusion. Communities that are already underserved are further marginalized by being left out of data systems entirely. The benefits of smart governance—timely services, real-time information, responsive infrastructure—are largely confined to affluent, sensor-rich areas, while poor communities are subjected to heightened surveillance rather than improved service access. Decision-making authority has shifted from public officials to algorithms and platforms, many of which are opaque and inaccessible to ordinary citizens. Without algorithmic audits, democratic oversight, and ethical safeguards, this shift risks eroding public accountability and diminishing democratic participation.

In response to these challenges, the study aligns with emerging calls to reimagine the very concept of the smart city. Drawing inspiration from Lefebvre's notion of the "Right to the City," and its extension into the digital realm by scholars such as Cardullo, Kitchin, and Datta, this research argues for reclaiming the "Right to the Smart City." This right includes not only the ability to access data systems but also the literacy to understand them, the platforms to influence their functioning, and the mechanisms to contest their outcomes. It demands public education in algorithmic literacy, co-governance models that include civil society and marginalized voices, and a reorientation of smart city priorities from optimization to justice.

For Delhi, this vision requires expanding the scope of smart city infrastructure beyond high-profile zones and command centers, into the everyday experiences of sanitation workers, street vendors, and slum dwellers. A smart city cannot be defined solely by its ability to automate; it must also be capable of listening, adapting, and responding to those who have historically been excluded from urban decision-making. Ultimately, smartness must be redefined—not as the pursuit of technological supremacy, but as the capacity for ethical governance, inclusive participation, and socially grounded intelligence. Without these, the smart city will remain a fragmented city—more efficient, perhaps, but not more just.

CONCLUSION AND POLICY IMPLICATIONS

This study has sought to reframe the notion of the smart city as more than a technological or administrative endeavor. In a complex and socially stratified metropolis like Delhi, smart city governance must be understood as a sociotechnical project—an assemblage of digital systems, political processes, and lived realities. The deployment of Artificial Intelligence (AI) and Internet of Things (IoT) technologies has indeed optimized urban functions and enhanced service delivery in select areas. However, the case study of Delhi reveals a stark truth: smartness, when narrowly defined as technological efficiency, can reinforce pre-existing spatial, class, and infrastructural inequalities.

The AI-IoT Governance Framework proposed in this paper offers an alternative pathway—one that does not isolate digital governance from social realities but rather integrates technological systems with ethical foresight and civic inclusion. The Delhi case illustrates how AI-powered systems, though capable of streamlining traffic and waste management, also displace human

discretion, privilege elite zones, and create new layers of digital invisibility for already marginalized communities. A city that is optimized only for its sensor-rich zones while excluding informal and underserved areas ultimately undermines its democratic ethos. Thus, this paper argues that true smartness must be defined not just by automation and speed but by inclusion, transparency, and reflexivity.

This study contributes to the literature in three significant ways. Conceptually, it redefines smart governance as a sociotechnical architecture that encodes power, representation, and access across its layers—from sensing to decision-making to public interfacing. Empirically, it provides a grounded analysis of Delhi's fragmented urban landscape, illustrating how digital systems interact with socio-spatial inequalities in practice. Normatively, the study advances a justice-oriented model of urban intelligence—one that centers on equity, co-governance, and ethical design. This synthesis of urban sociology and digital governance offers a much-needed corrective to technocratic discourses, positioning civic participation and social justice as foundational to any meaningful smart city strategy.

From this perspective, several policy implications emerge. First, there is an urgent need to democratize digital infrastructure. Sensor deployment and data services must extend beyond planned urban enclaves into unauthorized colonies, slums, and peripheries. Visibility in governance platforms should not be a reward for formal planning, but a right for every urban resident. Second, algorithmic transparency and accountability must become standard governance practices. Public-facing dashboards should show not only what decisions are being made, but also how AI models are constructed, what data they rely on, and who is affected. Regular audits of algorithmic systems should be mandatory, involving civil society, academia, and legal experts in ethical oversight.

Third, civic participation must be structurally embedded into smart governance systems. Feedback should not be treated as customer service, but as a mechanism for democratic deliberation. Non-digital modes of engagement, such as ward-level assemblies, NGO partnerships, and community consultations, must complement digital platforms to ensure inclusivity. Fourth, promoting data justice and digital literacy is critical for long-term equity. Marginalized communities should receive targeted training in how digital governance works and how it impacts their daily lives. This should be accompanied by education reforms that integrate the idea of the "Right to the Smart City" into curricula for urban planning, public policy, and civic education.

Fifth, policymakers must design for friction—not merely for flow. Over-optimization in the name of efficiency can erase points of human discretion that are essential for empathetic and context-sensitive governance. In areas such as welfare distribution, grievance redressal, and public health, deliberate pauses in automation can preserve fairness. Friction, when designed with care, can serve as a safeguard against technocratic excess and algorithmic bias. Thus, rather than treating every delay as a failure, governance models must acknowledge that slow processes can sometimes be more just.

Looking ahead, the future of urban transformation in India will not be decided by how many sensors a city can install or how fast its data pipelines can operate. It will be shaped by whether cities can become reflexive systems—systems that not only adapt to real-time conditions but also listen to dissent, recognize exclusions, and respond to diverse ways of being urban. For Delhi, this means investing not just in advanced technologies but in the ethics and politics that guide their application. It means resisting governance models that prioritize surveillance over consent, and efficiency over justice.

Ultimately, a truly smart city is not one that automates governance but one that humanizes it—a city wise enough to ask who is being left behind, and courageous enough to redesign itself in response. This paper offers not only a framework for understanding these challenges but a call to action: to build cities that are not just intelligent but inclusive, not just digital but democratic, and above all, not just smart but just.

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Anticoagulant Therapy for Alzheimer's Disease: A Review of Recent Research

Vinayaka Madivalar [1], Shubham Teli [1], Shivaraj Hiremath [1], Vani Chatter [1], Gouthamachari Shrinivas [1], Anjana Kulkarni [1], Bhushan Khombare [1], Mallappa Shalavadi [1*]

[1] Department of Pharmacology, B.V.V Sangha's Hanagal Shri Kumareshwar College of Pharmacy Bagalkote-587101, Karnataka, India

***Corresponding Author:** mallu.sha007@gmail.com

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ABSTRACT

Alzheimer's disease (AD) is a neurodegenerative, vascular, and hemostatic disease characterized by cerebral-amyloid angiopathy (CAA). Thrombin, fibrin, and amyloid-(Aβ) toxic proteins are important initiators of vascular anomalies and resulting neurodegeneration in AD, which can be managed with anticoagulants, as this article reviews. Recent research suggests that the pathophysiology of AD is influenced by risk factors for cardiovascular disease, dysregulated intrinsic coagulation, and cerebrovascular damage. Anticoagulants may be a viable treatment option for AD patients with vascular condition cognitive impairment. This article provides a thorough analysis of recent research, demonstrating that anticoagulant-particularly those of the direct oral anticoagulants (DOAC) type-may be able to combat the vascular-driven progression of AD-related neuroinflammation and CAA, given complete cerebral perfusion and a decreased milieu that accumulates fibrin and Aβ. When administered early, either therapeutically or prophylactically, DOAC may be more effectively utilized to reduce inflammation and vascular dysfunction due to pharmacological reasons. Preclinical research in AD animal models will be the first step in determining whether this treatment strategy can actually effectively combat the cerebral-vascular dysfunction that are a component of AD etiology.

Keywords: Alzheimer's disease, anticoagulant, brain perfusion, cerebral amyloid–Angiopathy, fibrin, neuroinflammation, thrombin, vascular dysfunction.

INTRODUCTION

Neocortical and hippocampus brain regions are the primary sites of neurodegenerative, vascular, and hemostatic changes that culminate in a complicated condition known as AD. AD pathogenesis culminates in the gradual disappearance of a person's known personality along with memory, cognition, behavioural, and motor functions. Over 40 million individuals globally, with one million residing in Germany alone, are afflicted by this illness, which is becoming more common as the number of older people who are affected by it rises. In the case of early-onset AD, less than 10% of these patients have symptoms because of a genetic and inherited predisposition long before they turn 65.1

For over 25 years, cholinesterase inhibitors, including galantamine, rivastigmine, and donepezil, have been the cornerstone of treatment for AD in its early, mild, or moderate phases. Cholinesterase inhibitors are frequently used in conjunction with glutamate antagonists like memantine in later, more severe phases.2 Additionally thought to have a preventative and delaying effect are dietary and lifestyle modifications, as well as the avoidance of cardiovascular risk factors.3 Novel medications that are either in the research pipeline or currently available for clinical use are what are still lacking after decades of rigorous study and expenditure.4 Because they address the underlying causes of the disease, disease-modifying drugs are especially desirable for efficiently combating it. Symptomatic drugs, which solely address the disease's symptoms, are less significant.2, 5, 6 although the exact cause of this is yet unknown, the accumulation of toxic amyloid-β-proteins (Aβ) in the afflicted brain is

thought to play a significant role in AD development. Recently, aducanumab, an anti-Aβ antibody, was approved by the U.S. Food and Drug Administration (FDA) to treat a new condition.5, 6 In order to counteract this causal component, aducanumab targets Aβ and clears these peptides. However, the approval of aducanumab for the treatment of mild AD has prompted a contentious debate about whether the scientific trials that were filed to support this treatment can indeed prevent memory loss and cognitive decline with this antibody.2, 5, 6

Anticoagulant therapy appeared to have a beneficial impact on the development of senile dementia symptoms in early clinical trials involving small groups of patients .7 The notion that AD is partly caused by cerebrovascular dysfunction has been reinforced by the findings of basic research conducted over the past several years.8,9 Thrombin, fibrin, and amyloid-(Aβ) toxic proteins are important initiators of vascular anomalies and resulting neurodegenerative alterations in AD, which can be managed with anticoagulants, as this article reviews. Given this, anticoagulants may be a viable treatment option for AD patients' hemostatic and cerebrovascular dysfunctions as well as related neurodegenerative processes.9-12 Recent research suggests that the pathophysiology of AD is influenced by risk factors for cardiovascular disease, dysregulated intrinsic coagulation and cerebrovascular damage. This has led to the renaissance of anticoagulative therapy, which was first evaluated clinically over 55 years ago.10,13,14 Dysregulation of blood flow has also been revealed by quantitative transcriptome profiling of major vascular and perivascular cell types from hippocampal and cortical brain tissues of AD patients. It is interesting to note that gene expression patterns connected the vasculature to 30 of the top 45 genes for AD risk.15 In instance, it was discovered that toxic Aβ accumulations, in addition to elevated thrombin and fibrinogen accumulations, are directly responsible for cerebrovascular and blood–brain barrier (BBB) dysfunction. Anticoagulants may be used to treat these alterations mechanistically by addressing their root causes.10, 12, 16 This article provides a thorough analysis of recent research, demonstrating that anticoagulants-particularly those of the DOAC type-may be a viable treatment option for AD patients with vascular conditioned cognitive impairment.

DEPRESSICE IMPACT ON THROMBOSIS AND CLOTTING

The multi-stage process of hemostasis prevents excessive blood loss in the organism in the event of blood vessel damage.[17] the blood clotting (coagulation) phase, which leads to wound closure and healing, is when the soluble blood protein fibrinogen changes into insoluble fibrin. Following that, a fibrin clot (thrombus) is created, which is a fibrin fiber network with integrated erythrocytes and platelets. Numerous tissue and coagulation factors, such as factor Xa, cascade-like to induce the manufacture of the main core enzyme, the serine protease thrombin. A process depending on vitamin K activates several of these factors. The overproduction of fibrin clots is inhibited by endogenous inhibitors. One example is the conversion of plasminogen to the proteolytic enzyme plasmin, which is induced by the tissue plasminogen activator (t-PA). During the fibrinolysis process, plasmin breaks down fibrin, dissolve fibrin clots. [17] Large wound areas after surgeries and injuries, genetic variations in certain coagulation factors or inhibitors, and slowing blood flow (e.g., through atrial fibrillation, changes in blood vessels due to atherosclerosis, surgeries, limited movement) can all contribute to increased blood clotting with the formation of thrombin. When these thrombi detach and move through the circulatory system, they can cause brain infarction or pulmonary embolism. Alternatively, they can close blood channels throughout the thrombosis process.[18] Anticoagulant drugs are used either preventatively or therapeutically to stop blood clotting, which minimizes the risk of emboli or thrombosis developing. Different mechanisms exist for anticoagulants to prevent blood clotting.[19]

i. Indirectly, as in the case of heparins (e.g., enoxaparin), heparinoid dana paroid sodium and fondaparinux (with parenteral action), and vitamin K antagonists (VKAs, e.g., warfarin, phenprocoumon, acenocoumarol, with oral impact);

ii. Directly, for instance, in the case of blood clotting factor inhibitors (e.g., factor Xa inhibitors, such as apixaban, rivaroxaban, edoxaban, betrixaban with oral effect; otamixaban, with parenteral effect); thrombin inhibitors (e.g., dabigatran texilate, ximelagatran, with oral effect; hirudin, bivalirudin, argatroban, with parenteral effect). DOACs are the combination of factor Xa and direct thrombin inhibitors.

HISTORICAL MARKS AND CURRENT THERAPEUTIC MEDICATIONS FOR ALZHEIMER'S DISEASE

The medications now on the market for the treatment of AD, such as glutamate antagonists like memantine and cholinesterase inhibitors like donepezil, galantamine, and rivastigmine, can only postpone the onset of dementia symptoms for a limited amount of time.[20] Therefore, a pressing goal of pharmaceutical research is to find new, more potent medications.[21]

According to recent studies, the pathogenesis of AD is mostly initiated by toxic accumulations of misfolded amyloid-(Aβ) proteins in brain tissue.[21, 22] enzymatic release of amyloid-protein precursor (APP) Aβ is facilitated by secretases. Fission products of varying lengths, known as secreted APP, are delivered by APP, which is anchored in the cell membrane of neurons and is crucial for the performance of synapses.[23] On the other hand, poisonous Aβ builds up as insoluble fibrils that are deposited and as soluble dimers and oligomers (Aβ plaques). Aβ plaques and oligomers are found around and in cerebral blood vessels (specifically Aβ 40) as well as between neurons in specific parenchymal tissue sections of the brain, particularly in the

neocortex and hippocampus (Aβ42 and Aβ43). An intricate equilibrium exists between the soluble and insoluble forms of Aβ. Aβ is actively transported into the circulatory system via the blood-brain barrier, which is the vascular interface of the brain (BBB).[24] Aβ causal role of these Aβ accumulations in early AD pathogenesis suggests that 1) Synapses and neurons were damaged due to hyperactivation caused by soluble Aβ aggregates[22, 25] 2) The production of Aβ plaques is linked to all key gene changes that are associated with an elevated risk of AD, and 3) Early administration of Aducanumab, an anti-Aβ antibody, to AD patients may enhance cognitive function even with decreased Aβ accumulation.[26] Furthermore, the development of AD pathogenesis is characterized by the spread of tau-protein fibrils and intraneural deposits, abnormalities in the blood-brain barrier, neural inflammatory processes that result in the production of reactive oxygen species (ROS), and the loss of synapses and neurons. Consequently, there is a great deal of therapeutic research focused on these mechanisms.[25, 27–30] Specifically, the development and dissemination of cerebral Aβ deposits are facilitated by inflammatory processes originating from activated microglia cells, which produce interleukins and ASC (apoptosis associated speck-like protein containing a CARD) protein complexes during microgliosis.[31, 32] Conversely, early in the disease, active microglia cells caused the cerebral Aβ deposits to break down. Thus, mutations in the microglia cell activating gene TREM2 enhanced the risk of AD by increasing the production of Aβ plaques.[33] Estimates suggest that cerebral Aβ accumulates in AD patients 10–20 years prior to the onset of symptoms. Similarly, 16 years before symptoms appeared, the blood levels of people with known AD showed a rise in neurofilament light chain protein (Nfl), an indicator protein for the loss of brain neurons.[34]

ANTICOAGULANTS PREVENT THE FORMATION OF THROMBIN AND FIBRIN IN HAEMOSTASIS

When the blood vessel system is injured, the multi-stage process of hemostasis keeps the body from losing too much blood.[35]To seal and mend a wound, a soluble blood protein called fibrinogen is changed into an insoluble fibrin during the blood clotting (coagulation) process. A fibrin clot, or thrombus, is formed when platelets and erythrocytes are integrated into a fibrin network. Numerous tissue and coagulation factors, including factor Xa, regulate the generation of the causative enzyme, thrombin, which is released from its precursor protein prothrombin. This process occurs in a cascade. A procedure that depends on vitamin K is used to activate some of these in advance.[36] However, during the fibrinolysis process, the proteolytic enzyme plasmin breaks down fibrin, dissolving fibrin clots.[35] In cases where there is a genetic alteration in coagulation factors, large wounds from surgery or injuries, slower blood flow from incidents like atrial fibrillation, damaged blood vessels from atherosclerosis, and limited physical exercise, the risk of forming harmful thrombi increases as blood clotting is stimulated. When these thrombi detach, they can travel through the circulatory system to organs and induce conditions like brain infarction or pulmonary embolism. Alternatively, they might cause obstruction of blood vessels during the thrombosis process.[37] Anticoagulants inhibit blood clotting to stop thromboembolism from happening, either therapeutically or preventively. Short-term anticoagulation is advised for the prophylaxis of thrombosis and for the acute treatment of venous thrombosis in risk scenarios, such as following surgery. For example, individuals with cardiac arrhythmias such atrial fibrillation, elevated cardiovascular risk, or mechanical heart valve replacement are prescribed persistent anticoagulation as a preventive measure against thromboembolism,[36] medications with an alternative mode of action are available for the antithrombotic effect; these medications might indirectly affect blood coagulation in parenteral heparins (enoxaparin), heparinoid danaparoid sodium, Fonda parinux, and in oral active VKAs (warfarin, phenprocoumon, and acenocoumarol). Parenteral thrombin-inhibiting drugs such as hirudin, bivalirudin, and argatroban, as well as oral active thrombin inhibitors like dabigatran and factor Xa inhibitors like apixaban, betrixaban, edoxaban, and rivaroxaban, all directly suppress blood clotting .[37] DOACs include many drugs and factor Xa inhibitors. In Germany, DOACs are prescribed to around two million patients, the majority of whom are over 70 years old, in accordance with anticoagulant indications.[16] In contrast, the number of patients in Germany who are currently receiving VKA prescriptions has fallen over the past few years to about one million.[38] In susceptible people, the treatment significantly lowers the chance of a deadly heart attack or stroke. But the antithrombotic action also raises the chance of bleeding.[37] There is now debate regarding the medicinal repositioning of anticoagulants for the treatment of brain amyloidosis because AD involves vascular and haemostatic alterations in the etiology.[1, 39]

ALZHEIMER'S DISEASE: TRIGGERED NEUROPATHOGENIC PHENOMENA AND TOXIC AMYLOID PROTEINS

A neuropathologist alois Alzheimer made the first identification and description of protein deposits in the brain tissue of a deceased dementia patient.[40] In fact, misfolded, toxic Aβ build-up in brain tissue has been shown to be a critical driver of AD pathogenesis. To try to halt the progression of the illness, this notion today serves as the main treatment foundation.[41, 42] by working in succession, and-secretes liberate Aβ from the amyloid-protein precursor (APP). APP produces fission products of varying lengths and is attached in the membrane of the neuron. (Secreted APP). Aβ may have functions in the healthy brain that include controlling hippocampal synaptic activity, sealing blood-brain barrier leakage, and warding off infections.[43] A complicated equilibrium of soluble dimers and oligomers is formed in the AD brain when toxic Aβ are released from APP and aggregate into insoluble fibrils that are deposited (Aβ plaques). Neuritic plaques of Aβ and oligomeric Aβ, specifically Aβ42 and Aβ43, are found between neuron cells in the brain parenchyma, while Aβ oligomers of shorter subtype, specifically Aβ40,

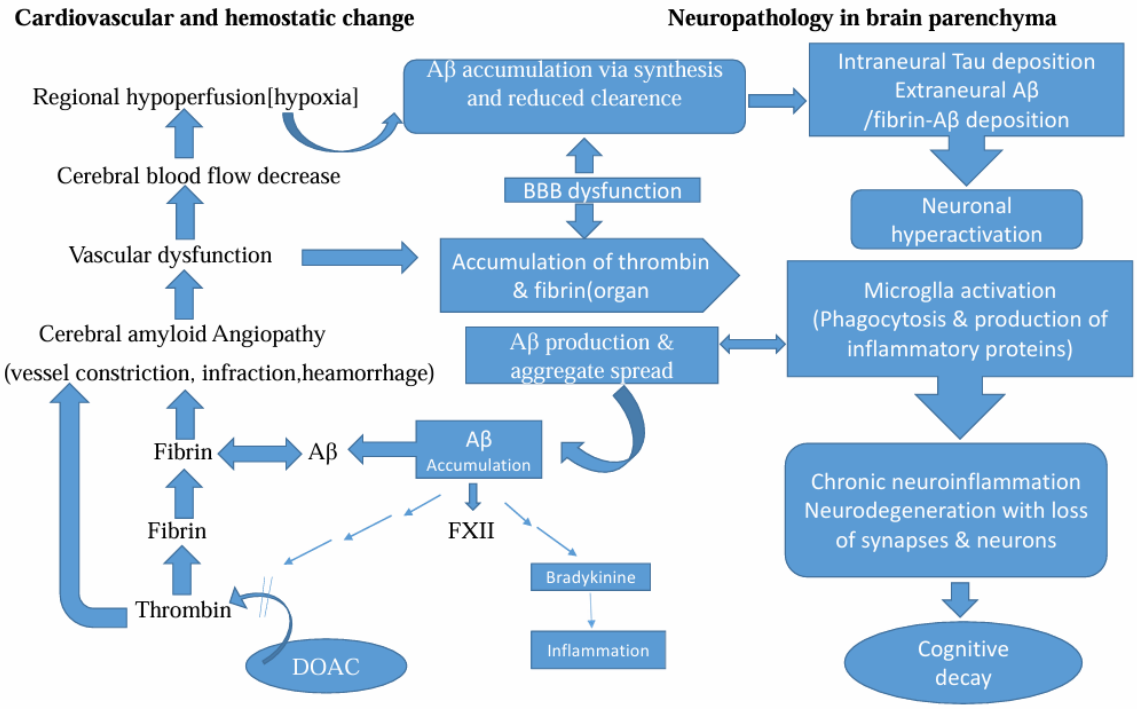
are found in and around the blood vessels of leptomeningeal and cortical arteries as well as occasionally veins. Particularly in the neocortical and hippocampus regions of the brain, both activities occur Excessive neuronal activity, malfunction, and synaptic loss in these particular brain regions have been linked, in a substantial way, to progressive cognitive impairment in the early stages of AD.[42, 44] The brain's vascular interface, or BBB, actively facilitates the entry of Aβ into the bloodstream.[45] The following arguments point to these Aβ accumulations' potential causative role in early AD. Glutamatergic neurons and synapses can be hyper activated and damaged by soluble Aβ dimers and oligomers.[42, 46] Furthermore, Aβ production, aggregation and clearance, and microglia responses are linked to every major gene alteration that has been found to date to be associated with an elevated risk of AD. Additionally, when individuals are treated with anti-Aβ antibodies relatively early in the disease, aducanumab[47] and donanemab[48] have demonstrated potential to prevent cognitive decline by lowering brain Aβ load. Clinical research is presently being conducted on these and additional anti-Aβ antibodies, including gantenerumab and BAN2401.[47, 48] Additional features of the progressive pathogenesis of AD include intraneural deposits of tau protein aggregates, which are toxic to neurons and spread from one to another. Neurofibrillary tangles (NFT), which are commonly seen in AD, are created when the microtubule-associated tau protein is phosphorylated under pathological circumstances. These insoluble, filamentous tau aggregates result from this process. The illness known as tau opathies may be exacerbated by filamentous and oligomeric tau aggregates and fragments, which can lead to synaptic dysfunction and neuronal cell death.[49] Perhaps via stimulating cyclic-dependent kinase activity for tau Hyperphosphorylation and aggregation, Aβ enhances tau-seeded diseases in AD.[50, 51] Hyperphosphorylation of soluble tau has been linked to both the rise in Aβ oligomers and the decrease in cerebral blood flow (CBF) in AD. Soluble tau gets transferred from axonal micro tubules to dendrites. Cognitive decline may result from the myelin breakdown and ensuing synapse disruption.[49, 51]

ALZHEIMER'S DISEASE, CEREBRAL AMYLOID ANGIOPATHY, AND NEUROLOGICAL DISORDERS

Although cerebral-amyloid angiopathy (CAA; Figure 1), a condition well-known and typical of AD, has only recently attracted more attention in therapeutic research due to pathogenic alterations in cerebral blood vessels linked to Aβ. Cerebrovascular abnormalities are identified very early in the etiology. CAA mostly affects the neocortical and hippocampal brain areas. Aβ aggregates collect and deposit in and around the walls of brain arteries, arterioles, and capillaries, interfering with their function.[52, 53, 54, 55] Aβ is derived from neurons and can spread out from their original site to accumulate in the cerebral vasculature. Therefore, cerebral blood flow and perfusion are impaired in the Aβ-loaded, diseased brain, reducing the amount of blood and its components that reach the tissue, such as oxygen, nutrients (including glucose, ions, and amino acids), hormones, proteins, and cellular components.[56,57,58–60] Aβ is initially deposited in the brains of AD patients around the edges of arterioles, at the location of purported interstitial fluid drainage pathways, because blood capillaries damaged by CAA also prevent the release of proteins, such as Aβ, into the bloodstream from the interstitial brain fluid (ISF).[61, 62] 65This impairs the blood's capacity to distribute and eliminate parenchymal Aβ (perivascular Aβ clearance), leading to an increasing accumulation of Aβ in the brain parenchyma.[61,63] Transgenic mouse lines are gaining popularity as a model for investigating the role of CAA-induced vascular dysfunction in AD, in addition to investigations on AD patients. Transgenic mouse lines are gaining popularity as a model for investigating the role of CAA-induced vascular dysfunction in AD, in addition to investigations on AD patients.[64, 65] Vascular Aβ build-up, mainly in neocortical and hippocampal brain areas, is the primary trigger for CAA, according to recent studies on AD patients and rodent models.[52, 66–69] However, this tau buildup is typically not a characteristic that distinguishes CAA disease.68 A reduction in CBF, a progressive loss of vascular function, hypoperfusion, and insufficient oxygen and nutrition reaching the brain (hypoxia) are all related to the degree of Aβ deposition in CAA.[56,69,70] (Figure 1). Experiments employing in vivo AD mice models and living human brain biopsy tissue, as well as mechanistic experiments involving the addition of medications and Aβ to rat cortical slice capillaries, have exemplarily proven the vascular involvement to AD. A close relationship has been observed between the deposition of Aβ in cortical capillaries and the expansion of their pericytes on the walls of the outer vessels.[70] Venules and arterioles, on the other hand, did not change. The Aβ-mediated mechanism for pericyte contraction appears to be based on endothelin-1 release induced by ROS. [71] Pericyte contraction lowered capillary diameter, resulting in vasoconstriction, or constriction of the capillaries, and decreased blood flow within the vessels. As a result, the impacted brain regions experienced prolonged hypoperfusion (ischemia), which resulted in hypoxia-a well-known occurrence in the early stages of AD.[70] Both in AD mice and AD patients, vascular dysfunction, and a simultaneous reduction in CBF, measured within a 25% range, have been noted.[69, 71] Research has also demonstrated that brain hypoxia/ischemia conditions cause the neural precursor APP to produce Aβ through activation of secretases and up-regulation of the gene expression for secretase1 (BACE1), which essentially happens in a self-amplifying process [72–74]. This promotes degenerative and inflammatory changes that impair cognition.[73, 74] Additional clinical investigations demonstrated that 82–98% of AD patients have both CAA and AD disease co-occurring in their brains. [75] Consequently, vascular function restriction in CAA, along with the ensuing drop in CBF and hypoperfusion, are thought to constitute an early and important pathophysiological mechanism in AD [54,72,76] which takes its origin from cerebrovascular Aβ deposition and evoked vasculopathies. In addition to the constriction of vessels caused by Aβ, they also involve micro infarction (occlusion) and micro-haemorrhagic (bleeding) events that damage the blood-brain barrier and generate inflammatory and degenerative changes in brain tissue [52,76,77] (Figure 1). It is interesting to note that exercise, which increases CBF and brain perfusion, has

been shown to slow down neuropathological processes in AD rodent models [79] and in those with a hereditary susceptibility to the disease.[78]

Figure 1: *Mechanism of action of DOACs, in AD.*



Mechanism of action of DOACs, a major factor in AD, in the therapeutic treatment of vascular abnormalities produced by thrombin. Early and distinctive characteristics of AD include Aβ-containing fibrinogen clots that are hard to break down, an inflammatory milieu, elevated thrombin generation in the blood that leads to fibrin formation, and the accumulation of toxic tau and Aβ proteins in the brain parenchyma. Particularly in the neocortical and hippocampal parenchyma, the release of Aβ into the blood causes the formation of thrombin and proinflammatory bradykinin. In the plasma contact system, Aβ causes blood coagulation factor XII to become activated, producing FXIIa. It is made easier for thrombin to be produced from prothrombin by factor Xa (FXa). Thrombin catalyzes the conversion of fibrinogen to fibrin and stimulates platelet aggregation in conjunction with fibrinogen, both of which can result in vessel obstruction. Amyloid plaque build-up in the brain and vascular constriction is brought on by the deposition of oligomeric Aβ and fibrin clots containing Aβ (CAA). Aβ-induced brain vasculopathies and related lesions, like (Figure 1), are primarily caused by CAA. Mechanism of action of DOACs, a major factor in AD, in the therapeutic treatment of vascular anomalies produced by thrombin. Early and distinctive characteristics of AD include Aβ-containing fibrinogen clots that are hard to break down, an inflammatory milieu, elevated thrombin generation in the blood that leads to fibrin formation, and the accumulation of toxic tau and Aβ proteins in the brain parenchyma. The release of Aβ into the blood causes the synthesis of thrombin and proinflammatory bradykinin. This is particularly true in the neocortical and hippocampal parenchyma in the plasma contact system, where Aβ stimulates blood coagulation factor XII to create FXIIa. It is made easier for thrombin to be produced from prothrombin by factor Xa (FXa). Thrombin catalyzes the conversion of fibrinogen to fibrin and stimulates platelet aggregation in association with fibrinogen, both of which can result in vessel obstruction. The deposition of fibrin clots containing Aβ and oligomeric Aβ cause vessel constriction and cerebral amyloid angiopathy (CAA). The deposition of fibrin clots containing Aβ and oligomeric Aβ cause vessel constriction and cerebral amyloid angiopathy (CAA). This leads to a decrease in cerebral blood flow (CBF) and perfusion, as well as a decrease in the amount of oxygen and nutrients that reach brain tissue (hypoxia). Simultaneously, perivascular Aβ clearance is impeded by the BBB, leading to Aβ accumulation and aggregates spreading in the parenchymal tissue due to hypoxia-induced Aβ synthesis. The self-amplifying build-up of Aβ leads to neurotoxic tau diseases by causing synaptic disruption and neuronal hyperactivation. Furthermore, when the blood-brain barrier is compromised, vascular thrombin and fibrinogen can permeate into the parenchymal tissue and stimulate glial cells in conjunction with Aβ. This results in persistent inflammation and increased production of Aβ. Cognitive decline is also a result of increasing brain injury, which results in the loss of neurons and synapses. The primary mediator in this vicious cycle, thrombin, is the goal of DOAC intervention. DOAC and FXa inhibitors, such rivaroxaban, can block thrombin's activity or synthesis. Early thrombin inhibition in AD patients may preserve vascular and blood-brain barrier integrity for full brain perfusion and function. In this manner, blood vessel-induced neurotoxicity and inflammation that result in cognitive decline could be prevented or at least modified.[90] as bleeding and

blockage of vessels, which ultimately result in vascular and blood-brain barrier (BBB) dysfunction. As a result, there is a drop in cerebral blood flow (CBF) and perfusion as well as a reduction in the nutrition and oxygen supplied to brain tissue (hypoxia). At the same time, hypoxia-induced Aβ synthesis and poor perivascular Aβ clearance via the BBB lead to an increased accumulation and dissemination of Aβ aggregates in the parenchymal tissue. The self-amplifying build-up of Aβ leads to neurotoxic tau diseases by causing synaptic disruption and neuronal hyperactivation. Furthermore, when the blood-brain barrier is compromised, vascular thrombin and fibrinogen can permeate into the parenchymal tissue and stimulate glial cells in conjunction with Aβ. This results in persistent inflammation and increased production of Aβ. Cognitive decline is also a result of increasing brain injury, which results in the loss of neurons and synapses. The primary mediator thrombin is the goal of DOAC intervention into this vicious cycle. DOAC and FXa-inhibitors can block thrombin's activity or synthesis. For complete brain perfusion and function, early thrombin inhibition in AD patients may maintain vascular and blood-brain barrier integrity. In this way, neurodegeneration and inflammation caused by blood vessels that lead to cognitive loss could be avoided.[90]

ALZHEIMER'S ILLNESS, THE FUNCTIONS OF THROMBIN, FIBRIN, AND AMYLOID IN FIBRIN-CONTAINING CLOTS

Recent research has demonstrated that the brains of individuals with hereditary and sporadic AD, as well as AD mice, exhibit co-occurring accumulations of toxic Aβ, thrombin, and fibrin/fibrinogen.[53, 54, 80–84] It has been discovered that fibrinogen and Aβ co-colonize the walls of cerebral vessels and the parenchyma of the nervous system[54, 80,84] neuro-inflammatory processes are initiated by thrombin and fibrinogen, and fibrinogen can also interact with Aβ [54,80,82–84] (Figure 1). Because of the developing vascular dysfunction in CAA, the BBB becomes increasingly leaky for plasma proteins, which leads to an accumulation of fibrinogen and thrombin in parenchymal tissue. [77, 85, 86] it is possible for fibrinogen to enter parenchymal tissue from blood vessels. Here, after vascular disruption, it is transformed into fibrin by thrombin, extra perivascular tissue factor, and procoagulant proteins, which are also widely distributed in this tissue.[77,85,86] The breakdown of pericytes in capillary walls, which disrupts connections between neighbouring endothelial cells, causes haemorrhage and infarction damage, which cause the blood-brain barrier to leak.[86] In general, increased Aβ synthesis, microglia activation, and malfunctioning and loss of synapses and neurons are linked to BBB disruption and the processes that follow[57] (Figure 1). Fascinatingly, recent studies have revealed that, in accordance with Aβ42, fibrinogen can bind to Aβ through its central region, while Aβ binds the C section of fibrinogen[81, 83] Aβ-containing fibrin-Aβ clots are created when fibrinogen and Aβ combine to promote Aβ oligomerization.[80, 83, 87] Compared to normal clots, these fibrin-Aβ clots are more resistant to the plasmin fibrinolysis enzyme-degrading enzymes because of an aberrant fibrin mesh structure.[80, 83, 87] Compared to normal clots, these fibrin-Aβ clots are more resistant to the plasmin fibrinolysis enzyme-degrading enzymes because of an aberrant fibrin mesh structure. It has been found that these fibrin clots containing Aβ are deposited in the cerebral blood vessels of the neocortical and hippocampal brain areas of CAA. Additionally, they accumulate in parenchymal brain regions of dystrophic neuritis along with Aβ oligomers and plaques.[80, 81, 83–85] Fibrin-Aβ clot deposition in blood arteries impairs blood flow in CAA regions and disrupts BBB and vascular function. Blood flow in CAA regions is impeded by fibrin-Aβ clot formation in blood vessels, which also compromises BBB and vascular function.[54] Aβ mutations that facilitate the production and deposition of cerebral fibrin-Aβ clots in the pathophysiology of AD have been found in patients with hereditary CAA.[87] Conversely, RU-505, which binds directly to Aβ, and other pharmacological inhibitors of the fibrinogen-Aβ interaction can stop fibrin-Aβ clots from forming.[54,88] As a result, RU-505 treatment for an extended period of time dramatically decreased cerebral microgliosis, vascular amyloid deposition, vessel blockage, and cognitive impairment in an AD animal model.[54,88] Interestingly, the amide side chain portion of RU-505,[87] which may be involved in the fibrinogen-Aβ interaction, shares some structural similarities with the pharmacophore for thrombin binding of the DOAC.[89] Beyond its well-known ability to inhibit thrombin and may also be able to interfere with the production of fibrin-Aβ clots, which is something worth looking into.

NEW THERAPEUTIC METHODS INCLUDING ANTICOAGULANTS

The treatment strategy is predicted on the theory that anticoagulants impact the development of critical drivers in AD-related neuroinflammation and CAA. Anticoagulants work by blocking thrombin's ability to create fibrin, which prevents the build-up of fibrin clots that contain Aβ and are resistant to breakdown, as well as thrombin that promotes inflammation and microglia activation. In regions of CAA, these fibrin-Aβ clots are seen in the cerebral blood vessels and brain parenchyma, which disrupts cerebral blood flow. As a result, anticoagulant therapy can compensate for hypoperfusion and limited oxygen and nutrition delivery to brain tissue. Simultaneously, it is possible to mitigate hypoperfusion-enhanced neurodegenerative processes, including synapse and neuron cell death, neuroinflammation, and increasing accumulation of Aβ through production and decreased clearance (Fig. 1). When administered early in the process, anticoagulants may be able to slow the vascular-driven progression of the neurodegenerative and cognitive abnormalities associated with AD, given complete cerebral perfusion and a decreased milieu that accumulates fibrin and Aβ. Consequently, administration of the indirect heparin-type thrombin inhibitor enoxaparin decreased cortical Aβ formation, as demonstrated by earlier research using AD mice models.[91, 92] Moreover, administration of the direct thrombin inhibitor such as DOAC resulted in a reduction in the production of ROS and

vascular inflammatory proteins[93] as well as in the activation of microglia.[94] Thrombin inhibitors have been proposed as a potential treatment for AD symptoms due to their inhibitory action on vascular pro-inflammatory thrombin.[95] The drawbacks of heparin infusion therapy are as follows: 1) non-specific plasma protein binding can alter anticoagulation unpredictable; 2) thrombocytopenia can be caused; and 3) fibrin-bound thrombin, a significant stimulant of fibrin clot development, is not inactivated.[1, 96] In contrast, oral anticoagulants offer advantages for treating vascular dysfunction in AD due to their broad application and unique mode of action. On the other hand, bleeding difficulties and the impact of vitamin K insufficiency on vital proteins of the neurological and circulatory systems are un favourable side effects of oral anticoagulants of the VKA type, such warfarin[1, 97] The particular acting DOACs, such as the blood clotting factor Xa-inhibitors rivaroxaban (Xarelto®), apixaban (Eliquis®), edoxaban (Lixiana®), and betrixaban (Bevyxxa®), and the direct thrombin inhibitor etexilate (Pradaxa®), are far more appropriate. For the following reasons, commercial choice when treating vascular dysfunction in AD patients. The prodrug version of some drugs is the one that releases the active ingredient in vivo. Thrombin is the enzyme that directly converts fibrinogen into insoluble fibrin at the end of the blood clotting cascade. This enzyme is specifically inhibited by DOAC.[98] Certain these have been associated with a decreased risk of ischemic stroke, a 66% reduction in cerebral hemorrhage, and a decreased risk of death in elderly patients with atrial fibrillation. These drugs have a shorter half-life in humans than the VKA warfarin.[99, 100] In a research FDA, it was shown that taking DOAC reduced the incidence rate of cerebral haemorrhage per 1000 person-years to 3.3 (0.33%), whereas taking warfarin increased the rate to 9.6 (0.96%) [100] Thus, in the AD mouse model, DOAC did not result in an increase in cerebral micro bleed.[101] And also has no effects on vitamin K insufficiency or nutritional interactions with anticoagulation because of its mode of action. The substance produces anticoagulation that is efficient, dependable, and predictable.[98] additionally, the trade antibody idarucizumab offers a particular counteragent that instantly negates the effects of DOAC, effectively reducing the danger of bleeding.[102] A modified recombinant inactive form of human factor Xa, and the reversal agent have made this option available for factor Xa-inhibiting DOACs as of late.[103] However, considering the correlation between vascular fragility and CAA, the use of DOAC or other antithrombotic medicines to AD patients who are at higher risk of bleeding needs to be carefully assessed for bleeding risk.[104]

CONCLUSION

Theoretically, anticoagulants of the DOAC type, in particular, such as the direct thrombin inhibitor and the indirect thrombin impacting factor Xa inhibitors, are suitable for treating the cerebrovascular changes associated with AD. Anticoagulants have the potential to inhibit the production of inflammatory thrombin and fibrin, as well as the deposition of fibrin clots containing Aβ that are resistant to breakdown in cerebral blood arteries of CAA and brain parenchyma. When administered early, either therapeutically or prophylactically, DOAC may be more effectively utilized to reduce inflammation and vascular dysfunction due to pharmacological reasons Anticoagulant therapy may lessen the disruption of cerebral blood flow, brain perfusion and supply with oxygen and nutrients, and enhanced advancement of neurodegenerative processes, all of which contribute to cognitive loss (Figs. 1). The therapeutic translation to this novel illness indication is likely to be accomplished more quickly and at a lower cost because DOAC a medication that has been clinically approved, given for many years, and has a recognized safety profile. Preclinical research in AD animal models will be the first step in determining whether this treatment strategy can actually effectively combat the cerebrovascular dysfunction that is a component of AD etiology. Interestingly, Cortes-Canteli and colleagues (2019) have revealed results in the AD mouse model that support the idea that was put forth.[90] over time, brain fibrin build-up, hypo perfusion, and memory loss were prevented by DOAC therapy. In parallel, there was a decrease in the amount of Aβ plaques and oligomers as well as neuroinflammatory activity, which was typified by T cells infiltrating and phagocytic microglia. In addition, the absence of astrogliosis and changes in pericytes showed that BBB function was maintained. There were no signs of intracranial bleeding or haemorrhages Sub-sequently, extensive clinical trials of This-type anticoagulants on their therapeutic efficacy in AD would be strongly advised if these findings are validated by more research in AD animal models. When conducting clinical trials to test the theory, position emission tomography (PET) and magnetic resonance imaging (MRI) approaches can be used to visualize brain biomarkers such as micro bleeds, CBF dynamics, and plaques of Aβ in order to study the effects of DOAC on early AD and CAA progression in patients[4, 52, 89, 91] Furthermore, evaluations of cognitive function and biochemical assays, namely for blood biomarkers that indicate neurodegenerative[31] and haemostatic (e.g., fibrin clot formation) alterations, can supplement the analysis. However, before to study, the desired methodologies' cost/benefit should be evaluated [91] Despite this, every attempt should be taken, as there is presently no recognized potential medication on the horizon for the successful treatment of this horrible illness, which is estimated to affect over 40 million people globally [92, 93] Of these, 5% are thought to have early-onset AD (hereditary AD susceptibility), which causes symptoms to typically appear well before the age of 65.[94]

ABBREVIATIONS

Abbreviation	*Full Form*
AD	Alzheimer Disease
AÎ²	Amyloid
APP	Amyloid-protein precursor
ASC	Apoptosis associated speck-like protein containing a CARD
BBB	Bloodâ€“brain barrier
PET	Position emission tomography
CAA	Cerebral-amyloid angiopathy
CBF	Cerebral blood flow
DOAC	Direct oral anticoagulants
FDA	Food and Drug Administration
ISF	Interstitial brain fluid
NFL	Neurofilament light chain protein
NFT	Neurofibrillary tangles
ROS	Reactive oxygen species
T-PA	Tissue plasminogen activator
TREM2	Triggering receptor expressed on myeloid cell 2

ETHICAL DECLARATION

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A Review: Case Studies Involving Glass Evidence

Dr. Komal Yadav[1*], Agastya Arsh[1], Bibaswan Maitra[1], Ayushi Sinha[1], Sristy Agarwal[1], Vanshika [1]

[1] Forensic Science Department, National Forensic Sciences University- Delhi Campus, Delhi, India, India

***Corresponding Author:** komal.y@nfsu.ac.in

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ABSTRACT

This paper reviews forensic case studies highlighting the pivotal role of glass evidence in criminal investigations. Focusing on five diverse cases, it explores how meticulous forensic analysis of glass can uncover crucial details, such as the direction of impact, the sequence of events, and potential sources of contact. The paper outlines the primary methods used in forensic glass analysis, including refractive index measurement, elemental analysis and density gradient techniques. Each method's role in establishing connections or exclusions is evaluated in the context of the cases presented. This study highlights the forensic value of glass evidence in linking suspects to crime scenes and reinforces the need for precision to avoid misinterpretation and investigative delays.

Keywords: Glass, glass evidence, glass fracture, case study, vehicular crime.

INTRODUCTION

Glass evidence has emerged as an indispensable tool in the domain of forensic science, particularly in the investigation of crimes involving burglary, vehicular incidents, armed robbery, and violent physical confrontations. As a material that is omnipresent in modern settings—ranging from architectural structures and automotive components to household items and electronic devices—glass is not only susceptible to breakage but also prone to transfer. When shattered, microscopic glass fragments can adhere to clothing, skin, and objects, facilitating an inadvertent exchange between individuals and the environments they interact with. This transference makes glass an excellent form of trace evidence, providing a tangible connection between suspects, victims, and crime scenes. Given the dynamic and often violent nature of criminal acts, glass fragments frequently become embedded in the physical narrative of the crime, offering forensic experts an avenue for reconstructing events and establishing associative links.

Forensic glass analysis hinges on the inherent variability of glass compositions. Though glass may appear homogeneous to the naked eye, it is in fact a heterogeneous material, with properties influenced by its source materials, manufacturing techniques, and intended use. Differences in elements such as sodium, calcium, silicon, and trace metals contribute to distinct chemical fingerprints for each piece of glass. These fingerprints, once identified, can be compared across samples to determine whether two fragments share a common origin. This scientific capability empowers forensic professionals to move beyond circumstantial evidence, allowing for precise, evidentiary connections that can hold weight in judicial proceedings.

In forensic practice, multiple methodologies are employed to analyze glass. These include—but are not limited to—fracture pattern analysis, refractive index (RI) measurement, scanning electron microscopy coupled with energy-dispersive X-ray spectroscopy (SEM-EDX), density testing, and trajectory or impact analysis. Each technique offers a unique perspective, contributing to a multi-dimensional understanding of the sample in question. For instance, fracture pattern analysis enables experts to determine the direction, angle, and sequence of impact that led to glass breakage. This can help ascertain whether a glass pane was broken from the inside or outside, or whether multiple impacts occurred. Meanwhile, refractive index analysis, a well-established method, involves immersing glass fragments in a calibrated liquid and observing the match or mismatch of

light refraction, thereby facilitating sample comparison.

Additionally, SEM-EDX allows for microscopic and elemental analysis, helping to uncover minute structural features and compositional nuances that are invisible to traditional microscopes. This level of scrutiny is crucial when attempting to differentiate between glasses of similar appearance but different manufacturing sources. Density assessments further contribute to classification efforts, as variations in constituent materials affect the mass-to-volume ratio of glass samples. When combined, these techniques create a robust framework for forensic interpretation.

To contextualize the relevance and practical application of these analytical techniques, this paper explores five real-world case studies in which forensic glass analysis was instrumental in solving complex criminal cases. These case studies, drawn from varied crime types and geographical contexts, demonstrate how detailed scientific investigation of glass fragments enabled law enforcement to identify suspects, understand crime scene dynamics, and, ultimately, secure convictions.

The first case involves a nighttime burglary at a commercial retail store. Investigators discovered that a large display window had been smashed, and several items were stolen. Although there were no eyewitnesses, a suspect was later apprehended whose clothing bore small glass particles. Forensic analysis using refractive index measurement and SEM-EDX confirmed that the glass on the suspect's jacket was compositionally identical to the shattered window at the crime scene. This direct evidence substantiated the suspect's presence at the location during the time of the break-in, contributing significantly to the prosecution's case.

In the second case, a high-speed vehicular accident resulted in the deaths of two passengers, while the driver fled the scene. The front windshield had shattered on impact. When a person was later taken into custody under suspicion, glass fragments embedded in his scalp and clothing were analyzed. Trajectory analysis of the glass pattern and density testing revealed that the fragments likely came from a windshield, and matched the broken windshield found at the crash site. This finding linked the suspect to the driver's seat position and helped reconstruct the accident sequence.

The third case involved a domestic assault, wherein the victim was injured by a thrown glass object. Police found glass shards on the floor and on the assailant's hand. Using fracture pattern analysis and SEM-EDX, forensic scientists demonstrated that the glass on the suspect's hand aligned perfectly with the fractured rim of the broken object. This evidence corroborated the victim's testimony and was instrumental in establishing intent and culpability in the courtroom.

The fourth case study pertains to a shooting incident where the victim was inside a vehicle and the bullet had passed through the passenger window. Investigators sought to determine the trajectory of the bullet and whether the shooting occurred from outside the vehicle or was staged. Forensic experts analyzed the radial and concentric fracture lines on the glass and used impact cone geometry to determine the bullet's direction. Combined with SEM analysis of the gunshot residue and glass particles on the suspect's clothing, the investigation concluded that the shot originated from outside, dispelling the defense's claim that it was self-inflicted or accidental.

The final case concerns an attempted arson at a residential property. Entry had been gained by breaking a small kitchen window. Investigators retrieved glass fragments from the inside of the house and from the gloves found in a suspect's possession. Refractive index comparisons and elemental analysis revealed that the fragments on the gloves had a unique composition matching the kitchen window glass, including traces of specific stabilizers used in heat-resistant glass found only in that building's renovation materials. This forensic link directly implicated the suspect in the unlawful entry and subsequent arson attempt.

These case studies highlight not only the versatility of forensic glass analysis but also its power to provide definitive, science-backed conclusions. They also underline the critical importance of meticulous collection and preservation of trace evidence at crime scenes. In each of the cases reviewed, it was the combination of advanced analytical techniques and methodical investigative procedures that enabled authorities to reconstruct events with clarity and confidence.

As forensic science continues to evolve, there is a growing emphasis on refining analytical tools to increase accuracy, reduce error margins, and address challenges such as sample contamination or environmental degradation. Techniques like laser ablation-inductively coupled plasma-mass spectrometry (LA-ICP-MS) are being explored to provide even more precise elemental profiling. Such advancements promise to expand the evidentiary potential of glass and other trace materials, reinforcing their value in modern forensic investigations.

Glass evidence, when analyzed through rigorous scientific methods, holds immense potential for revealing hidden narratives within criminal acts. As illustrated by the case studies in this paper, forensic glass analysis is a vital pillar in the pursuit of justice—one that bridges the gap between crime scene and courtroom by transforming tiny, seemingly insignificant fragments into powerful tools of truth. Continued investment in training, instrumentation, and interdisciplinary collaboration is essential to keep this forensic frontier robust and responsive to the ever-changing landscape of crime and technology.

LITERATURE REVIEW

The forensic analysis of glass evidence has attracted significant scholarly attention due to its vital role in modern criminal investigations. Historically, the foundational principles of forensic glass examination were grounded in trace evidence theory as proposed by Locard, which emphasized the exchange principle—any contact between individuals and objects results in a transfer of material. This principle has guided the collection and interpretation of glass evidence for decades. Over time, researchers began to explore more refined techniques for analyzing glass, including physical, chemical, and optical methodologies. One of the most widely studied and implemented techniques is refractive index (RI) measurement. According to Koons and Buscaglia (2002), the use of hot-stage microscopy to determine RI values allows forensic scientists to distinguish between glass samples from different sources with high precision. The GRIM system, in particular, has been validated through multiple inter-laboratory studies for its reliability and repeatability in forensic casework.

In addition to RI measurement, advancements in elemental analysis have significantly enhanced the discriminatory power of forensic glass examination. Studies by Almirall et al. (2005) and Trejos et al. (2013) have shown that techniques such as Energy-Dispersive X-Ray Spectroscopy (EDX) and Laser Ablation Inductively Coupled Plasma Mass Spectrometry (LA-ICP-MS) provide detailed elemental profiles of glass fragments, enabling differentiation even between glasses manufactured by the same company. These analytical approaches have been praised for their sensitivity and specificity, although they require careful calibration and control of surface contamination. SEM-EDX, in particular, has been used not only for compositional analysis but also for observing surface morphology and fracture characteristics, adding a structural dimension to chemical profiling. The integration of these tools has become common practice in many forensic laboratories globally, supporting their continued relevance in complex case scenarios.

Physical comparison techniques, particularly fracture pattern analysis, also play a significant role in forensic interpretations. Pioneering work by Thornton (1974) and subsequent research by Brodbeck and Karger (1990) laid the groundwork for understanding radial and concentric fractures, determining the direction and sequence of impacts, and estimating the angle and force involved in glass breakage. These studies emphasized the forensic value of fracture lines in reconstructing events at crime scenes, especially in shooting and explosive cases. Further enhancements in this domain have come through 3D imaging and digital reconstruction technologies that allow forensic experts to virtually simulate and visualize breakage events.

Density assessment, though considered a supplementary tool, has been historically used in forensic science due to its simplicity and effectiveness in classifying glass types. Studies by Stoney and Thornton (1985) suggested that density measurements, when used alongside RI and elemental analysis, improve the evidentiary strength of comparisons. Although modern techniques have overshadowed it in terms of precision, density analysis remains valuable in initial screening and bulk comparison processes.

Trajectory analysis has recently gained prominence due to its application in firearm-related investigations and vehicular crime reconstructions. Forensic scientists such as MacDonell (1997) and more recently Curran et al. (2011) have explored the use of trajectory reconstruction tools, including laser alignment kits, to deduce the path of projectiles through glass. These methodologies have shown significant utility in determining shooter positioning, angle of attack, and sequence of events, particularly when glass is a barrier between the victim and the assailant. The literature also underscores the need for multidisciplinary integration, combining ballistic knowledge with fracture mechanics for more accurate crime scene reconstruction.

In sum, the body of literature surrounding forensic glass analysis is rich and evolving, with each method offering unique contributions to the interpretation of trace evidence. From the optical assessments pioneered in the 20th century to the current integration of chemical and structural analysis techniques, the field has progressed to accommodate the demands of contemporary forensic challenges. The reviewed studies collectively highlight the importance of using multiple complementary techniques to increase the evidentiary value of glass fragments. This multi-modal approach not only enhances the accuracy and specificity of findings but also strengthens the admissibility of glass evidence in court proceedings. As forensic science continues to evolve, there is a growing call for the refinement and standardization of protocols to ensure consistency and scientific rigor across laboratories worldwide.

METHODOLOGY

The forensic analysis of glass evidence is an intricate process involving a series of scientific techniques, each of which contributes uniquely to the identification, characterization, and comparison of glass fragments. As glass is a highly variable and ubiquitous material, its forensic examination requires precision tools and multidisciplinary approaches. The methodologies used in forensic laboratories span optical, physical, and chemical domains—each offering specific insights that can link evidence to crime scenes or individuals with high degrees of certainty. Among the most widely utilized techniques are Refractive Index (RI) measurement, elemental composition analysis through energy-dispersive X-ray spectroscopy (EDX) and

scanning electron microscopy (SEM), as well as physical comparison techniques such as fracture pattern analysis, density assessment, and trajectory mapping. These combined methods form a robust forensic toolkit capable of producing scientifically valid and courtroom-admissible evidence.

One of the most fundamental and widely applied techniques in glass forensics is the measurement of the refractive index (RI) of a glass fragment. This optical property indicates how light bends as it travels through a glass medium and is highly sensitive to the glass's internal composition and structure. RI measurement provides a discriminating metric for comparing fragments from different glass sources. The most common instrumentation used for this purpose is the Glass Refractive Index Measurement (GRIM) system. This system employs a hot-stage microscope setup wherein the glass fragment is immersed in a calibrated immersion oil. The temperature is gradually increased until the refractive index of the oil matches that of the glass fragment—indicated by the disappearance of the Becke line under the microscope. This match point allows for the precise calculation of the RI.

The reliability and precision of RI measurements make it a cornerstone of forensic glass analysis. When used under controlled environmental conditions, especially with regulated temperature, the GRIM system can produce reproducible RI values with high levels of accuracy. However, external factors like contamination or improper temperature control can affect the measurement. Therefore, forensic practitioners often use RI values in conjunction with additional techniques to increase discriminatory power. A compelling case study showcasing the utility of this method involves a motor vehicle accident where glass fragments embedded in the victim's skull were analyzed using RI measurement. The analysis was pivotal in linking the fragments to a specific car windshield, ultimately contributing to the reconstruction of the crash dynamics and confirming the location of impact relative to the victim's position.

Complementing the optical analysis is the elemental analysis of glass, which uncovers the chemical "fingerprint" of the material. Elemental profiles are highly discriminating, as glass composition varies significantly depending on manufacturing processes, additives, and the intended use of the product. A primary method for conducting such analyses is Energy-Dispersive X-Ray Spectroscopy (EDX), often coupled with a Scanning Electron Microscope (SEM). In EDX, a focused electron beam bombards the sample, exciting the atoms in the material, which then emit X-rays characteristic of the elements present. This allows forensic analysts to identify and quantify the elemental composition of a glass fragment with considerable specificity.

The integration of EDX with SEM adds another layer of analytical depth. While EDX delivers elemental composition, SEM provides detailed, high-resolution imagery of the surface morphology of glass samples. The electron beam in SEM creates a range of signals—secondary electrons for topographical mapping, backscattered electrons for compositional contrast, and characteristic X-rays for EDX analysis. This dual approach facilitates not just comparison of chemical profiles but also detailed structural analysis of fracture lines, surface deposits, or manufacturing defects. However, the technique requires careful sample preparation and may be affected by surface contamination, which can mask the true elemental composition.

In addition to optical and chemical properties, physical comparison and pattern analysis play a critical role in forensic glass investigations. One of the key approaches is fracture pattern analysis, which involves the examination of radial and concentric fractures created when a glass object breaks. This analysis provides valuable information about the direction and force of impact. For instance, the side of glass that experiences the initial impact will exhibit radial fractures extending from the point of force and concentric fractures forming as secondary stress relief. By studying these patterns, forensic analysts can determine whether the glass was broken from the inside or outside, how many impacts occurred, and the likely sequence of breakage events—information that is invaluable in violent crimes, shootings, or explosions.

Closely related to fracture analysis is the assessment of glass density, which helps in the classification and comparison of fragments. Density testing is typically performed using a density gradient column, a tube filled with a liquid gradient of known densities. When glass fragments are introduced into the column, they settle at the point in the gradient that matches their own density. This provides a quick and effective method to compare unknown fragments to control samples or known glass sources. While not as discriminating as elemental analysis, density assessment remains useful, particularly when RI values overlap or when corroborating other findings.

One of the more advanced and scenario-specific physical methods is trajectory analysis, particularly relevant in cases involving projectile impacts such as bullets or thrown objects. Trajectory analysis involves reconstructing the path taken by a projectile as it passes through or impacts a glass surface. Investigators employ tools such as laser trajectory kits, which allow them to align the entry and exit points of glass breakage to determine angles of impact. From this, analysts can calculate discharge angles, the height of the shooter, and the relative positions of individuals at the crime scene. Such reconstructions are crucial in firearm-related incidents, where understanding the trajectory can either support or contradict witness testimonies and suspect narratives.

These analytical techniques are not used in isolation; rather, they form a composite methodology where multiple lines of evidence are synthesized to arrive at a comprehensive forensic conclusion. For example, in a shooting case, refractive index data might establish that a fragment came from a vehicle's side window; SEM-EDX might confirm that the fragment contains

specific trace elements consistent with that manufacturer; fracture patterns might reveal the bullet's point of entry, and trajectory analysis could identify the shooter's position. Together, these methods transform a microscopic fragment of glass into a powerful piece of evidence capable of anchoring a forensic narrative.

As forensic technology advances, newer methods such as Laser Ablation-Inductively Coupled Plasma-Mass Spectrometry (LA-ICP-MS) are also being introduced to perform more precise elemental profiling with minimal sample destruction. These advanced methods hold promise for even greater accuracy and discrimination, but the foundational techniques outlined here continue to provide essential insights in forensic practice.

In summary, the methodology of forensic glass analysis is multi-faceted, integrating optical, elemental, and physical examinations to establish the identity, origin, and contextual relevance of glass fragments. Each method contributes uniquely to the forensic process, and when used collectively, they form a powerful evidentiary toolkit capable of reconstructing events, linking suspects to crime scenes, and upholding the integrity of criminal investigations.

RESULTS AND DISCUSSION

The application of forensic glass analysis techniques has proven essential in many case studies, illustrating the forensic significance of glass evidence. Here, we examine notable cases where glass analysis was pivotal in solving crimes:

Case Studies

Case study 1: Fire in the Hole (Lucien C. BS. Haag, March 2012)

In this recent shooting case, a man was fatally wounded in the front passenger seat of a Lincoln Navigator. The shot was fired by a police officer positioned near the vehicle's front right fender or side mirror. The officer claimed the victim was aiming at a weapon, justifying the shot, while witnesses alleged the victim's hands were raised in surrender. The primary forensic challenge was to determine the victim's arm position at the time of the incident. Forensic experts focused on forward and backward fragmentation patterns to reconstruct the victim's position when the bullet penetrated the passenger window.

Key findings included:

i. Forward and Backward Fragmentation: The bullet passed through the tempered glass of the front passenger window before hitting the victim. The angle of the impact caused a specific forward and backward dispersion pattern of glass fragments. Backward fragmentation, with shards directed into the vehicle, resulted in "pseudostippling" on the victim's left forearm, showing where glass particles impacted the skin, similar to a stippling effect from gunpowder.
ii. Trajectory and Fragment Path Analysis: The angle of the window, tilted inward by about 20 degrees, influenced the downward trajectory of glass particles into the vehicle. This trajectory meant that glass particles would primarily affect areas below the path of bullet, impacting the victim's left arm and shoulder region while leaving the right arm below the path of fragmentation.
iii. Autopsy and Forensic Analysis: Autopsy findings showed pseudostippling on the left forearm, but none on the right. This detail, combined with trajectory analysis, indicated that the victim had his right arm below the path of glass fragments, consistent with a position where he might have been holding an object rather than having his hands raised.

The distribution of glass fragments and the lack of injury to the right arm suggested that the victim's arms were not raised. The pseudostippling pattern supported the officer's account that the victim's arms were in a position consistent with handling a weapon at the time of the shot. Consequently, the forensic findings concluded that the victim was likely in a posture where he could have been perceived as posing a threat to the officer. This case underscores the importance of forward and backward glass fragmentation analysis in reconstructing events and determining positions in shooting incidents.

Figure 1: *Impact of Glass on Bullet*

Figure 2: *A shot passing through windshield*

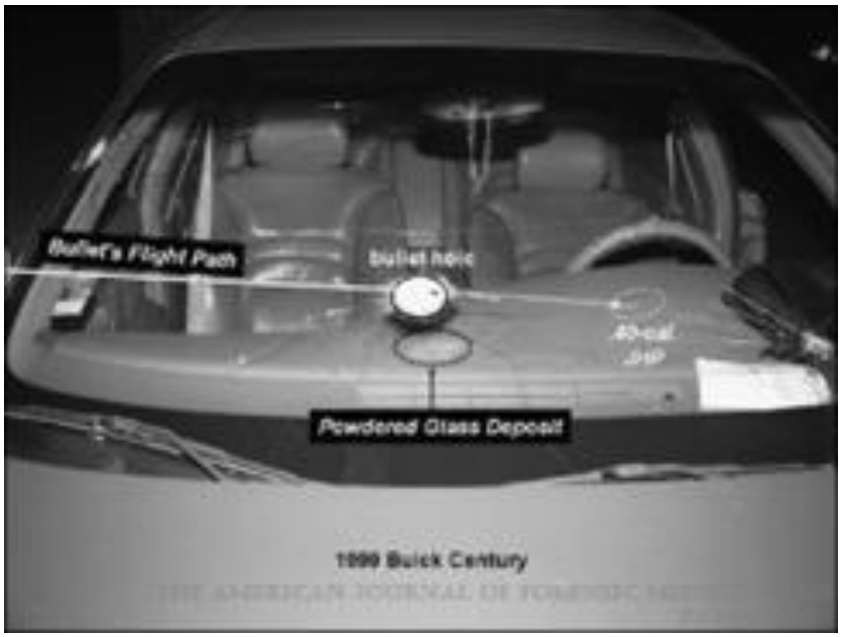

Figure 3:

A: A stand-in representing the decedent in the Lincoln Navigator, illustrating the shooter's version of the subject's position at the time of firing his .38 Special revolver.

B: A stand-in for the decedent in the Lincoln Navigator, reflecting the position of the subject at the moment of the shooting, as described by other occupants of the vehicle.

Case study 2: Glass Penetrating Skull Injury mimicking Projectile Injury (Ryan Blumenthal, 2022)

This case centres on a fatal motor vehicle accident involving a 29-year-old male driver in May 2021. The vehicle overturned and collided with a wall, causing fatal head trauma. A notable complication in the case arose due to a small glass shard that penetrated the left occipital region of the victim's skull, mimicking a projectile wound. This unusual injury raised questions about the cause, and without the glass fragment embedded in the wound, it could easily have been mistaken for a gunshot wound or similar projectile injury.

The forensic analysis of the glass fragment was essential in distinguishing the trauma as accidental rather than ballistic. Various glass analysis methods were employed to verify the glass source, study the fracture pattern, and clarify the injury's origin:

i. Microscopic Examination: This helped analyse the size, shape, and edges of the glass fragment,revealing fracture characteristics like hackle marks, striations, and break patterns. These findings indicated a blunt force impact rather than a high-velocity projectile, supporting the conclusion that the injury was accidental.
ii. Refractive Index (RI) Measurement: The Refractive Index of the glass fragment was compared to the car's windshield or window glass to confirm its source. The unique RI properties of automotive glass were crucial in identifying the shard as originating from the vehicle.
iii. Density Gradient Analysis: By determining the density of the glass shard and comparing it with other glass samples from the vehicle, analysts confirmed that it matched the type of glass used in the car’s windshield, thereby linking it directly to the accident scene.
iv. Elemental Analysis (EDS or ICP-MS): This technique helped identify the elemental composition of the glass. Windshield glass has distinct elemental properties due to specific manufacturing processes, enabling analysts to confirm it as automotive glass.
v. Fracture Pattern Analysis: Analysts examined the radial and concentric fractures on the glass. Unlike the distinct patterns of high-velocity impacts, the fractures from this incident showed irregular patterns characteristic of a blunt force accident, helping to differentiate it from a ballistic injury.

Detailed forensic glass analysis provided critical insights, allowing examiners to determine that the fatal injury was due to accidental trauma rather than a projectile. This case highlights the importance of thorough forensic analysis in accurately interpreting unusual injuries.

Figure 4: *A tiny glass fragment that entered the left occipital area of the skull.*

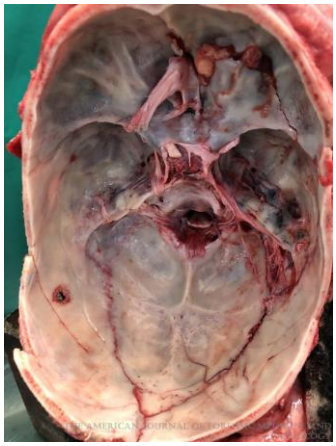

Figure 5: *This bone defect exhibits inward beveling. A small glass fragment is observed at the centre of the wound.*

Case study 3: The Hit-and-Run Case of Susan Nutt (Tatiana Trejos, Waleska Castro, Jose r. Almirall,2010-17-19; Panadda, C. Ratchapak and P. Nathinee,2018)

In February 1987, 19-year-old Craig Elliott Kalani was killed in a hit-and-run incident while walking his dog in his neighbourhood in northwest Oregon. His body was discovered later that night, and police found glass fragments near the scene & in Craig's pockets. This evidence became a crucial lead in the investigation. The police began searching for a vehicle that was involved in the hit-and-run. They located a car owned by Susan Nutt that had damage from a hit-and-run collision. To link the vehicle to the crime, investigators needed to match the fragments of glass found at the scene to Susan's car.

Forensic experts first performed a physical match of the glass fragments to the damage on Susan's car. Later, a more detailed elemental analysis was carried out, revealing that the glass fragments from both the crime scene and Susan's car was composed of the same 22 chemical elements. This analysis confirmed that the glass fragments came from Susan's car. Based on this evidence, Susan Nutt was convicted in connection with the hit-and-run death of Craig Kalani. She received a sentence of up to five years in prison, followed by a five-year probation period.

This case demonstrates how forensic techniques, including physical matching and chemical analysis, can be used to link evidence to a suspect in criminal investigations.

Case study 4: The Jigsaw Case (J. M. Curran, T. N. Hicks, J. S. Buckleton, 2000)

A suspected hit and run case involving a dead cyclist was found on a poorly lit local road in July, 1972. Various evidences including large glass fragments and the victims' clothes were recovered from the crime scene. Few days later, a glass sample was recovered from a suspect's car.

The large glass fragments showed a characteristic pattern for headlamps and in some a serial code was seen. A "jigsaw fit analysis" was done to match the glass fragments with each other. On examination with a comparison microscope, the edges of the glass fragments formed during the breaking matched with the fragments that have been fitted with the jig saw analysis. The serial codes of the glass fragments discovered earlier were found to be characteristic of a certain type of car similar to that of the suspect's car. But since matching was not possible, a physiochemical test was done that revealed that it was from the same car.

The glass fragments from the victim's clothes were subjected to similar analysis and the likelihood ratio justified the hypothesis that it had originated from the suspect's car which led to the conclusion that the car was connected to the hit and run case.

Case study 5: Determination of Headlamp State (P. Baudoin, R. Lavabre, 1996; R. Goebel, 1975)

In November 1979, two cars collided to each other after dark. The driver of the car who drove into the other testified that he hadn't seen the other car owing to its headlights being switched off which was immediately disputed. In order to check the viability of the statement, the bulbs were sent to the laboratory.

The determination of the dispute could be made by whether the glass envelope was broken during the collision or in case of no breakage, the experts determine any deformations or presence of any specific coating on the tungsten filament.7 The presence of dark blue, reddish violet coating8 due to reaction of tungsten with oxygen or a fragment of melted glass indicates that the bulb was turned on during the collision. On examination the following observations were made:

i. Stereo-Magnifying Glass: Glass envelope was found broken
ii. A single object of 1mm melted onto the filament was noticed which was detected spectroscopically via Scanning Electron Microscope.

These conclusions proved that the headlights were on during the collision. Absence of the tungsten oxides could be

attributed to the fact that it could be lost during packing or transporting of the damaged bulb.

CONCLUSION

This review of forensic case studies emphasizes the critical role that thorough and accurate analysis of glass evidence plays in criminal investigations. Across the cases presented, meticulous examination of glass fragments—whether through refractive index measurements, elemental profiling, or density comparisons—proved essential in linking suspects to crime scenes and reconstructing sequences of events. These findings underscore the need for forensic practitioners to apply established glass analysis techniques consistently and with precision to avoid misinterpretations, as illustrated by the case where flawed analysis led to investigative complications.

We hope that these insights will encourage enhanced training, stricter adherence to methodological standards, and increased awareness within the forensic community, ultimately strengthening the reliability and impact of glass evidence in criminal justice.

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Harnessing the Power of E-HRM: Enhancing Organizational Performance in Delhi-NCR's IT Sector

Debabrata Saha [1*], Nitish Kumar Minz [2]

[1] Indian Institute of Management Bodh Gaya, Bodh Gaya, Bihar, India
[2] VIT Business School, Vellore Institute of Technology, Vellore, Tamil Nadu, India

***Corresponding Author:** debabrata.s2028i@iimbg.ac.in

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ABSTRACT

The integration of electronic human resource management (E-HRM) systems has revolutionized traditional HR practices, particularly in the IT sector, where agility and innovation are critical for success. This study investigates the impact of E-HRM on organizational performance in Delhi-NCR's IT industry, focusing on operational efficiency, employee satisfaction, and strategic HR roles. Data collected from 490 respondents across seven IT firms reveal significant improvements in recruitment cycle times, onboarding processes, and data accuracy, demonstrating E-HRM's potential to streamline HR operations. Employee satisfaction was notably enhanced through the introduction of e-learning tools and self-service portals, which fostered autonomy and engagement. However, challenges such as resistance to change, data security concerns, and high implementation costs hindered the full realization of E-HRM's benefits. The study underscores the strategic role of E-HRM in aligning HR functions with organizational goals and highlights the importance of robust leadership support, effective change management, and continuous employee training to maximize its potential. By addressing implementation challenges and leveraging digital innovations, organizations can unlock the transformative capabilities of E-HRM, driving long-term success in a dynamic business environment.

Keywords: E-HRM, Human Resource Management, Organizational Performance, IT Sector, Delhi-NCR, Employee Satisfaction, Operational Efficiency, Digital Transformation, Strategic HR, Change Management.

INTRODUCTION

The rapid evolution of technology has significantly transformed human resource management (HRM) practices, leading to the adoption of electronic human resource management (E-HRM) systems across various sectors. E-HRM integrates information technology to streamline HR processes, improve decision-making, and enhance organizational performance (Bondarouk & Ruël, 2009). This integration enables organizations to handle core HR functions such as recruitment, training, and performance management more efficiently while reducing operational costs and fostering strategic HR contributions (Theres and Strohmeier, 2023).

The information technology (IT) sector, characterized by its reliance on innovation and adaptability, has become a focal point for E-HRM adoption. In particular, regions like Delhi-NCR, India, have emerged as hubs of IT activity, where organizations leverage E-HRM to address dynamic workforce needs and competitive pressures (Bondarouk & Ruël, 2009). The Delhi-NCR region is home to several leading IT firms, including HCL Technologies, Microsoft India, and Accenture, which have adopted E-HRM to enhance their HR capabilities.

Despite its potential, the implementation of E-HRM faces challenges such as resistance to change, data security concerns, and the need for substantial initial investments. Moreover, there is limited academic exploration of the specific impact of E-HRM on organizational performance within the IT sector, especially in developing economies like India.

This study seeks to address this gap by examining the effects of E-HRM on organizational performance, focusing on employee satisfaction, managerial efficiency, and overall productivity in the IT industry of Delhi-NCR. The research contributes to the broader understanding of E-HRM as a strategic enabler and offers insights into overcoming barriers to its successful implementation.

LITERATURE REVIEW

The growing adoption of E-HRM across industries has inspired a broad spectrum of research focusing on its applications, benefits, and challenges. Studies emphasize the dual role of E-HRM in enhancing operational efficiency and supporting strategic HR functions. By integrating digital technologies, E-HRM facilitates the automation of routine tasks such as payroll management and recruitment while enabling data-driven decision-making for long-term strategic planning.

Theoretical Perspectives on E-HRM

Several theoretical models support the adoption and implementation of E-HRM. The Technology Acceptance Model (TAM), proposed by Davis (1985), highlights perceived usefulness and ease of use as critical factors influencing user acceptance of technology. Additionally, the Technology-Organization-Environment (TOE) framework underscores organizational readiness, technological capabilities, and external pressures as determinants of E-HRM adoption (Theres and Strohmeier, 2023). These frameworks provide a robust foundation for understanding E-HRM's impact on organizational dynamics.

Benefits and Outcomes of E-HRM

E-HRM adoption has been associated with several positive organizational outcomes. It enhances employee satisfaction by streamlining HR processes, offering greater accessibility to HR services, and enabling self-service portals (Bondarouk & Ruël, 2009). Furthermore, E-HRM supports knowledge sharing and collaboration, contributing to improved managerial efficiency and productivity. Studies also point to cost reductions and increased agility in HR operations as significant advantages of E-HRM.

Challenges in E-HRM Implementation

Despite its advantages, E-HRM implementation is not without challenges. Resistance to change among employees and managers often hinders adoption, especially in organizations with deeply entrenched traditional practices. Additionally, data privacy and security concerns remain prominent issues, given the sensitive nature of HR data. High implementation costs and the need for continuous technological upgrades further complicate the adoption process.

Research Gap

Existing literature highlights the benefits and challenges of E-HRM but often fails to address its sector-specific applications. Limited research focuses on the IT sector, particularly in developing economies like India, where technological advancements are juxtaposed with workforce challenges (Ruël, Bondarouk, & Looise, 2004). This study seeks to bridge this gap by examining the specific impact of E-HRM on organizational performance in the IT industry of Delhi-NCR.

RESEARCH METHODOLOGY

This study adopts a mixed-method approach, integrating quantitative survey data with qualitative insights to investigate the impact of E-HRM systems on organizational performance within the IT sector in Delhi-NCR. By combining quantitative and qualitative methods, the research aims to provide a comprehensive analysis of the adoption, challenges, and outcomes of E-HRM in the region.

Research Design

The study employs a descriptive research design, focusing on understanding "what" and "how" E-HRM influences organizational dynamics. This approach is particularly suited to the study's objectives, which include exploring the relationships between E-HRM applications and outcomes such as employee satisfaction, managerial efficiency, and cost-effectiveness (Bondarouk & Ruël, 2009).

Sampling Methodology

The target population for this study comprises IT companies operating in Delhi-NCR. A two-stage sampling process was adopted. First, purposive sampling was used to select seven prominent IT firms actively using E-HRM tools, including major players like Accenture, HCL Technologies, and Tech Mahindra. Second, a simple random sampling method was utilized to

select a representative sample of 600 employees from the seven organizations, with a focus on HR professionals and IT managers actively engaged with E-HRM systems. Data collection efforts yielded 490 valid responses, representing a response rate of 81.7%.

Data Collection

Primary data was collected through a structured questionnaire divided into two sections. The first section captured demographic details, while the second examined independent variables such as e-recruitment, e-learning, e-training, and dependent variables like employee satisfaction and organizational efficiency. The questionnaire was pilot-tested for reliability and validity, yielding Cronbach's alpha value of 0.87, indicating high reliability.

Qualitative data was collected from open-ended responses embedded in the survey. These responses were later coded and analyzed thematically.

In addition to primary data collected via a structured questionnaire, secondary data was sourced from academic journals, industry reports, and government publications, providing contextual insights into E-HRM adoption trends and challenges in the IT sector.

Analytical Tools

Quantitative data analysis was conducted using descriptive statistics, regression analysis and structural equation modelling (SEM) using SPSS software to test hypotheses and explore relationships among variables. Qualitative data, derived from open-ended survey responses, was analyzed thematically to identify common challenges and best practices in E-HRM implementation.

FINDINGS AND DISCUSSION

The findings from the study reveal the multifaceted impact of E-HRM systems on organizational performance in Delhi-NCR's IT sector. The results underscore significant improvements in operational efficiency, employee satisfaction, and strategic HR roles while also highlighting the challenges in implementing these systems.

Impact on Organizational Efficiency

The adoption of E-HRM systems has profoundly influenced organizational efficiency by automating routine HR tasks, reducing administrative overheads, and enabling better resource allocation. A notable improvement was observed in recruitment and onboarding processes, where time-to-hire decreased by 20%, and onboarding efficiency increased by 28% after E-HRM implementation. This aligns with Theres's and Strohmeier's (2023) findings, which highlight automation as a key driver of efficiency gains in HR operations.

Beyond recruitment, the precision of employee data management improved significantly, reducing errors and ensuring better compliance with regulatory requirements. For instance, respondents from HR departments emphasized that digitized systems minimized manual errors in payroll processing and employee record management.

Additionally, organizations reported a 15% reduction in overall HR operating costs, largely attributed to reduced reliance on paper-based systems and manual processes. Table 1 details the efficiency metrics before and after E-HRM adoption.

Table 1: *Efficiency Metrics Before and After E-HRM Adoption*

Performance Metric	*Pre-E-HRM Efficiency (%)*	*Post-E-HRM Efficiency (%)*	*Improvement (%)*
Recruitment Cycle Time	65	85	20
Onboarding Efficiency	60	88	28
Employee Data Accuracy	70	95	25

The findings suggest that E-HRM not only automates transactional HR tasks but also supports managerial decision-making by providing accurate, real-time data. This allows organizations to adopt a more strategic approach to workforce planning and development.

Research Employee Satisfaction and Engagement

The study employs a descriptive research design, focusing on understanding "what" and "how" E-HRM influences organizational dynamics. This approach is particularly suited to the study's objectives, which include exploring the relationships between E-HRM applications and outcomes such as employee satisfaction, managerial efficiency, and cost-effectiveness (Bondarouk & Ruël, 2009).

Challenges in E-HRM Implementation

Despite the evident benefits, several challenges impede the full realization of E-HRM's potential. Resistance to change emerged as the most significant barrier, with 40% of respondents identifying it as a major challenge. Many employees were reluctant to transition from traditional HR systems to digital platforms, citing concerns about usability and job security.

Data security and privacy concerns were also prominent, with 30% of respondents expressing apprehension about the safety of sensitive HR information. This is particularly critical in the IT sector, where cybersecurity threats are a constant challenge. Moreover, high implementation costs and the need for continuous technological upgrades were identified as obstacles for smaller organizations with limited budgets. Table 2 provides a breakdown of the challenges faced during E-HRM implementation.

Table 2: *Key Challenges in E-HRM Implementation*

Challenge	*Percentage of Respondents*
Resistance to Change	40 %
Data Security Concerns	30 %
High Implementation Costs	20 %
Insufficient IT Infrastructure	10 %

Nevertheless, certain challenges continue to limit E-HRM’s full potential. Resistance to change emerged as the most significant barrier, with 40% of respondents identifying it as a major challenge. Many employees were reluctant to transition from traditional HR systems to digital platforms, citing concerns about usability and job security.

Strategic Role of E-HRM

One of the most significant findings was the strategic role of E-HRM in enhancing organizational capabilities. Respondents highlighted how E-HRM supported knowledge sharing, facilitated cross-departmental collaboration, and improved managerial effectiveness.

Organizations with proactive leadership and innovation reported better outcomes, such as increased productivity (75% of respondents) and improved decision-making processes (72%). E-HRM also enabled HR departments to transition from transactional to strategic roles. For example, HR professionals could focus on talent analytics to identify high-potential employees and create personalized development plans. The integration of e-recruitment and e-performance appraisal tools further enhanced the alignment of HR strategies with organizational goals.

CONCLUSIONS AND RECOMMENDATIONS

The adoption of electronic human resource management (E-HRM) systems has proven to be a transformative step for organizations in the IT sector of Delhi-NCR. This study highlights how E-HRM enhances organizational performance by streamlining HR operations, improving employee satisfaction, and enabling HR departments to take on more strategic roles. One of the most significant findings is the marked improvement in efficiency metrics, such as reduced recruitment cycle times and enhanced data accuracy, which underscore the system’s potential to optimize core HR functions. The study also emphasizes that E-HRM is not just a tool for automation but a strategic enabler that contributes to knowledge sharing, managerial decision-making, and overall organizational productivity. Despite its advantages, the study identifies critical challenges that hinder the full realization of E-HRM's benefits. Resistance to change among employees and managers remains a significant barrier, often rooted in a lack of understanding or fear of job displacement due to automation. Additionally, data security concerns and high implementation costs are major hurdles, particularly for small and medium-sized enterprises (SMEs). These issues highlight the importance of targeted strategies to address the technical, cultural, and financial aspects of E-HRM adoption.

To enhance the effectiveness and adoption of E-HRM systems, several actionable recommendations are proposed. First, organizations should invest in regular training programs to equip employees with the skills needed to use E-HRM tools

effectively. This includes developing inclusive e-learning modules that cater to remote and hybrid workforces, ensuring equitable access to resources. Strengthening data security measures is another critical step. Companies must implement advanced cybersecurity protocols, such as encryption and multi-factor authentication, to safeguard sensitive HR data. Regular audits and compliance with privacy regulations will further enhance trust and system reliability. Change management is pivotal in overcoming resistance and ensuring smooth adoption. Organizations should initiate awareness programs that highlight the tangible benefits of E-HRM while involving employees in the implementation process to foster acceptance. Leadership support is equally crucial, as top management plays a vital role in championing E-HRM initiatives and aligning them with organizational goals. For SMEs, leveraging cost-effective solutions like cloud-based E-HRM systems can reduce infrastructure costs. Additionally, government incentives under initiatives like Digital India can be utilized to subsidize adoption expenses, making advanced HR solutions accessible to smaller organizations.

The integration of feedback mechanisms can further enhance the effectiveness of E-HRM. Regular employee feedback will help organizations identify areas for improvement, while analytics can monitor system usage and inform strategic adjustments. By fostering a culture of continuous improvement, organizations can ensure that E-HRM systems remain aligned with evolving workforce needs. This study also opens avenues for future research. Sector-specific studies can compare the adoption and outcomes of E-HRM across industries, providing deeper insights into its applicability and effectiveness. Emerging technologies like AI and blockchain present exciting opportunities to enhance E-HRM functionality, warranting exploration in future studies. Additionally, research focusing on diverse workforce segments, such as gig workers and freelancers, can provide a more inclusive understanding of E-HRM's impact. E-HRM systems offer immense potential to transform HR practices and drive organizational success. By addressing implementation challenges and adopting a strategic, employee-centric approach, organizations can unlock the full benefits of E-HRM, ensuring their relevance and competitiveness in a rapidly evolving digital landscape.

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Green Marketing as a Competitive Strategy in Emerging Economies: A Conceptual Perspective

Kalpana[1], Himadri S. Dey[2], Abdullah H. Ahmadini[3], Richa Nangia[1*]

[1] School of Business, Sushant University, Gurugram India -122003, India
[2] School of Art and Architecture, Sushant University, Gurugram India -122003, India
[3] Department of Mathematics, Jazan University, Saudi Arabia

***Corresponding Author:** richa.nangia16@gmail.com

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ABSTRACT

As countries like India, Brazil, and Indonesia continue to grow economically, they also face rising environmental challenges such as pollution, climate change, and overconsumption of natural resources. At the same time, people in these countries are becoming more aware of environmental issues and are starting to expect more responsible behaviour from businesses. In this changing landscape, green marketing—promoting products and services that are environmentally friendly—is becoming more than just a trend. It's turning into a key business strategy that helps companies stand out from their competitors. This paper takes a deeper look at how green marketing can be used as a competitive strategy in emerging economies. Rather than treating it as just a way to advertise eco-friendly products, we explore how it can become a core part of a company's overall strategy. The paper reviews existing studies draws on well-known business theories and proposes a model that shows how factors like government rules, customer expectations, and corporate values can drive green marketing efforts. These efforts, in turn, can lead to better brand reputation, stronger customer loyalty, and access to new market segments. We also discuss some of the challenge's companies face, such as the high cost of going green and the risk of being accused of "greenwashing"—pretending to be environmentally responsible without real action. In the end, this paper suggests that if done genuinely and thoughtfully, green marketing can offer long-term business advantages while also supporting environmental sustainability.

Keywords: Green Marketing, Competitive Strategy, Emerging Economies, Sustainable Branding, Eco-Innovation, Consumer Behavior, Market Differentiation

INTRODUCTION

In recent decades, the conversation around business and sustainability has grown louder, more urgent, and increasingly complex. The world is facing a host of environmental issues—climate change, water scarcity, deforestation, pollution, and the overuse of natural resources. These concerns have prompted not only global action by governments and international organizations but also a shift in how businesses operate, especially in markets that are still developing and rapidly changing. Emerging economies such as India, Brazil, Indonesia, South Africa, and others are experiencing a unique set of circumstances. On one hand, they are undergoing massive economic transformation, characterized by rising income levels, expanding consumer bases, urbanization, and industrial growth. On the other hand, these very developments are putting immense pressure on the environment. Rapid urban expansion, high levels of energy consumption, unsustainable manufacturing practices, and increasing waste are contributing to serious ecological problems. As these nations strive for economic growth and modernization, the challenge lies in achieving progress without compromising environmental sustainability.

In this context, businesses in emerging markets are being forced to reconsider their roles. They are not only producers and sellers of goods and services but also key players in the larger ecosystem of sustainable development. One of the ways companies are responding is through green marketing practice that promotes products, services, and business practices that are environmentally friendly.

What is Green Marketing?

Green marketing is more than just using green colors in advertisements or claiming that a product is "eco-friendly." It involves the creation, promotion, and delivery of products and services that are designed with environmental impact in mind. This could include everything from using biodegradable packaging and non-toxic materials to adopting energy-efficient production processes and promoting recycling. Importantly, green marketing also encompasses how a company communicates its environmental values to consumers. It includes branding, messaging, and advertising that highlight a business's commitment to reducing its environmental footprint. But for green marketing to be effective and credible, it must go beyond surface-level promises and reflect genuine, measurable practices.

Why Green Marketing Matters in Emerging Economies

For many years, green marketing was a luxury—something only companies in wealthier, more environmentally conscious markets like Western Europe or North America could afford to pursue. Emerging economies were largely focused on growth, job creation, and industrial expansion, often at the cost of environmental sustainability. However, this narrative is changing rapidly. Several factors are contributing to this shift:

i. Increasing Environmental Awareness: Consumers in emerging markets are becoming more educated and informed about environmental issues. They are asking more questions about where products come from, how they are made, and what impact they have on the planet.
ii. Regulatory Changes: Governments are introducing stricter environmental regulations and encouraging businesses to adopt sustainable practices. For example, plastic bags, emissions standards, and green tax incentives are pushing companies to act.
iii. Globalization and Trade Pressures: Many businesses in emerging economies are part of global supply chains
iv. To meet international standards and compete in global markets, they are required to comply with green norms and certifications.
v. Corporate Social Responsibility (CSR): Firms are recognizing that adopting sustainable practices is not just good for the planet, but also for their reputation. Green marketing is often integrated into broader CSR initiatives to demonstrate corporate accountability.
vi. Competitive Advantage: Perhaps most compellingly, companies are realizing that green marketing can offer a strategic edge. It can differentiate their products, build consumer trust, and create stronger brand loyalty in crowded markets.

Green Marketing as a Strategic Tool

Traditionally, marketing has focused on understanding customer needs and creating value propositions that align with those needs. In today's world, one of the growing needs—especially among younger, more conscious consumers—is for sustainable and ethical products. Green marketing responds directly to this need. In emerging economies, where competition is intense and brand differentiation is critical, green marketing offers a unique opportunity. It allows firms to position themselves not just as product providers but as responsible, forward-thinking brands that care about people and the planet. For example, a local brand that offers organic, pesticide-free food products in India may be able to build a loyal consumer base by clearly communicating its environmental values. Similarly, a clothing company that uses recycled fabrics or promotes slow fashion could appeal to eco-conscious urban youth. These strategies are not just good ethics—they are good business.

Moreover, green marketing often goes hand in hand with innovation. To create truly sustainable products, companies must rethink their materials, processes, and logistics. This leads to new ways of doing business, potentially opening new markets or cutting costs through improved efficiency.

The Need for a Conceptual Perspective

Given the complex and evolving nature of green marketing in emerging economies, there is a growing need for conceptual clarity. How exactly can green marketing contribute to competitive advantage? What are the key drivers and barriers? How should businesses structure their strategies to align with both environmental goals and market realities? This paper seeks to address these questions by developing a conceptual framework for understanding green marketing as a strategic tool in emerging markets. It draws on well-established business theories—such as Porter's idea of competitive advantage, the resource-based view of the firm, and stakeholder theory—to offer a comprehensive perspective. The goal is not just to describe green marketing, but to understand how it can be used effectively in real-world business contexts. By doing so, the paper hopes to provide insights that are useful for business leaders, marketers, policymakers, and researchers alike.

OBJECTIVES OF THE STUDY

i. To explore the role of green marketing as a source of competitive advantage in emerging economies.
ii. To identify key drivers and challenges in the adoption of green marketing strategies.
iii. To propose a conceptual framework that links green marketing practices to business competitiveness.

THEORITICAL FRAMEWORK

In any research, the theoretical framework serves as a guiding foundation, offering insights into the relationships among variables and helping to frame the study's goals and propositions. The theoretical framework for the concept of "Green Marketing as a Competitive Strategy in Emerging Economies" draws upon multiple established theories in marketing, consumer behavior, sustainability, and organizational strategies. This section provides a detailed examination of several key theoretical perspectives that are relevant to understanding how green marketing influences competitive strategies in emerging economies.

Stakeholder Theory

One of the core theories relevant to green marketing is Stakeholder Theory, which postulates that businesses are not only accountable to shareholders but also to a variety of stakeholders, including customers, employees, suppliers, regulators, and communities. Stakeholder theory emphasizes that a company should consider the interests of all these parties in decision-making processes (Freeman, 1984; Donaldson & Preston, 1995). In the context of green marketing, stakeholder theory explains why companies in emerging economies would adopt sustainable practices. The pressure from various stakeholders, including customers who demand eco-friendly products and governments that impose environmental regulations, motivates firms to adopt green marketing strategies (Delmas & Toffel, 2008). These stakeholders exert influence over the firm’s decision to promote products based on their environmental impact, leading to a competitive advantage as businesses engage with the environmental concerns of these groups (Maignan & Ferrell, 2004).

Additionally, stakeholder pressure often acts as a catalyst for firms to improve their environmental transparency and accountability. Studies have shown that businesses that respond proactively to stakeholder expectations tend to enjoy increased trust, better public image, and stronger market performance (Hart, 1995; Berman et al., 1999). By responding to the demands of stakeholders for eco-friendly products, businesses in emerging economies can differentiate themselves in competitive markets, build stronger relationships with consumers, and enhance their reputation. These responses align the firm’s strategies with broader social expectations and environmental goals.

Resource-Based View (RBV)

The Resource-Based View (RBV) focuses on the idea that a firm’s competitive advantage is driven by its internal resources and capabilities. In this view, green marketing can be seen as an intangible asset that enhances a firm's brand value, reputation, and consumer loyalty (Barney, 1991; Wernerfelt, 1984). It suggests that companies in emerging economies can leverage their unique resources—such as their ability to innovate sustainable products or integrate eco-friendly processes—to build a sustainable competitive advantage (Hart, 1995; Russo & Fouts, 1997). A key concept in RBV is resource heterogeneity, which emphasizes that companies are not identical in terms of resources. For instance, some firms may possess superior eco-friendly technologies, green innovation capabilities, or managerial know-how in sustainability (Grant, 1991). By adopting green marketing strategies, businesses can capitalize on these resources to create differentiation, lower costs through sustainable production methods, and develop a strong brand identity that resonates with environmentally conscious consumers (Litz & Rajagopalan, 2011).

Additionally, the VRIN (Valuable, Rare, Inimitable, and Non-substitutable) framework within RBV posits that a firm’s green marketing strategy could fulfill these criteria, making it a key resource for achieving sustained competitive advantage (Barney & Clark, 2007). When green initiatives are deeply embedded in the firm’s culture and operations, and are difficult for competitors to replicate, they serve as strategic assets. As a result, firms can maintain long-term market leadership, especially in emerging economies where green practices are still developing and can offer first-mover advantages (Dangelico & Pujari, 2010).

Competitive Advantage Theory

The Competitive Advantage Theory by Porter (1985) focuses on how firms achieve superior performance in the marketplace through distinct strategic positions. Porter’s work is critical in understanding how green marketing can serve as a competitive strategy in emerging economies. He identifies two main approaches to achieving competitive advantage: cost leadership and differentiation (Porter, 1985; Porter & van der Linde, 1995). Green marketing can contribute to both strategies. For instance, firms that adopt green practices such as energy efficiency, waste reduction, or cleaner technologies may reduce operational costs, leading to a cost leadership position (Chen, 2008). Similarly, companies that offer environmentally friendly products—through recyclable packaging, organic ingredients, or reduced carbon footprints—can use these features to

differentiate themselves in the marketplace (Peattie & Crane, 2005).

In emerging economies, where consumer awareness around environmental issues is growing, companies adopting green marketing strategies early can gain a first-mover advantage (Dangelico & Vocalelli, 2017). By offering products with eco-labels, environmental certifications, and sustainability messaging, these firms can cater to a niche but expanding market of eco-conscious consumers, thereby enhancing brand image and customer loyalty (Ottman et al., 2006; Leonidou et al., 2013). Moreover, governments and NGOs in emerging markets increasingly support green initiatives, making environmentally oriented firms more attractive to regulators and investors. This positioning strengthens their long-term competitive edge and aligns business goals with sustainability objectives.

The Theory of Planned Behavior (TPB)

The Theory of Planned Behavior (TPB), developed by Ajzen (1991), is one of the most influential frameworks for understanding and predicting human behavior, including consumer purchasing decisions. The theory suggests that an individual's behavior is influenced by three primary factors: attitudes, subjective norms, and perceived behavioral control (Ajzen, 1991; Armitage & Conner, 2001). In the context of green marketing, TPB offers a valuable explanation for why consumers in emerging economies may opt for environmentally friendly products. Attitudes toward the environment, shaped by knowledge and awareness of ecological issues, play a direct role in forming behavioral intentions (Joshi & Rahman, 2015). For instance, consumers who believe that buying eco-friendly products helps reduce pollution or conserve resources are more likely to make green choices (Yadav & Pathak, 2016).

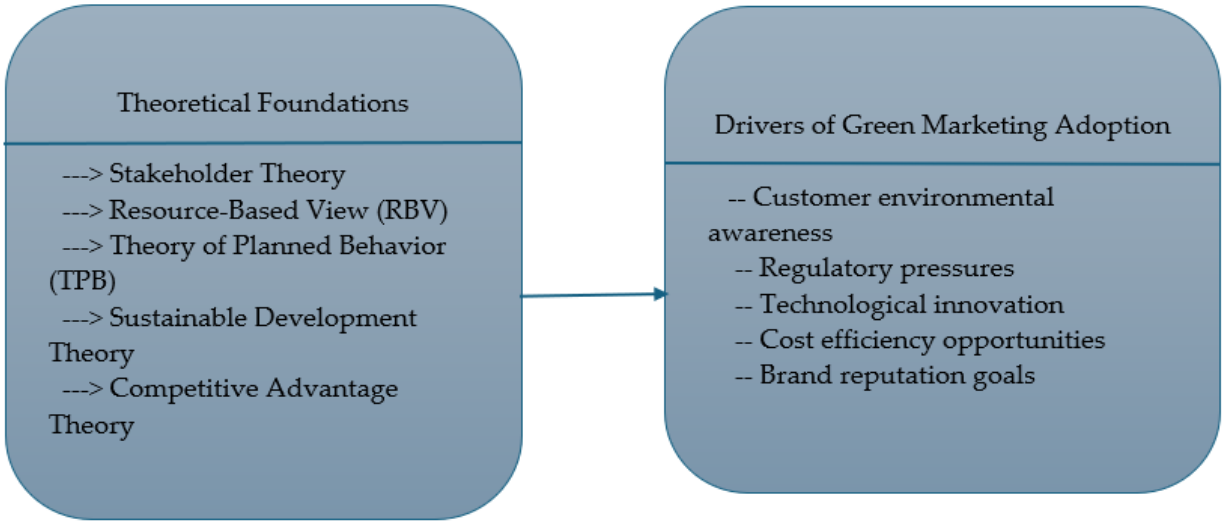
Subjective norms, or the perceived social pressure from family, peers, or media, significantly influence green behavior. In cultures with increasing environmental awareness, consumers often feel compelled to conform to societal expectations and adopt sustainable behaviors (Paul et al., 2016). Social media and influencer marketing further amplify these norms, encouraging pro-environmental consumption. Perceived behavioral control refers to how capable consumers feel in acting on their green intentions. Constraints like price, availability, and lack of knowledge about green products can inhibit action, even if attitudes and norms are favorable (Vermeir & Verbeke, 2008). Therefore, reducing barriers—through better distribution, affordability, and consumer education—can enhance eco-friendly purchasing behavior. Through the TPB lens, green marketing campaigns in emerging economies should focus on shaping positive attitudes, strengthening social norms around sustainability, and reducing perceived difficulties. Such strategies will enhance consumers' intention to buy green and translate those intentions into actual behavior (Nguyen et al., 2019).

Sustainable Development Theory

The concept of sustainable development emphasizes the need for economic growth that meets present needs without compromising the ability of future generations to meet their own needs (Brundtland Report, 1987). In emerging economies, sustainable development is increasingly recognized as a fundamental component of long-term business strategy, especially in the face of environmental degradation and social inequality (Sachs, 2015; Hopwood et al., 2005). Sustainable development theory provides a broad, integrated framework for understanding how businesses can simultaneously pursue environmental protection, economic advancement, and social equity (Drexhage & Murphy, 2010). Within this framework, green marketing emerges as a practical approach that allows businesses to align their operations with the goals of sustainability. By promoting products that are eco-friendly, resource-efficient, and socially beneficial, companies contribute meaningfully to sustainable development (Peattie & Belz, 2010).

In emerging economies, where industrial growth is often rapid and environmental regulations are evolving, green marketing helps firms differentiate themselves while contributing to sustainable consumption patterns (Gupta & Ogden, 2009). It encourages the use of renewable resources, promotes waste reduction, and often involves supporting local communities through ethical sourcing and fair labor practices (UNCTAD, 2019). As such, green marketing not only enhances brand image and consumer loyalty but also helps firms support national and global sustainability goals such as the UN's Sustainable Development Goals (SDGs) (UNDP, 2015). Therefore, the adoption of green marketing strategies becomes a vital tool for firms in emerging markets to support sustainable development in a competitive and socially responsible way.

Figure 1: *Theoretical Foundations and Key Drivers of Green Marketing Adoption*



DRIVERS AND CHALLENGES IN THE ADOPTION OF GREEN MARKETING STRATEGIES

The adoption of green marketing strategies in emerging economies is influenced by several key drivers and challenges that shape how businesses approach sustainability in their operations. Understanding these drivers and challenges is crucial for companies aiming to implement effective green marketing strategies and gain a competitive edge. This section explores both the primary drivers of green marketing adoption and the challenges businesses face in integrating sustainability into their marketing practices.

Drivers of Green Marketing Adoption

i. Rising Consumer Demand for Sustainable Products: One of the most significant drivers for the adoption of green marketing strategies is the growing consumer demand for sustainable products. As environmental awareness increases, consumers are becoming more conscious of the ecological impact of their purchasing decisions. In emerging economies, where urbanization and disposable incomes are rising, consumers are increasingly prioritizing eco-friendly products. This shift in consumer behavior is particularly noticeable among younger generations—Millennials and Generation Z—who are more likely to value sustainability in the brands they support. The demand for organic, fair-trade, and environmentally friendly products is transforming the way businesses approach product development, packaging, and marketing.

ii. Regulatory Pressures and Incentives: Government policies and regulatory frameworks play a significant role in driving green marketing practices. In many emerging economies, governments are enacting environmental regulations and offering incentives for businesses that adopt sustainable practices. For instance, tax breaks, subsidies for renewable energy, and support for eco-friendly certifications are some of the initiatives used to promote green marketing. In countries like China and India, policies aimed at reducing carbon emissions and promoting cleaner technologies are pushing companies to integrate green strategies into their marketing practices. Businesses that align with these regulatory frameworks not only meet compliance standards but also enhance their reputation as responsible corporate entities, which can foster consumer trust and loyalty.

iii. Global Sustainability Trends and Market Access: As international trade and global supply chains become increasingly interconnected, there is growing pressure on businesses in emerging economies to align with global sustainability standards. Many Western markets, especially in Europe and North America, now demand eco-friendly products and services. Companies that adopt green marketing strategies are able to tap into these global markets, thereby expanding their reach and increasing sales. Global sustainability trends, such as the rise of the circular economy, are pushing businesses worldwide to reconsider their production and consumption models, making green marketing not only a competitive advantage but also a necessity for long-term growth.

iv. Corporate Social Responsibility (CSR) and Brand Image: Increasingly, businesses are realizing that integrating sustainability into their marketing strategies contributes to corporate social responsibility (CSR) goals and improves overall brand image. Companies are no longer just focused on profit maximization but also on enhancing their reputation as socially responsible entities. Green marketing initiatives that emphasize sustainability can help businesses build goodwill and strengthen their brand image. For instance, a company that adopts sustainable sourcing or reduces its carbon footprint

can promote these efforts through its marketing channels, which enhances customer loyalty and trust. Strong CSR initiatives have been shown to foster emotional connections with consumers, leading to increased customer retention and brand advocacy.

Challenges in the Adoption of Green Marketing Strategies

i. High Initial Costs and Financial Barriers: One of the primary challenges businesses face in adopting green marketing strategies is the high initial costs associated with sustainable practices. Whether it is investing in eco-friendly technologies, sourcing sustainable materials, or obtaining green certifications, the financial commitment required can be substantial. For small and medium-sized enterprises (SMEs) in emerging economies, these costs can be prohibitively high, making it difficult for them to implement green initiatives without external support or funding. The upfront costs of transitioning to sustainable operations may also outweigh the immediate financial returns, especially in markets where consumers are not yet willing to pay a premium for green products.

ii. Lack of Consumer Education and Awareness: While demand for green products is rising, consumer education remains a significant hurdle. In many emerging economies, especially in rural or economically disadvantaged areas, consumers may not fully understand the environmental impact of their purchasing decisions or the benefits of sustainable products. Without adequate education and awareness campaigns, even businesses that offer environmentally friendly products may struggle to reach their target audience. Furthermore, some consumers may be skeptical of green marketing claims, seeing them as merely a marketing tactic or "greenwashing" unless there is transparency and credibility in the business's sustainability efforts.

iii. Cultural and Societal Norms: In many emerging economies, cultural values and societal norms play a crucial role in shaping consumer behavior. In some regions, sustainability may not yet be a central priority, with consumers placing more importance on price and product availability rather than environmental factors. Additionally, traditional consumption patterns and local practices may not align with global sustainability trends, making it harder for businesses to convince consumers to embrace green products. Overcoming these cultural barriers requires businesses to tailor their marketing messages to local contexts and focus on highlighting how sustainable practices can benefit consumers in tangible ways, such as cost savings or improved health outcomes.

iv. Supply Chain Limitations and Infrastructure Challenges: The adoption of green marketing is also limited by challenges in supply chain management and infrastructure in emerging economies. For businesses to implement sustainable practices, they often require access to eco-friendly materials, renewable energy, and efficient waste management systems. However, many emerging economies lack the infrastructure to support these sustainable practices at scale. In regions where recycling programs are underdeveloped or where sustainable supply chains are difficult to establish, businesses may find it challenging to source environmentally friendly materials or manage waste in an eco-efficient manner. Moreover, limited access to reliable green technologies and services can make it difficult for businesses to reduce their environmental footprint.

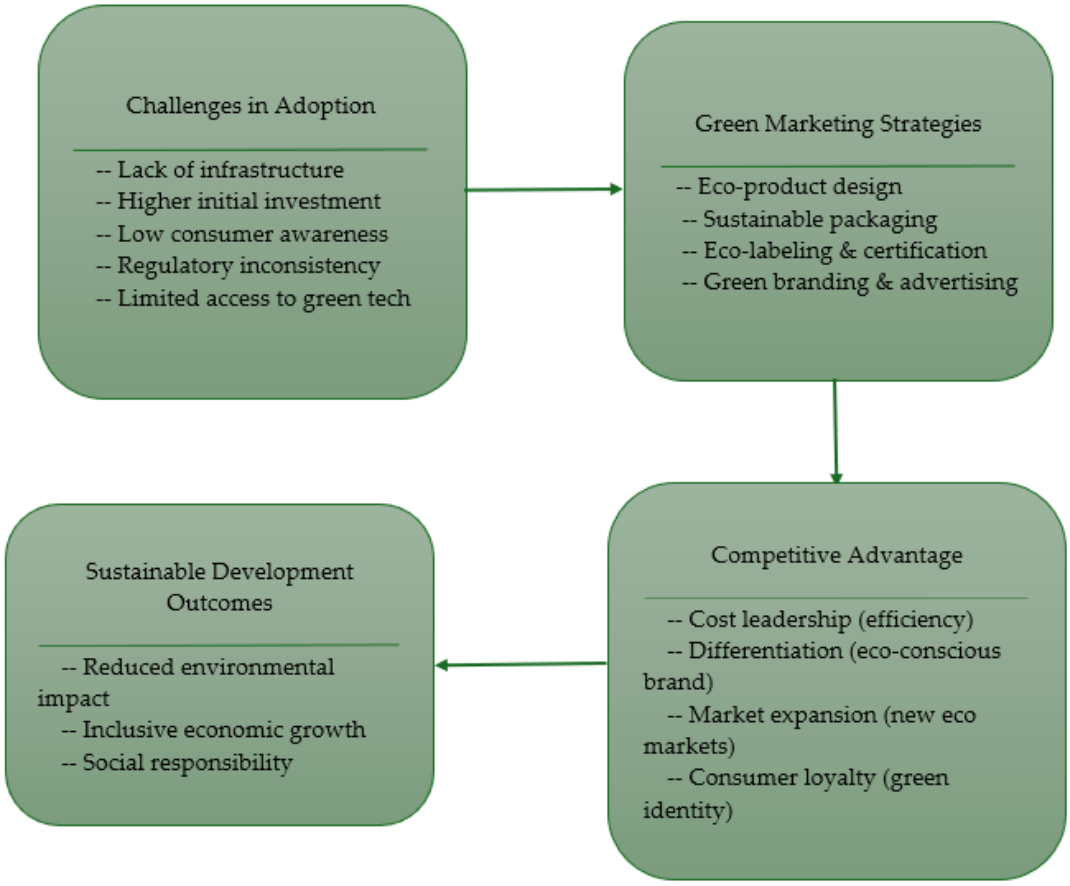
v. Greenwashing and Credibility Issues: As the demand for sustainable products grows, some businesses may attempt to capitalize on the green trend without genuinely adopting eco-friendly practices. This practice, known as greenwashing, undermines consumer trust and creates skepticism about the authenticity of green marketing claims. Companies that exaggerate their sustainability efforts without delivering on their promises risk facing reputational damage and legal consequences. Therefore, it is essential for businesses to ensure that their green marketing claims are credible, substantiated, and transparent to avoid falling into the trap of greenwashing.

CONCEPTUAL FRAMEWORK

A conceptual framework serves as the blueprint for understanding the relationships between various variables in a research study. It helps to visually represent the main factors that influence the phenomenon under investigation and illustrates how these factors interact with each other. For the topic "Green Marketing as a Competitive Strategy in Emerging Economies," the conceptual framework integrates the major elements of green marketing strategies, competitive advantage, and the unique characteristics of emerging economies.

In this section, we will describe the conceptual framework by discussing its components, how they relate to each other, and how they provide insights into the role of green marketing in emerging economies.

Figure 2: *Framework Linking Green Marketing Challenges, Strategies, Competitive Advantage, and Sustainable Development Outcomes*



The conceptual framework for this study incorporates three main components: Green Marketing Strategies, Competitive Advantage, and the Emerging Market Context. These components work together to shape the competitive landscape of businesses in emerging economies. Each of these components influences the firm's green marketing approach, and in turn, green marketing becomes a competitive strategy that enhances business performance.

Green Marketing Strategies

The foundation of the conceptual framework is built around the green marketing strategies adopted by companies. These strategies include:

i. Product Innovation: Creating eco-friendly products, such as those with reduced environmental impacts, biodegradable packaging, or products made from sustainable materials. Product innovation plays a key role in differentiating a company's offering in the marketplace. For example, in an emerging market, a company that produces energy-efficient appliances or organic foods is likely to stand out due to the increasing awareness of environmental issues.

ii. Green Advertising and Communication: A critical part of green marketing is communicating the environmental benefits of products and services to consumers. Effective green advertising includes clear messaging about the company's environmental commitments, the sustainability of the product, and the positive impact of using it. Companies in emerging markets may utilize digital platforms and social media to spread awareness and build relationships with environmentally conscious customers.

iii. Corporate Social Responsibility (CSR): Green marketing is closely tied to CSR initiatives, where companies demonstrate their commitment to sustainability not just through products but also by supporting environmental causes, reducing waste, and improving supply chain practices. By aligning CSR with green marketing, companies reinforce their eco-friendly positioning in the market.

iv. Eco-Labeling and Certification: Eco-labeling is an essential element of green marketing, as it provides consumers with a trusted indicator of a product's environmental credentials. Many emerging economies have adopted certification programs for eco-friendly products, and companies that obtain certifications like the ISO 14001 (Environmental Management Systems) or Fair Trade can use them as part of their green marketing strategy.

Competitive Advantage

The second major component of the conceptual framework is competitive advantage. This refers to the benefits a company

gains from its green marketing efforts that help it outperform competitors in the marketplace. Companies in emerging economies are increasingly realizing that adopting green marketing can lead to several key competitive advantages:

i. Market Differentiation: Green marketing strategies allow companies to differentiate their products in a market that is often dominated by price-based competition. In emerging economies, where consumers may have fewer choices of eco-friendly options, firms can set themselves apart by offering sustainable alternatives that align with evolving consumer preferences.
ii. Brand Loyalty and Trust: Consumers are more likely to develop brand loyalty to companies that adopt green practices, especially when there is transparency in their environmental claims. As emerging economies experience an increase in consumer awareness regarding environmental sustainability, companies that demonstrate environmental stewardship are likely to earn trust and foster long-term customer relationships.
iii. Cost Reduction and Efficiency: Green marketing does not only lead to improved brand image but can also bring about operational efficiencies. By adopting energy-efficient technologies, reducing waste, and optimizing supply chain processes, companies can lower their operational costs. For instance, a firm that invests in green technologies may save money in the long term by reducing its energy consumption or waste disposal costs.
iv. Regulatory Compliance and Global Integration: In emerging economies, companies that adopt green marketing strategies often do so to comply with both local and international environmental regulations. These practices can open the door to global markets, where consumers and regulators increasingly demand environmentally sustainable products. By aligning with international green standards, businesses can gain access to new markets and partnerships, creating a competitive edge over firms that are slower to adapt.

Emerging Market Context

The emerging market context refers to the unique socio-economic, cultural, and institutional factors that influence business operations in developing or emerging economies. This context plays a crucial role in shaping the adoption of green marketing strategies and their effectiveness. Some of the key factors in the emerging market context include:

i. Consumer Awareness and Demand: In many emerging economies, there is a growing awareness of environmental issues, but it varies across regions and income levels. A segment of the population is becoming more environmentally conscious, leading to increased demand for sustainable products. However, green marketing strategies may face challenges in areas where consumer awareness is still low or where eco-friendly products are perceived as more expensive.
ii. Economic Growth and Purchasing Power: Economic growth in emerging economies has led to increased consumer purchasing power, making it possible for more individuals to afford eco-friendly products. However, the economic disparities in these regions also mean that a large segment of the population may still prioritize price over sustainability. Green marketing strategies in such markets must consider the balance between product pricing and environmental benefits.
iii. Government Regulations and Support: Governments in emerging economies are increasingly introducing regulations and incentives that encourage sustainable business practices. For instance, subsidies for renewable energy projects or tax incentives for companies that adopt green practices can motivate businesses to invest in environmentally friendly technologies. Green marketing strategies are influenced by these regulations, as firms need to comply with national and international standards to avoid penalties and attract eco-conscious consumers.
iv. Cultural and Societal Norms: In emerging economies, cultural factors play an important role in consumer behavior. For instance, the concept of sustainability may be closely linked to traditional values such as respect for nature, community-based resource sharing, and stewardship of natural resources. Companies that align their green marketing strategies with local cultural values may be able to connect more effectively with their target audience and build stronger emotional ties with consumers.

Interrelationships in the Conceptual Framework

The conceptual framework highlights the interconnections between green marketing strategies, competitive advantage, and the emerging market context. These components do not operate in isolation but interact with each other in several ways:

i. The Influence of the Emerging Market Context on Green Marketing Strategies: The socio-economic conditions, regulatory environment, and consumer awareness in emerging economies shape the way green marketing strategies are implemented. For example, in a market where consumers are highly aware of environmental issues, companies may adopt more aggressive green advertising and eco-labeling strategies. In contrast, in regions where awareness is low, businesses may focus on education and awareness-building as part of their green marketing efforts.
ii. Green Marketing Strategies as a Path to Competitive Advantage: The successful implementation of green marketing strategies leads to a competitive advantage. As companies differentiate themselves with environmentally friendly products, they build stronger brands and increase customer loyalty. Green marketing not only helps businesses comply with regulations but also positions them as forward-thinking leaders in sustainability, which can translate into better market performance.

iii. Feedback Loops Between Competitive Advantage and the Emerging Market Context: As companies gain competitive advantages through green marketing, their success influences the broader market. For example, if a company in an emerging economy successfully gains market share through eco-friendly product offerings, it may inspire competitors to adopt similar strategies, gradually changing the competitive landscape. Additionally, government regulations may evolve to reflect growing environmental concerns, further reinforcing the competitive advantages of firms that have already embraced green marketing.

CONCLUSION

This study highlights the growing relevance of green marketing as a strategic tool for businesses in emerging economies. The findings suggest that businesses embracing green marketing are better positioned to differentiate themselves in competitive markets, build stronger relationships with environmentally conscious consumers, and access global markets where sustainability is increasingly valued. Green marketing not only offers a competitive advantage but also aligns with broader global trends toward sustainability, which is increasingly demanded by both consumers and regulators. However, while the benefits of green marketing are evident, businesses in emerging economies face several challenges in fully capitalizing on these advantages. High initial costs, lack of consumer education, and cultural resistance in certain regions are significant barriers that companies must overcome. Furthermore, the inconsistency in enforcing environmental regulations in some markets presents an additional challenge, as it creates uncertainty and uneven competition among businesses. Despite these challenges, the study also underscores that green marketing, when executed strategically, can lead to increased customer loyalty and brand value, particularly in urban areas where environmental awareness is higher. As consumer preferences evolve, especially among younger generations, businesses that invest in sustainability today will likely reap the long-term benefits of strengthened brand equity and access to new consumer segments. Governments and institutions play a crucial role in this transformation by offering incentives for green practices and promoting regulations that foster a sustainable business environment. As environmental concerns continue to shape global markets, businesses that adopt green marketing strategies will not only improve their competitive position but also contribute to the global push for a more sustainable future. In the long run, green marketing will likely become a central component of business strategy in emerging economies, as companies realize that sustainability is not just a moral imperative but a key driver of growth and innovation.

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Structural Exclusion and Social Protection: A Critical Examination of India's Urban Informal Workforce

Anoushka Saxena[1], Siddhi Goyal[1], Aneesh KA[1]

[1] Department of Economics, CHRIST (Deemed to be University), Delhi NCR Campus, India

***Corresponding Author:** aneesh.ka@christuniversity.in

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ABSTRACT

The urban informal sector in India maintains a crucial role in facilitating city life involving the formal sector, household jobs, development projects and sustainable living for the urban poor. Approximately 80% of the urban workforce is employed informally, contributing 45% to the GDP. However, these contributions remain unrecognised by legal and social security frameworks. Being unrecorded and excluded from policy frameworks for social protection exposes them to insecurity and exploitation, depriving them of well-deserved options for sustainable livelihood. To recognise and uplift the sector from vulnerabilities, the government introduced the E-Shram Portal, PM-SVANidhi and the Street Vendors Act to ensure financial inclusion and legal visibility. Policies face bureaucratic challenges, exposed to barriers in formalisation deterring small businesses from entering the formal sector and low awareness among the workers, reducing the impact of existing policies. For a country as dynamic and varied as India, a comprehensive and centralised set of policies for the informal urban workers is required to uplift their status while maintaining the essence of their nature of work.

Keywords: Unorganized sector, informal economy, urban informal sector, government policies, social security.

INTRODUCTION

The workers employed in the urban informal sector are not covered under employment and social security benefits. Despite serving as the backbone of the formal sector, supporting the usual business of the cities and sustaining the urban poor, they have to face significant economic shocks and are exposed to vulnerabilities. They are paid less, are often exploited by employers and face financial insecurity. They usually go undocumented and unprotected in legal policy frameworks. A brief study of the dynamics of the formal and informal sectors in India gives an insight into the origin and status of the unorganized workers in the urban informal sector. It helps us decipher the framework and provision of policies for the formal sector, showing how the informal economy remains untouched.

The formal sector in India is referred to as the organized sector. The criteria for a sector to be called formal are (a) labour productivity is likely to be high, (b) incomes even in the unskilled category are relatively high, and (c) conditions of work and services are protected by labour legislations and trade unions (IGNOU, 2017). The word 'solely' used to mention the help of wage-paid labour signifies the presence of employment benefits for those employed in this sector. Characteristics of the formal sector are (a) Regulatory Compliance (Bravo-Ortega et al., 2024); (b) Institutional Framework (Misati & Walumbwa, 2023); (c) Skilled Labour and Productivity (Chakrabarti, 2010); (d) Wage Employment and Social Protection (Williams, 2023). According to the Economic Survey (2021-22), the formal sector holds 11% of the total workforce in India, out of which 86.41% are in the organised sector and 13.59% in the unorganised sector. The scale, number of employees, and legal status of the firm's registration are the essential criteria for dividing the organised and unorganised sectors. While the formally organised sector comprises 9.51% of the workforce, the formally unorganised sector holds only 0.001% of the total workers. Contrary to the formal sector, the informal sector originated from the term 'informal' discovered by the British Anthropologist

Keith Hart while working for the ILO's project in Accra, Ghana, in 1970. He mentioned four characteristics of the sector: (1) low levels of skill, (2) easy entry, (3) low-paid employment and (4) composed mainly of immigrant labour. Hence came the name informal, which was then used by the ILO for its further projects in Kenya and later popularized as the sector that describes 'the activities of the working poor' where workers are unprotected by labour legislations, unrecognized, and unorganised (ILO, n.d.).

In India, the government set up the National Commission for Enterprises in the Unorganized Sector (NCEUS) with the help of the Ministry of Small-Scale Industries Resolution on 20th September 2004 to act as a 'watchdog' for the informal sector. The NCEUS conducts research, provides policy recommendations, and monitors the conditions of the unorganised sector. According to the NCEUS, unorganised/informal workers are those working in unorganised enterprises or households, excluding regular workers with social security benefits and the workers in the formal sector without any employment/social security benefits provided by the employers. This implies that all unprotected workers in the formal and informal sectors constitute the informal economy (Unni, 2019, p.4). The term 'unorganised worker' has also been defined under the Unorganized Workers Social Security Act 2008 as a home-based worker, self-employed worker or wage-worker in the unorganised sector and includes a worker in the organised sector who is not covered by any of the Acts mentioned in the Schedule II of the Act namely Employee's Compensation Act 1923, Industrial Disputes Act 1947 and the Employee's State Insurance Act 1948 (Government of India). Categories of Informal work are: (a) wage workers in the unorganised sector, (b) self-employed in the unorganised sector, (c) unprotected wage workers in the organised sector, and (d) regular unorganised workers (Government of India, 2007). In India, approximately 79.2% of all workers are employed in informal employment (PLFS 2017-18).

The informal economy in India has two categories – urban informal and rural informal. The characteristics of the urban informal sector are casual/wage/self-employed work, relatively higher income from rural counterparts, but quite unstable, limited access to regulations and rights, year-round work, and better access to health and credit facilities than rural areas. How different the urban informal sector is from the rural sector lies in the fact that (a) the urban sector has more population density, (b) urban informal workers face the challenges of urbanisation like pollution, traffic, limited access to safe drinking water, sanitation etc, (c) their work is more exposed to the formal sector and a grand scale is involved with it, (d) work is varied as compared to seasonal agricultural, allied work in the rural areas, and (e) they have exposure to government system and management.

In urban areas, approximately 80% of workers are informally employed. In Delhi, 81% of male and 76% of female workers work informally. Urban India had an estimated 150.25 million workers in 2017-18. 2% of the total urban population is engaged in street vending in India, with Delhi In urban areas, approximately 80% of workers are informally employed. In Delhi, 81% of male and 76% of female workers work informally. Urban India had an estimated 150.25 million workers in 2017-18. 2% of the total urban population is engaged in street vending in India, with Delhi having 300,000 and Mumbai having 200,000 street vendors (WIEGO, 2020). Other names often used for the urban informal sector (GDRC, n.d.) are based on what the sector 'is not' – not formal (informal), not controlled (non-plan, hidden, unofficial, unobserved, unstructured, unorganised, unrecorded), not legal (illegal, black, shadow) and not taxable (unrecorded, parallel). Recent terminologies were based on some of its features – temporary status (intermediate, transient), poor workers (community of the poor), nature of work (casual, urban-subsistence, one-person enterprise, irregular, invisible, unremunerated) and others (street, grey, underground, shadow, invisible, irregular, lower-circuit of urban economy, petty commodity production). Key jobs in the urban informal sector include – street vendors, market traders, construction workers, barbers, carpenters, small-scale manufacturers, porters, waiters, unskilled office help, domestic workers, housemaids, cooks, caretakers, home-based workers, rickshaw pullers, waste and rag pickers, etc.

SIGNIFICANCE AND CHALLENGES OF THE INFORMAL SECTOR IN INDIA

The Informal sector generates employment for approximately 90% of India's workforce (Raveendran & Vanek, 2020). This is a vast number that signifies the importance of the informal sector in providing more employment than the formal sector. It also contributes 45% of the total GDP of the economy in the year 2022-23 (Government of India, 2025). It has substantial shares in sectors like real estate, ownership of dwellings, professional services, public administration, defence and other services (Murthy, n.d.), which indicates the support it gives to the formal economy in its working and management. The low barriers to entry allow employability and a source of income for anyone who is not skilled or trained enough for the formal sector to sustain a livelihood, generating immediate employment for millions of the urban poor. Many small-scale and home-based workers support the small industries that otherwise face tough competition from foreign goods and remain informal. Street vendors, construction workers, and domestic staff make essential goods affordable for the urban poor, and a large portion of these poor people sustain themselves through informal livelihoods.

However, the sector's challenges, as indicated by the name itself, 'informal', cannot be overlooked by its significant contributions to employment generation and GDP. Apart from the basic unavailability of legal rights, recognition, and social and employment benefits, the workers have to work in poor environments and have inadequate access to credit and capital, which is often lent by charging high interest rates, highly vulnerable to economic shocks (COVID-19) and harassment and exploitation

especially in women, limited skill development and education, and difficulty in formalising their work. The challenges to formalisation, as mentioned by Gërxhani & Cichocki (2023), are (a) the High cost of formalisation – due to high registration fees, compliance with regulations such as employing accountants, setting up software, obtaining certification for permits and high rate tax burdens with complex structure, the small businesses feel financially threatened to enter the formal sector (b) bureaucratic hurdles - the approval of licenses and registrations takes a long time for completion and requires huge task of paperwork and is often not transparent. It creates a sense of mistrust and ambiguity to the process of formalization. (c) weak institutional frameworks – inadequate law enforcement of property rights and corruption gives way to biasness and loss of regulation from the government, which makes the essence of formality ineffective and creates distrust in the procedure; (d) informal institutions and social norms – the cultural transformation to a professional atmosphere changes the atmosphere completely and might be perceived as difficult to adopt to when shifting to formal sectors. Fear of state interference also deters small businesses from opting for formality. According to the authors, the challenges of formalization form a loop of informality from which the firms cannot escape, and the state's role keeps weakening due to a lack of enforcement and regular assessment.

GOVERNMENT POLICIES FOR THE URBAN INFORMAL SECTOR

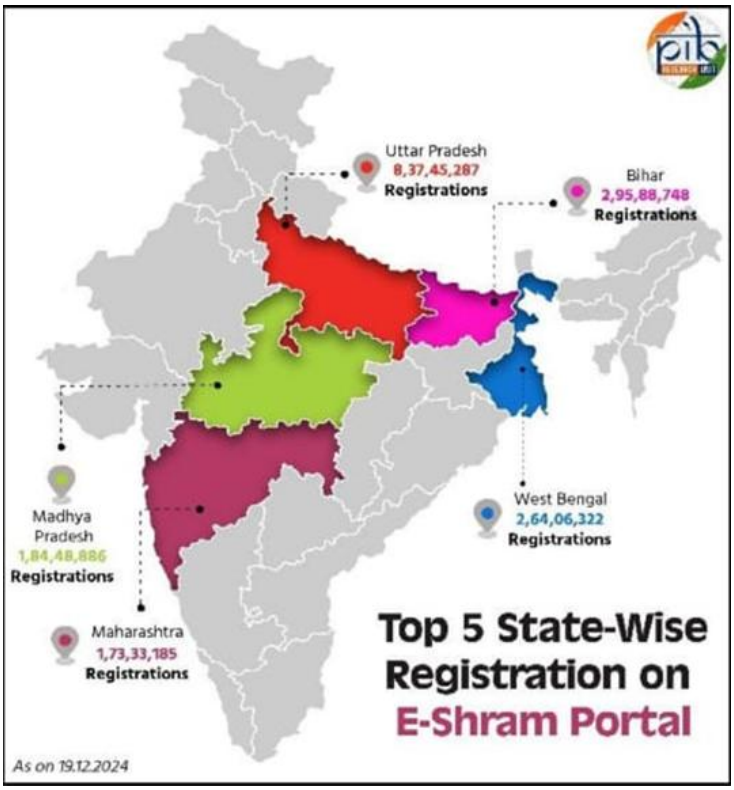
Considering the challenges of the informal sector in urban areas and the economic threat it poses to the workers, the government has introduced the following schemes and policies to address the issue of informality. The main objective is to introduce policies that (1) uplift the oppressive conditions of the informal workers in the short run and (2) formalize the informal sector to bring it under formal regulations. The government initiatives for correcting informality cover legal recognition, financial inclusion and social security for informal workers.

E-Shram Portal

E-Shram Portal, launched by the Ministry of Labour and Employment on August 26, 2021, is a flagship initiative by the Government of India with the primary aim of having a national central base of workers in the unorganised sector for better implementation of policies. It improves access to social security programs and benefits for individuals working in agriculture, construction, domestic work, and street vending. It promotes employment matching and skill enhancement possibilities and strengthens labour market resilience by including unorganised workers in the formal economy. Registering in the portal is a streamlined process, where the worker must have an Aadhaar card, a mobile number linked with an Aadhaar card, and bank details. Registered workers receive a Universal Account Number, which will enable them to access benefits all over the country. Information about migrant workers' families is collected, which helps in implementing educational programs for children and initiatives focused on women for those who have relocated with their families. Details of registered worker are shared with the respective boards, ensuring their access to schemes meant for them.

As of December 19, 2024, there are 30,48,02,313 registrations on the E-Shram portal. Individuals can register by visiting the e-SHRAM portal (www.eshram.gov.in) or the closest Common Services Centres (CSCs) and the State. The states with the highest e-Shram registration numbers are as follows: Uttar Pradesh, with 8,37,45,287 registrations; Bihar, with 2,95,88,748 registrations; West Bengal, with 2,64,06,322 registrations; Madhya Pradesh, with 1,84,48,886 registrations; and Maharashtra, with 1,73,33,185 registrations (Government of India, 2021).

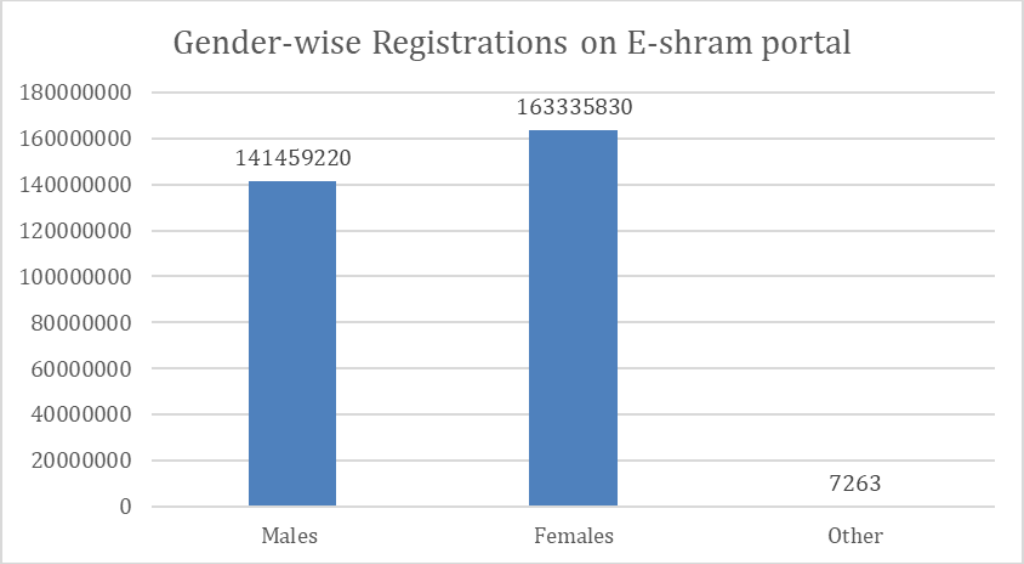
Figure 1: *Top 5 states with the highest registrations on the E-Shram portal*



Source: *Government of India (2024)*

A major note from the gender lens perspective of the portal registrations shows that more females have registered themselves than males.

Figure 2: *Gender-wise Registrations on the e-shram portal as of 19th December 2024*



Source: *Government of India (2024)*

In October 2024, there were approximately 60,000 new registrations on the e-Shram platform daily (Government of India, 2024). The E-Shram Portal is India's significant result after contributing its best in terms of good-for-nothing workers in the country. The portal is directed at narrowing the prevailing gaps in employment by creating opportunities and benefits from its central platform. With over 30 crore workers already enrolled, the E-Shram Portal is poised to substantially impact on the lives of millions and foster a more robust and resilient workforce for the future.

Pradhan Mantri Shram Yogi Maan-dhan (PM-SYM)

The Pradhan Mantri Shram Yogi Maandhan (PM-SYM) is a voluntary pension scheme initiated by the Government of India to offer social security to workers in the unorganised sector. This initiative guarantees a minimum monthly pension of ₹3,000 upon reaching 60 for unorganised workers earning up to ₹15,000 a month, and age eligibility is 18-40 years (Government of India, 2019). The Indian government matches the contributions made by workers on a one-to-one basis. In the event of the beneficiary's death, the spouse is entitled to 50% of the pension amount as a family pension. The family pension is exclusively available to the spouse. Individuals may withdraw from the program under certain conditions. Registration of PM-SYM can be done at the Common Service Centres (CSCs) anywhere in India. The steps include going to a CSC, the Aadhaar, and a savings bank account. Biometric authentication will be through Aadhaar. Fill out the online registration form. The first contribution has to be paid in cash. Select the auto-debit option from your bank account. You will receive the PM-SYM card once the registration process is completed successfully. As of March 2025, around 46,12,330 people have enrolled in the top 3 states: Haryana, Uttar Pradesh, and Maharashtra (Government of India, 2025).

Table 1: *Top 5 states with the highest number of cards issued as of 3rd March 2025*

State	***Number of Cards Issued***
Haryana	8,26,208
Uttar Pradesh	6,94,169
Maharashtra	6,21,500
Gujarat	3,91,043
Chhattisgarh	2,33,172

Source: *Government of India (2025)*

PM SVAnidhi Yojana

An important program inaugurated on June 1, 2020, by the Ministry of Housing and Urban Affairs, the PM Svanidhi schemes aim at putting in place a facility of working capital loans, at low interest, to the street vendors affected by the COVID-19 lockdown. The micro-financing is done through the Small Industries Development Bank of India (SIDBI). The scheme envisaged unsecured loan amounts of Rs 10,000 to street vendors at a low interest rate (below 12%) for one year to provide some financial succour to them. The first loan of Rs 10,000 would come, enabling one to take the second loan of Rs 20,000 after repayment. Subsequently, a third loan of Rs 50,000 is given only after the repayment of the second loan. The scheme endorses digital transactions with a 7% subsidy on timely repayments (Government of India, 2023). In one of their recent reports, SBI commented on the scheme's efficiency, where they found that 43% of the beneficiaries were female street vendors. According to the PM-SVANidhi scheme dashboard, as of October 26, 2023, 57.20 lakh loans have been approved under the first tranche, 15.92 lakh under the second tranche, and 1.94 lakh under the third tranche (Government of India, 2023). Around 68% of people repay the first loan of Rs 10,000 and take the second loan of Rs 20,000. The ratio of people who have repaid the second loan of Rs 20,000 and have taken the third loan of Rs. 50,000 is 75%.

Table 2: *Overview of achievements made by PM SVANidhi Yojana*

Eligible Applications	***1,14,60,159***
Loans Sanctioned	98,31,171
Loans Disbursed	96,06,276
Returned by Banks	12,67,955
Total Disbursed Amount	13,788 crores
Loans Repaid	46,68,694

Source: *Government of India (2025)*

The scheduled banks have disbursed Rs. 9,152 crore loans under the PM SVANidhi Scheme as of 27th January, 2025.

Table 3: *Banks with most loans disbursed*

Bank	***Proportion of Loans disbursed***
The State Bank of India	31%
Bank of Baroda	31%

Union Bank of India	10%
Punjab National Bank	8%

Source: *Government of India (2025)*

Approximately 5.9 lakh borrowers of the SVANidhi loans are distributed in 6 megacities, and 7.8 lakh borrowers come from the top 10+ million population cities.

Table 4: *Cities with most active spenders*

City	*Percentage of active spenders*
Varanasi	45%
Bengaluru	31%
Chennai	30%
Prayagraj	30%

Source: *Government of India (2025)*

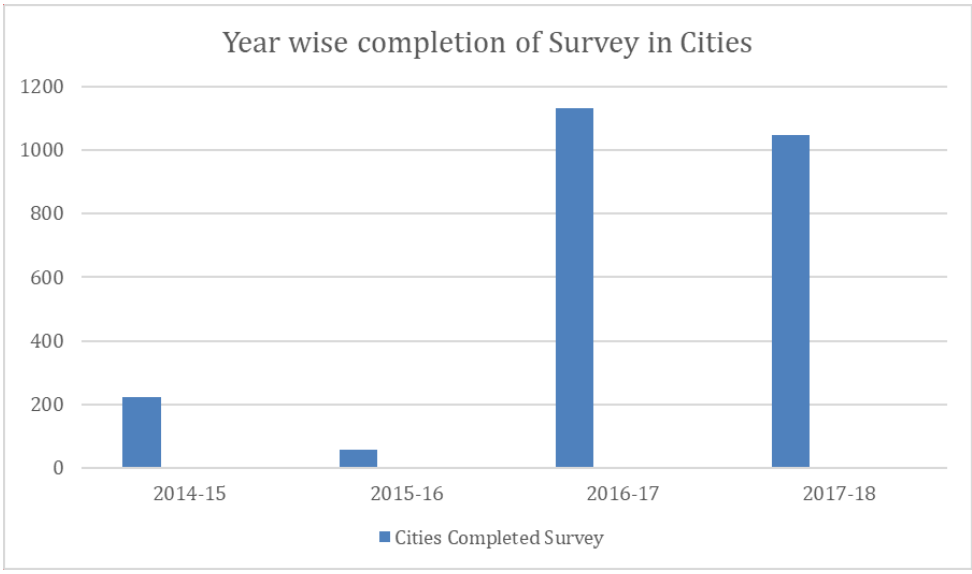
The Street Vendors (Protection of Livelihood and Regulation of Street Vending) Act

The government enacted this act through the Ministry of Housing and Urban Affairs in 2014, which came into effect on May 1, 2014. It was introduced in each state and Union territory to safeguard, protect, and regulate street vendors. It sets up a participatory governance structure by forming Town Vending Committees (TVCs), which require that street vendor representatives make up 40% of the committee members and that women street vendors comprise at least 33% of this representation (Government of India, 2014). As per the act, each Town vending committee has to conduct a survey every 5 years, provide street vending certificates to vendors, and regulate the vending zone. Provisions in the Constitution Concerning Street Vendors: Article 19(1)(g): The right to engage in any profession, occupation, trade, or business. Article 39(a): Both men and women citizens have the right to a sufficient means of livelihood. Article 39(b): The ownership and management of community resources should be allocated to best promote the common good.

Town vending plans have been successfully completed in 14 states. Andhra Pradesh, Bihar, Chhattisgarh, Himachal Pradesh, Jharkhand, Karnataka, Madhya Pradesh, Manipur, Mizoram, Nagaland, Telangana, and Uttar Pradesh have sanctioned proposals for infrastructure development in the vendor market. 2,777 Town Vending Committees have also been constructed.

Regular surveys are conducted to oversee compliance to vending regulations; however, data is unavailable for recent years.

Figure 3: *Cities and Survey Completion for Vending zones*

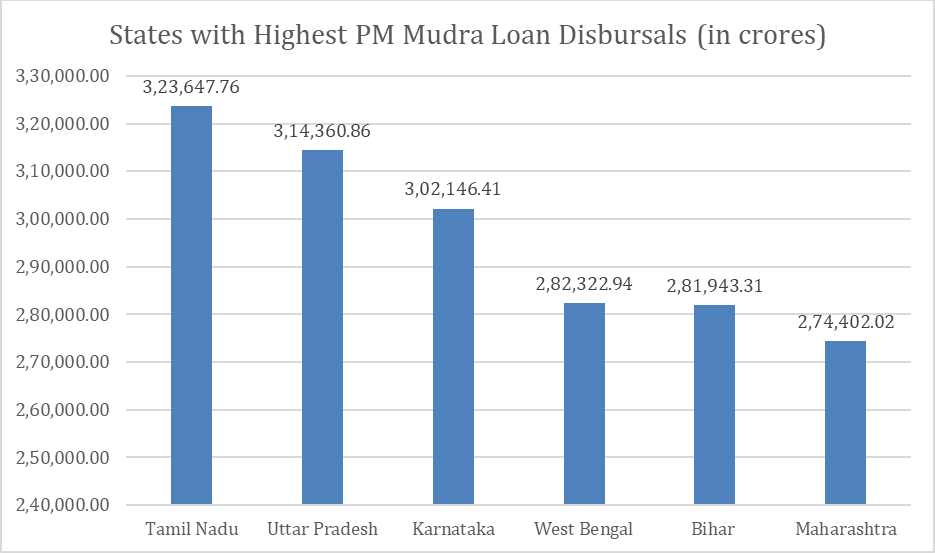


Source: *Implementation Status of Street Vendors Act, 2014*

Pradhan Mantri Mudra Yojana

PMMY is a flagship program launched by the Prime Minister on April 8, 2015, which has been introduced to provide loans to non-farm small and micro enterprises up to 20 lakhs in amount. The loans fall into the following categories: Shishu provides coverage for loans not exceeding Rs. 50,000/-. Kishore: provides coverage for loans more than Rs. 50,000/- to up to 5 lakhs. Tarun: provides coverage for loans from more than Rs. 5 lakhs to Rs. 10 lakhs. Tarun Plus: providing loans from Rs. 10 lakhs to Rs. 20 lakhs. PMMY has empowered numerous daring and aspirational individuals to enjoy self-esteem and self-reliance. As per the data, from initiation until 13-08-2017, the Mudra Scheme has sanctioned 87 million loans, of which 65.6 million were given to women (Government of India, 2025).

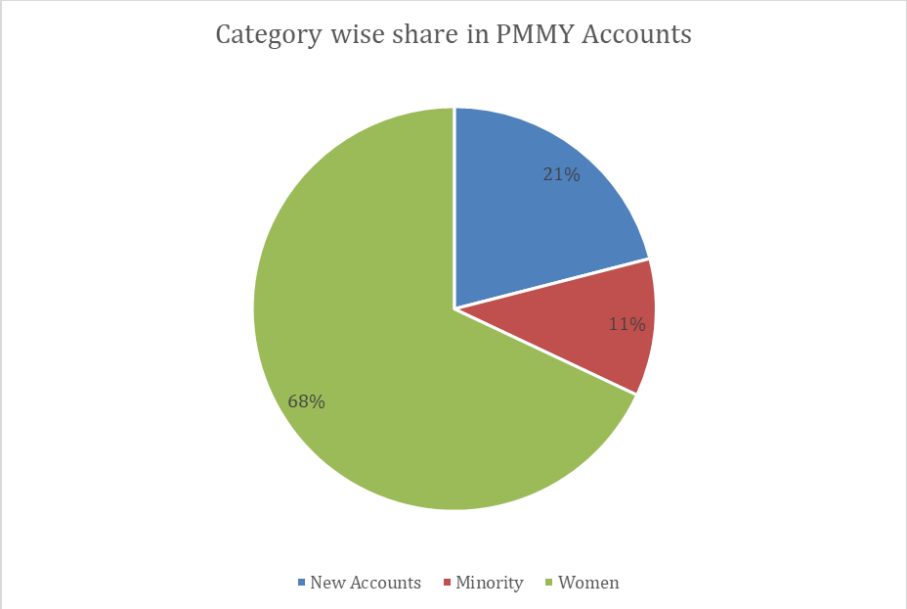
Figure 4: *Leading States and Uts in PM Mudra Loan Disbursements (As of 28th February 2025)*



Source: *Government of India (2025)*

Jammu and Kashmir is the leading UT with disbursal of Rs. 45,815.92 crore through 21,33,342 loan accounts. The share of women entrepreneurs in the PMMY indicates inclusivity and comprehensiveness.

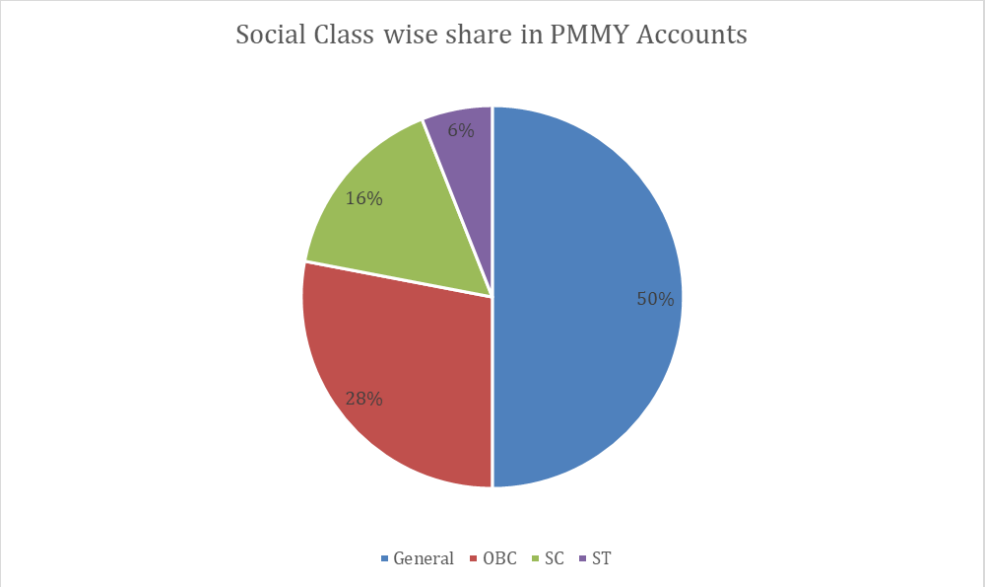
Figure 5: *Share of accounts in different categories*



Source: *Government of India (2025)*

The PMMY accounts encourage applicants of various social classes to participate and as a result, 50% of the accountholders are those of SCs, STs and OBCs who get equal opportunities to be eligible.

Figure 6: *Class-wise share of PMMY Accounts*

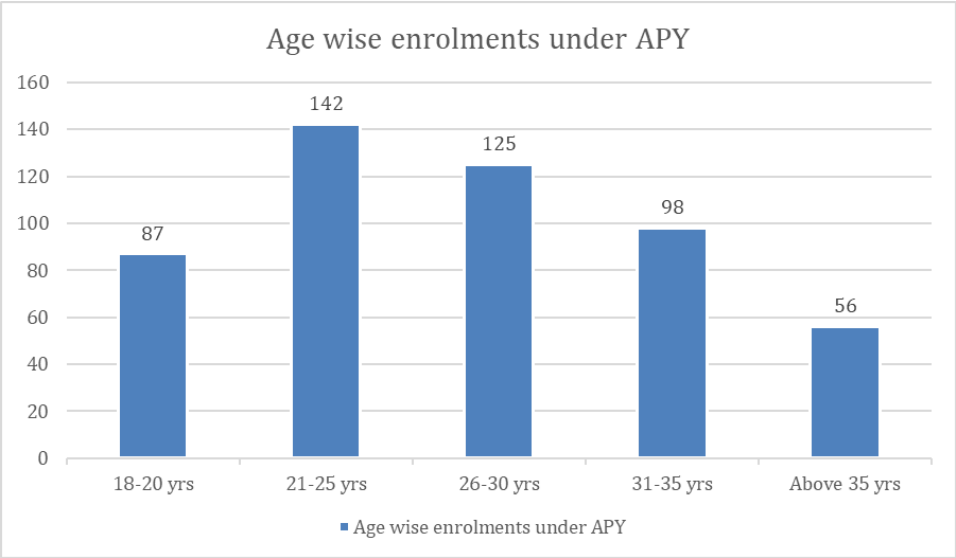


Source: *Government of India (2025)*

Atal Pension Yojana

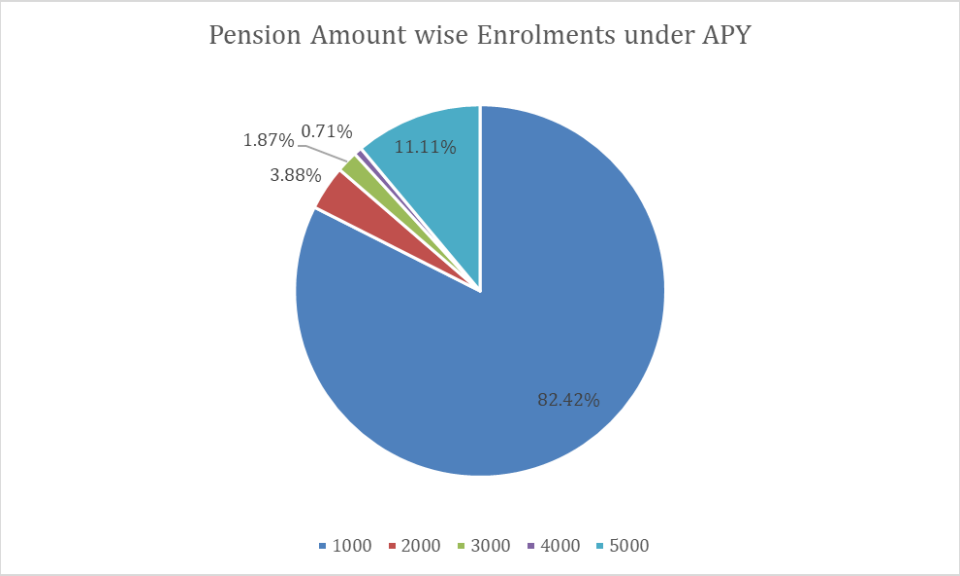
Atal Pension Yojana is a prime initiative initiated by the government of India on May 9, 2015, to provide social security to all Indians. APY has been structured to offer Sampurna Suraksha Kavach, ensuring a secure, life-defined pension for the subscriber and guaranteeing the same pension amount for the spouse after the subscriber's passing. Furthermore, it protects the family by returning the total accumulated corpus (up to the age of 60) to the nominee following the death of both the subscriber and the spouse. Approximately seven crores have gross enrolments in the Atal Pension Yojana, and today, more than 56 lakh people are enrolled for this Financial Year 2024-25. As the scheme is in its 10th year of implementation, It has achieved a massive milestone in the previous decade of providing pension coverage to the most vulnerable sections of society.More than 5 crore individuals have subscribed to APY (as of April 27, 2023) (Government of India, 2023). More than 5 crore individuals have subscribed to APY (as of April 27, 2023) (Government of India, 2023).

Figure 7: *Age-wise distributions of enrolments under the Atal Pension Yojana*



Source: *Government of India (2023)*

Figure 8: *Pension amount-wise distribution of enrolments under the Atal Pension Yojana*



Source: *Government of India (2023)*

Aam Admi Bima Yojana

The Aam Aadmi Bima Yojana (AABY) is a social security initiative introduced by the Ministry of Labour & Employment, Government of India, carried out through LIC. It offers coverage for death and disability to individuals from 48 designated occupational or vocational groups, as well as to rural landless families and unorganised labourers. Participants between 18 and 59 years of age contribute subsidized annual premiums of ₹200 for their insurance protection. Furthermore, scholarships are provided for children enrolled in grades nine and above. In case of natural death, RS 30,000 is provided, and in case of accidental death, Rs 75,000 is provided. Each of the two children of the beneficiary enrolled in the 9th to 12th Standard will be given ₹100/- monthly (for each child, the payment will be made twice a year on July 1 and January 1). If a worker gets permanently disabled due to an accident, he/she will get Rs 75,000; in case of partial disability, Rs 37,500. States with the least coverage were Chandigarh, Mizoram, Sikkim, Lakshadweep, Daman and Diu, and Dadra and Nagar Haveli.

Pradhan Mantri Jan Arogya Yojana

With an important step taken for accessible and affordable health care services across the country, Prime Minister Shri Narendra Modi inaugurated the Ayushman Bharat-Pradhan Mantri Jan Aarogya Yojana (AB-PMJAY) on September 23, 2018, at Ranchi, Jharkhand. Ayushman Bharat aims to give everyone access to health care to which they are entitled. Through Ayushman Bharat – Pradhan Mantri Jan Aarogya Yojana, the government is elevating healthcare security to a new level of aspiration. This program is recognized as the "largest government-funded healthcare initiative in the world," aimed at benefiting over 500 million people. It offers annual coverage of up to Rs. 5 lakhs for each family, specifically for secondary and tertiary care hospitalizations. Over 10.74 crore at-risk families (around 50 crore individuals) will qualify for these benefits. Over 354 million Ayushman cards have been distributed, providing innumerable families access to health insurance. A significant achievement is the approval of 7.79 crore hospital admissions, providing ₹1,07,125 crores in financial support. The gender-wise distribution reveals that 49% of Ayushman cards have been issued to women, who subsequently used 3.61 crore hospital admissions, showcasing the initiative's advancement of gender equity in health care. A total of 1.96 crore hospital admissions worth Rs. 24,315 crores have been authorized through a network of approximately 23,000 Empanelled Health Care Providers (EHCPs) (Government of India 2021).

AN ANALYTICAL REVIEW OF POLICIES

India's labour and social protection policies have experienced significant changes lately, characterized by efforts to bolster support for informal workers and improve opportunities for formal employment. Perhaps the most significant progress is the increase in social protection coverage from the International Labour Organization's data (2024–26), which has almost doubled, from 24.4% to 48.8%. This progress shows the government's aim to bring more workers under social welfare nets, particularly those who have been traditionally marginalized due to informal or unregistered job situations. A key initiative in this effort has been the E-Shram Portal, which has successfully registered over 300 million (30 crore) workers. This online platform plays a crucial role in streamlining the process for these workers to access targeted welfare benefits tailored to their specific needs (Press Information Bureau, PIB, 2025).

Nevertheless, the potential of this initiative is undermined by deficiencies in execution. Even though approximately 300 million individuals have registered on the e-Shram platform—an initiative aimed at organizing informal workers and connecting them to various social security benefits—many continue to face significant bureaucratic hurdles. These obstacles often prevent them from accessing the benefits the platform was designed to provide. Moreover, a considerable portion of the workforce remains unaware of the welfare schemes available to them. This lack of awareness translates into alarmingly low utilization rates, even among those who are officially registered on platforms like e-Shram.

In addition, there has been substantial progress in the formalization of employment. Over the last seven years, approximately 70 million (7 crore) workers have transitioned into secure, formal jobs through the Employee Provident Fund Organization (EPFO). This transition enhances their job security and ensures they receive essential benefits such as retirement savings (PIB, 2025b). It represents a step toward restructuring India's labour economy by integrating more workers into protected and regulated employment.

However, this formalization has not substantially solved the persistent problem of informality in India. This underscores a troubling reality: a staggering 90% of India's overall workforce operates in informal employment, a condition that leaves them without fundamental job security and essential benefits such as health insurance, retirement plans, or paid leave (WIEGO, 2020). The Ministry of Statistics and Programme Implementation (MoSPI) reveals a striking statistic: 61% of women workers in non-agricultural sectors are employed within the informal economy. This gender dimension shows that these formalization efforts are not reaching vulnerable groups. These numbers highlight that advancements have occurred, but are still inconsistent and inadequate in reshaping the larger employment environment.

In response to the economic challenges posed by the COVID-19 pandemic, the government has launched the PM SVANidhi scheme, which provides financial assistance to street vendors. Through this initiative, ₹5,000 crore has been disbursed to more than 5 million (50 lakh) vendors, providing them with crucial support to sustain their businesses and livelihoods in the aftermath of the pandemic. This financial aid is instrumental in helping these vendors rebuild and thrive in an increasingly competitive environment.

Nevertheless, the effectiveness and reach of PM SVANidhi are curtailed by administrative bottlenecks and varying levels of regional support. In some states, loan disbursal becomes a complicated and inconsistently followed process whereby many workers remain unaware of their eligibility for this scheme or the steps needed to access these funds. Moreover, a considerable portion of the workforce remains unaware of the welfare schemes available to them.

Informal workers face issues like income instability, lack of collateral, insufficient documentation and lack of financial literacy. All these issues create a barrier for them to engage in the formal banking sector. Although the E-shram portal aims to provide awareness about related schemes, it lacks creating awareness about the financial literacy programmes, credit schemes, etc. Hence, all these become the obstacles to meaningful change.

Additionally, capturing the fast-evolving nature of the informal sector presents substantial challenges for policymakers. These complexities ultimately undermine the effectiveness of policy implementation, leaving many workers without adequate support in navigating their precarious employment situations.

CROSS-COUNTRY COMPARISON

ILO's assertion that India's Social Protection coverage doubled from 24.4% to 48.8% in its World Social Protection Report 2025-26 is indeed an indicator of the considerable amount that has been done by the government and well-recognized internationally to address the issues of the unorganized sector in India. However, India has much to learn from developed and developing countries when it comes to dealing with the informal sector.

South Korea's National Pension Scheme has mandated participation from citizens aged 18-59 years working in the formal or informal sector. A foreign individual living in Korea must enrol in the National Pension Scheme, just as Korean citizens must. A part of the fund is contributed by the employee-employer in the formal sector, while for the informal sector, it is self-funded with some incentives. For this social security, India has enacted various schemes like Pradhan Mantri Shram Yogi Maandhan Yojana, Atal Pension Yojana, etc. All these schemes are voluntary, as in Korea, India can also mandate a universal pension scheme for the betterment of citizens, either in the informal sector or in the formal sector. Korea also has a centralized system that facilitates efficient management. Still, in contrast, there are many schemes and a decentralized system that lacks efficient management in India, where citizens are unaware of the schemes.

In Colombia, the government has implemented a Vendor Integration plan, which aims to regulate, formalize and support street vendors in every aspect. Colombia's Vendor Integration Plan to access designated vending zones, usually with high foot count and proper infrastructure, waste disposal, security, and sanitation. Also, a license is provided to them for better regulation and monitoring. In India, under the Street Vendors Act, Town Vending Committees provide street vending certificates to vendors and regulate the vending zone. But the government needs to work on the vending zones, they should have high footfall, sanitation facilities, waste management, adequate infrastructure, and more steps should be taken.

In Germany, the Dual Vocational Training System is a vocational training approach that integrates hands-on, real-world experience with theoretical learning in a classroom setting. It is regarded as one of the most successful methods for equipping young individuals for skilled professions. This helps them make a smooth transition to the formal sector. This approach can be used to enhance the Skill India Mission in a way that recognizes informal work experience of a specified time period and can be translated into formal skill certifications without additional training. Also, under this act, the government should focus on public-private collaborations and training programmes per the current industrial demand. Tax incentives can be given to companies hiring informal workers as apprentices, and helping them upskill to bridge the skill gap.

Brazil's 'Minha Casa Minha Vida' (Affordable Housing for Informal Workers): This program was created to encourage the development and purchase of new housing units for those with low and low-middle incomes. The relevant approach can be used to expand the PM Awas Yojana to provide rental and co-owned housing to groups of informal workers known as worker housing cooperatives.

A deeper overview of the policies of other countries compared to those of India reveals that India has begun the process of upliftment and formalization in most aspects, including legal recognition, financial support and social security. However, significant implementation challenges and the incomprehensiveness of policies make the initial efforts seem significantly inefficient. Implementation challenges include a lack of awareness, bureaucratic hurdles, lack of reach to targeted groups and barriers to access by vulnerable groups like women and migrants. All the policies are scattered and must be included under one umbrella to make them comprehensive and effective. The lack of real-time data on activities in the informal sector also accounts for a structural issue. With the advent of artificial intelligence and the age of digitalization, it is easier to navigate policy effectiveness and reach target groups. Financial technology also helps businesses scale. A step towards basic financial and digital literacy, along with upskilling, will go a long way to cover up for the implementation challenges and help informal workers complement the government in its effort to improve the situation of the unorganized sector.

CONCLUSION

The future of the urban areas is lined by digitalization, smart city initiatives and changing labour dynamics. However, the surge of the gig economy and application of sustainability concerns risk the informal sector's traditional work roles. Informal sector is exposed to job displacement, financial illiteracy, income instability and vulnerability to climate change. Addressing these challenges is the need of the hour as they are a substantial part of the population. To enhance the security and sustainability of workers in the informal sector regarding their living and working conditions, both the short-term challenges and the long-term needs must be addressed through a more comprehensive approach. Firstly, financial literacy programs should be expanded so that informal workers can benefit from various schemes, opt for loans and manage their income. Also, the foremost requirement is to spread awareness about the welfare and social security among the workers. The policies aiming inclusivity of urban planning and sustainable development should be prioritized. As India is moving towards digitalization, training on the same should be provided so that everyone benefits.

Priority should be given to make policies centralized and easily available to the remotest of regions for greater effectiveness, as a major workforce remains unaware of their options. Another effective idea is to make social security programmes automatically compulsory for workers when they join the workforce, reducing the chances of dropping out and ensuring greater reach.

The goal of regulating the unorganized sector is not to forcibly integrate it into the formal economy or alter its nature but to ensure the social and economic security of informal workers, whose livelihoods are far from casual and require legal protection. Like in other countries, the informal sector should continue to function as intended, but the workers within it must be safeguarded, ensuring that their lives are not treated with the same precariousness or lack of structure that defines the sector itself.

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Interplay of Academia, Market and Human Involvement: A Holistic Analysis of Puppetry in India through the Triple Helix Model

Anshika Prakash [1], Monika Yadav [1], Nitish Kumar Minz [2], Maryam Irfan [1*]

[1] School of Management & Commerce, K.R. Mangalam University, Gurugram, Haryana, India
[2] VIT Business School, Vellore Institute of Technology, Vellore, Tamil Nadu, India

***Corresponding Author:** monikayadav5008@gmail.com

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ABSTRACT

Puppetry, deeply rooted in Indian culture, transcends temporal boundaries to embody a cherished cultural heritage and dynamic artistic form. Scholars and practitioners have long celebrated the resilience and adaptability of puppetry, which continues to evolve in response to changing socio-cultural contexts. This study explores the interplay of academia, market dynamics, and human involvement in puppetry in India, shedding light on its enduring relevance and transformative potential within Indian society and beyond. Through the lens of the Triple Helix Model, this research delves into the multifaceted landscape of puppetry in India, examining its intersection with tradition, market dynamics, and human involvement. Key findings emerge by analyzing academic literature, government initiatives, case studies, and stakeholder perspectives regarding cultural heritage, government support, market dynamics, and human involvement in puppetry. The study highlights the complex interplay of supply and demand forces, the importance of collaborative efforts, and the challenges and opportunities puppeteers face in navigating a rapidly changing socio-cultural landscape. Ultimately, this research provides a holistic understanding of puppetry in India, offering insights for future research, policy interventions, and community engagement initiatives to support the sustainability and growth of this ancient art form.

Keywords: Puppetry in India, triple helix model, cultural heritage, market dynamics, human involvement, and sustainability.

INTRODUCTION

Background & Relevance of the Study

Puppetry, an ancient art form deeply rooted in Indian culture, has transcended time and space to become an integral aspect of the nation's cultural heritage. This introduction serves as a gateway to our exploration of puppetry in India, offering a panoramic view of the research landscape, delineating the study's objectives, and introducing the Triple Helix Model as the conceptual framework that guides our analysis. Puppetry, with its roots deeply embedded in ancient Indian civilization, epitomizes a form of cultural expression that transcends temporal boundaries. Scholars such as Chopra, Goyal, and Harish (2023) meticulously explore the traditional and contemporary facets of string puppets in Rajasthan, shedding light on the intricate craftsmanship and enduring cultural significance of these age-old art forms. Moreover, Ghosh and Banerjee's (2006, 2009) works provide comprehensive insights into the historical evolution and regional nuances of Indian puppetry, delineating its enduring allure as a folk-art form. The study of puppetry in India holds significant relevance in contemporary society, offering insights into the intricate interplay between tradition, market dynamics, and human involvement within cultural expression. As a repository of cultural heritage, puppetry plays a pivotal role in preserving and promoting centuries-old traditions, mythologies, and storytelling techniques amidst the pressures of globalization and modernization. Beyond its cultural significance, puppetry also carries economic implications, informing policy interventions and entrepreneurial initiatives to enhance livelihood sustainability for practitioners and artisans. Moreover, puppetry is a potent educational and

therapeutic tool, fostering creativity, self-expression, and learning opportunities in diverse settings such as schools, hospitals, and community centers. Furthermore, puppetry has historically fostered social cohesion, intercultural dialogue, and community engagement, contributing to cross-cultural understanding and collaboration. Lastly, the findings of this study can inform policymakers and cultural institutions about the importance of supporting and promoting puppetry as a cultural heritage asset, thereby fostering its continued vitality and relevance within India's cultural landscape and on the global stage. The study of puppetry in India holds significant relevance in contemporary society, offering insights into the intricate interplay between tradition, market dynamics, and human involvement within cultural expression. As a repository of cultural heritage, puppetry plays a pivotal role in preserving and promoting centuries-old traditions, mythologies, and storytelling techniques amidst the pressures of globalization and modernization. Beyond its cultural significance, puppetry also carries economic implications, informing policy interventions and entrepreneurial initiatives to enhance livelihood sustainability for practitioners and artisans. Moreover, puppetry is a potent educational and therapeutic tool, fostering creativity, self-expression, and learning opportunities in diverse settings such as schools, hospitals, and community centers. Furthermore, puppetry has historically fostered social cohesion, intercultural dialogue, and community engagement, contributing to cross-cultural understanding and collaboration. Lastly, the findings of this study can inform policymakers and cultural institutions about the importance of supporting and promoting puppetry as a cultural heritage asset, thereby fostering its continued vitality and relevance within India's cultural landscape and on the global stage.

Objectives, Significance, and Scope of the Study

The primary objective of this study is to comprehensively explore the multifaceted dimensions of puppetry in India, with a particular focus on understanding the interplay between tradition, market dynamics, and human involvement. By delving into puppetry's historical roots, cultural significance, and contemporary manifestations, this research aims to shed light on its enduring relevance and transformative potential within Indian society and beyond.

The significance of this study lies in its potential to contribute to various domains, including cultural preservation, economic development, education, social cohesion, and cultural diplomacy. By unraveling puppetry's intricate dynamics, this research informs policymakers, cultural practitioners, educators, and the general public about the importance of supporting and promoting puppetry as a cherished cultural heritage and dynamic artistic form.

This study encompasses a comprehensive analysis of scholarly literature, empirical research, and cultural artifacts related to puppetry in India. By synthesizing insights from diverse sources, this research endeavor aims to provide a holistic understanding of puppetry, spanning its historical origins to its contemporary manifestations. Additionally, this study will examine the role of academia, industry, and government in shaping the trajectory of puppetry, thereby offering insights into the mechanisms that govern its production, dissemination, and reception within Indian society.

Introducing the Triple Helix Model as the Conceptual Framework

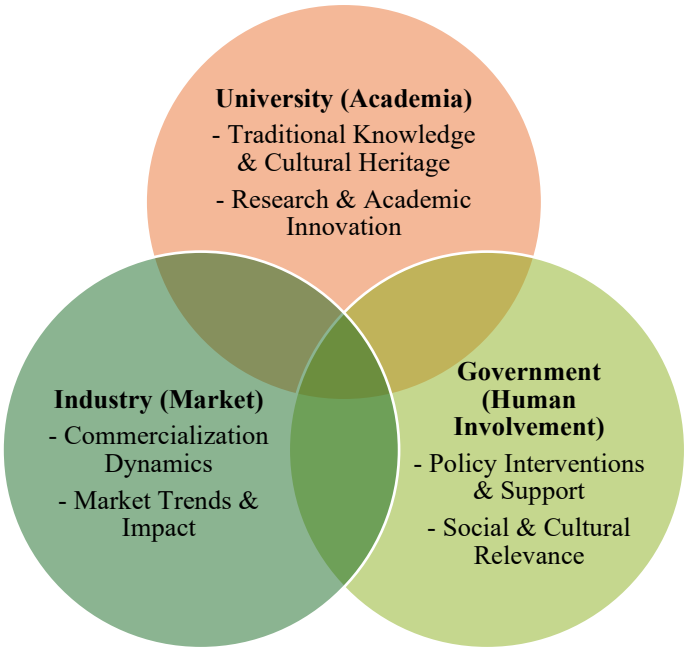
The Triple Helix Model serves as the guiding conceptual framework for this research, providing a comprehensive lens through which to analyze the interplay between tradition, market dynamics, and human involvement in puppetry in India. Initially proposed by Etzkowitz and Leydesdorff (2000), the Triple Helix Model conceptualizes innovation as emerging from dynamic interactions among academia, industry, and government, thereby shaping the socio-economic development trajectory.

In the context of puppetry, the Triple Helix Model offers a nuanced framework for understanding the complex dynamics that govern the production, dissemination, and reception of puppetry as a cultural artifact and economic enterprise. The academic sphere contributes to preserving and disseminating puppetry traditions through research, documentation, and educational initiatives. Scholars and cultural institutions play a pivotal role in documenting puppetry practices, exploring their historical roots, and disseminating knowledge to wider audiences, thereby contributing to cultural preservation and enrichment. Simultaneously, the industrial dimension encompasses the commercial aspects of puppetry, including production, distribution, and consumption. Market dynamics, consumer preferences, and technological advancements influence puppetry's economic viability and sustainability as a livelihood option for practitioners and artisans. Understanding market forces and industry trends is essential for informing policy interventions, entrepreneurial initiatives, and market-driven strategies to enhance economic empowerment within the puppetry sector.

Lastly, the governmental dimension encompasses policy frameworks, regulatory mechanisms, and cultural diplomacy initiatives that shape the institutional landscape within which puppetry operates. Government policies and cultural interventions can have profound implications for preserving, promoting, and supporting puppetry as a cherished cultural heritage asset. By fostering conducive policy environments, governments can nurture innovation, creativity, and cultural entrepreneurship within the puppetry sector, enhancing its resilience and vibrancy.

The Triple Helix Model provides a holistic framework for analyzing the intricate interactions among academia, industry, and government within the context of puppetry in India. By examining the roles, relationships, and dynamics within each helix, this research aims to illuminate the mechanisms that shape puppetry's production, dissemination, and reception, thereby offering insights into its enduring relevance and transformative potential within Indian society and on the global stage.

Figure 1: *Triple Helix Model as the Conceptual Framework.*



UNIVERSITY (ACADEMIA)

Exploring the academic contributions to India's puppetry research, education, and cultural preservation

Academic contributions to puppetry research, education, and cultural preservation in India represent a significant scholarly endeavor characterized by meticulous inquiry, interdisciplinary collaboration, and a commitment to enriching cultural heritage. Within puppetry research, scholars have investigated extensively the historical origins, artistic intricacies, and socio-cultural implications of puppetry practices across India. Through archival research, ethnographic studies, and critical analysis, academics such as Chopra, Goyal, and Harish (2023) have elucidated the traditional and contemporary dimensions of string puppetry in regions like Rajasthan, offering valuable insights into its craftsmanship and enduring cultural significance. Similarly, Pandey's (2017) exploration of puppetry as a traditional folk theatre underscores its cultural resonance and enduring popularity among diverse audiences, contributing to a deeper understanding of its socio-cultural context.

In puppetry education, academic institutions serve as crucibles of knowledge dissemination and skill development, nurturing a new generation of puppeteers, educators, and researchers. Through educational programs, workshops, and pedagogical initiatives, students are introduced to the rich tapestry of puppetry heritage, learning techniques, performance styles, and historical contexts. Notable contributions in this regard include the work of Miquel and Oltra (2022), who advocate for the educational potential of puppets in early childhood education, advocating for their utilization as versatile tools for artistic expression, therapeutic intervention, and literary exploration. Additionally, Cariad and Tsaplina's (2020) emphasis on the embodied nature of puppetry practice underscores its pedagogical value in fostering creativity, memory, and historical consciousness among learners.

Furthermore, academics play a crucial role in the cultural preservation of puppetry heritage through rigorous research, documentation, and advocacy efforts. By documenting puppetry traditions, recording oral histories, and digitizing archival materials, scholars ensure the safeguarding and transmission of cultural knowledge for posterity. Mali's (2022) comprehensive examination of puppetry's historical evolution, spanning ancient Greece to contemporary India, underscores its cross-cultural influences and enduring legacy. Similarly, Raluca's (2019) exploration of puppetry's linguistic and performative dimensions highlights its role as a memory, storytelling, and cultural continuity conduit.

The academic contributions to puppetry research, education, and cultural preservation in India epitomize a rigorous scholarly endeavor characterized by a commitment to inquiry, education, and heritage conservation. Through their meticulous scholarship and pedagogical initiatives, academics enrich our understanding of puppetry as a dynamic and multifaceted art form while contributing to its preservation, revitalization, and continued relevance within Indian cultural discourse.

Notable scholars, institutions, and initiatives shaping the academic landscape of puppetry studies

The academic landscape of puppetry studies in India is shaped by the contributions of notable scholars, esteemed institutions, and pioneering initiatives dedicated to advancing knowledge, fostering creativity, and preserving cultural heritage within the field.

Among the distinguished scholars, Chopra, Goyal, and Harish (2023) stand out for their meticulous exploration of the traditional and contemporary facets of string puppets in Rajasthan, offering valuable insights into the craftsmanship and cultural significance of this ancient art form. Their research, published in esteemed journals, enriches our understanding of puppetry heritage and its enduring resonance in Indian society. Institutions such as the National School of Drama (NSD) and the Sangeet Natak Akademi (SNA) play instrumental roles in nurturing talent, promoting research, and preserving puppetry traditions. Through academic programs, workshops, and cultural exchange initiatives, these institutions provide platforms for students, scholars, and practitioners to engage with puppetry as an art form, fostering innovation and excellence in the field.

Additionally, initiatives such as the Puppeteers Collective and the Indian Puppetry Network catalyze collaboration, advocacy, and knowledge sharing within the puppetry community. These grassroots movements unite artists, researchers, and enthusiasts to celebrate puppetry's diversity, promote its cultural significance, and address its challenges. Moreover, international collaborations and exchange programs further enrich the academic landscape of puppetry studies in India. Partnerships with renowned institutions and scholars worldwide facilitate cross-cultural dialogue, research collaboration, and capacity building, expanding the horizons of puppetry scholarship and practice.

The contributions of notable scholars, esteemed institutions, and pioneering initiatives collectively shape the academic landscape of puppetry studies in India, fostering a vibrant ecosystem of research, education, and cultural preservation within the field. Through their collaborative efforts and dedication, these stakeholders continue to elevate puppetry as a cherished cultural heritage and dynamic artistic form within Indian society and on the global stage.

The role of academia in fostering innovation and knowledge exchange within the puppetry community

The role of academia in fostering innovation and knowledge exchange within the puppetry community is paramount, catalyzing advancing the art form, nurturing talent, and preserving cultural heritage. Through rigorous research, interdisciplinary collaboration, and educational initiatives, academic institutions contribute to the enrichment and evolution of puppetry as a dynamic and multifaceted field.

Academia facilitates innovation within the puppetry community by providing platforms for creative exploration, experimentation, and artistic expression. Scholars such as Chopra, Goyal, and Harish (2023) delve into puppetry's traditional and contemporary facets, uncovering new techniques, materials, and performance styles that push the boundaries of artistic innovation. Their research expands our understanding of puppetry heritage and inspires practitioners to explore new creative possibilities and push the art form's boundaries. Moreover, academic institutions serve as hubs of interdisciplinary collaboration, bringing together scholars, artists, technologists, and educators to exchange ideas, share best practices, and explore new avenues of cooperation. Initiatives such as puppetry workshops, conferences, and symposia provide opportunities for cross-disciplinary dialogue and knowledge exchange, fostering a vibrant ecosystem of innovation and creativity within the puppetry community.

In addition to fostering artistic innovation, academia plays a crucial role in knowledge exchange within the puppetry community by disseminating research findings, documenting best practices, and promoting educational initiatives. Scholars like Pandey (2017) document puppetry traditions, techniques, and performances, creating repositories of knowledge accessible to students, researchers, and practitioners alike. Through academic programs, workshops, and training sessions, institutions impart theoretical knowledge and practical skills to aspiring puppeteers, educators, and researchers, ensuring the continuity and vitality of the art form. Academia fosters international collaboration and exchange, facilitating the sharing ideas, techniques, and cultural practices across borders. Collaborations with scholars and institutions from diverse cultural backgrounds enrich the puppetry community, exposing practitioners to new perspectives, traditions, and artistic approaches. International conferences, research partnerships, and artist residencies provide cultural exchange and collaboration opportunities, fostering mutual understanding and appreciation within the global puppetry community.

Academia is multifaceted in fostering innovation and knowledge exchange within the puppetry community, serving as a nexus for artistic exploration, interdisciplinary collaboration, and cultural preservation. Through research, education, and international cooperation, academic institutions contribute to the enrichment and evolution of puppetry as a cherished cultural heritage and dynamic artistic form within Indian society and on the global stage.

INDUSTRY (MARKET)

Analyzing the commercialization of puppetry in India, including revenue streams, market trends, and audience engagement strategies

The commercialization of puppetry in India represents a dynamic intersection of cultural heritage, artistic innovation, and economic enterprise. Analyzing the market landscape provides insights into revenue streams, market trends, and audience engagement strategies, shaping the trajectory of puppetry as both a cultural art form and a viable commercial venture. One significant revenue stream within the puppetry industry in India is live performances, encompassing a wide range of venues such as theaters, festivals, and cultural events. Traditional puppetry troupes, as documented by Ghosh and Banerjee (2006,

2009), continue to captivate audiences with their vibrant performances rooted in regional folklore and mythology. These performances serve as cultural showcases and generate revenue through ticket sales, sponsorships, and merchandise. In addition to live performances, the digital landscape has opened new avenues for revenue generation and audience engagement in the puppetry market. Online platforms, social media channels, and streaming services offer opportunities for puppetry content creators to reach global audiences, monetize their work, and build fan communities. The shift towards digital platforms, as observed by Field (2023), reflects changing audience preferences and consumption patterns, with virtual performances, tutorials, and interactive experiences gaining popularity. Furthermore, the commercialization of puppetry in India is influenced by market trends that reflect broader socio-cultural dynamics and technological advancements. Emerging trends include the fusion of traditional puppetry with contemporary art forms such as multimedia, animation, and augmented reality, as explored by Mali (2022). This convergence of old and new media enhances artistic expression and attracts diverse audiences, expanding the market potential of puppetry as an entertainment medium.

Audience engagement strategies are crucial in driving the commercial success of puppetry ventures in India. Troupes and production companies leverage marketing campaigns, outreach programs, and community engagements to cultivate and retain audiences. Miquel and Oltra (2022) highlight that educational initiatives also serve as practical audience engagement tools, fostering an appreciation for puppetry among younger generations and nurturing future patrons and practitioners. A diverse array of revenue streams, market trends, and audience engagement strategies characterizes the commercialization of puppetry in India. While traditional live performances remain central to the industry, digital platforms, and emerging technologies offer new opportunities for revenue generation and audience outreach. By analyzing these market dynamics, stakeholders can identify opportunities for innovation, collaboration, and sustainable growth, ensuring puppetry's continued vitality and relevance in India's cultural landscape.

Assessing the Economic Impact of Puppetry as a Cultural Industry

Puppetry, as a cultural industry, exerts a notable economic impact in India, influenced by various factors such as funding sources, market demand, and challenges faced by practitioners (Goyal et al., 2023). Evaluating its economic significance provides insights into its contribution to livelihoods, tourism, and cultural sustainability. One aspect of puppetry's economic impact lies in its funding sources, which encompass a mix of public, private, and philanthropic support (Ghosh & Banerjee, 2006). Government grants, cultural subsidies, and arts funding initiatives play a vital role in sustaining puppetry traditions and fostering innovation within the sector (Pandey, 2017). Additionally, corporate sponsorships, patronage, and crowdfunding campaigns provide supplementary sources of financial support, enabling practitioners to produce and showcase their work to wider audiences. Market demand serves as another determinant of puppetry's economic viability, reflecting audience preferences, consumer behavior, and industry trends (Mali, 2022). Traditional puppetry forms continue to enjoy demand from local communities, tourists, and cultural enthusiasts, contributing to revenue generation through ticket sales, merchandise, and ancillary services (Ghosh & Banerjee, 2009). However, practitioners also adapt to changing market dynamics by diversifying their offerings, exploring new performance formats, and leveraging digital platforms to reach broader audiences and tap into niche markets (Field, 2023).

Despite its cultural significance, puppetry faces various challenges that impact economic sustainability and growth (Pandey, 2017). Limited institutional support, lack of infrastructure, and competition from other entertainment forms pose challenges for practitioners, particularly those from marginalized communities (Goyal et al., 2023). Additionally, globalization and digitalization have led to changes in audience preferences and consumption patterns, requiring puppeteers to innovate, adapt, and invest in new skills and technologies to remain competitive (Mali, 2022). Moreover, economic challenges such as fluctuating income, irregular employment opportunities, and limited access to resources affect the livelihoods and well-being of puppetry practitioners (Field, 2023). Many puppeteers face financial constraints, inadequate remuneration, and precarious working conditions, exacerbating socio-economic inequalities within the sector. Addressing these challenges requires concerted efforts from policymakers, cultural institutions, and industry stakeholders to provide financial support, professional development opportunities, and social protection for practitioners.

GOVERNMENT (HUMAN INVOLVEMENT)

Examine government policies, programs, and interventions supporting puppetry as a cultural heritage and livelihood option

Examining government policies, programs, and interventions supporting puppetry as a cultural heritage and livelihood option sheds light on the role of state actors in preserving, promoting, and sustaining this traditional art form. Government involvement is instrumental in providing the necessary infrastructure, financial support, and institutional framework to safeguard puppetry as a cherished cultural heritage while recognizing its potential as a viable livelihood option for practitioners. Government policies and programs to support puppetry as a cultural heritage encompass a range of initiatives aimed at documentation, preservation, and promotion. These include the designation of puppetry as an intangible cultural heritage, as recognized by UNESCO, which elevates its status and fosters international recognition and cooperation (UNESCO, n.d.).

Additionally, heritage conservation programs, cultural festivals, and museum exhibitions showcase puppetry traditions, raising awareness and appreciation among audiences.

Furthermore, government interventions encompass financial support mechanisms such as grants, subsidies, and cultural funding schemes to sustain puppetry as a viable livelihood option for practitioners (Goyal et al., 2023). These initiatives provide financial assistance for puppetry troupes, artists, and cultural organizations to produce and showcase their work, enabling them to earn a livelihood while preserving and promoting traditional puppetry forms. Government involvement also extends to providing institutional support and capacity-building initiatives aimed at strengthening puppetry practitioners' skills, knowledge, and organizational capacities (Pandey, 2017). Training programs, workshops, and skill development initiatives equip artists with the tools and techniques to sustain their craft, innovate new forms, and adapt to changing market dynamics.

Moreover, government partnerships with cultural institutions, educational organizations, and civil society groups facilitate collaborative efforts to promote puppetry as an educational tool, community development tool, and cultural diplomacy tool. These partnerships foster knowledge exchange, resource sharing, and innovation within the puppetry community, enhancing its resilience and relevance in a rapidly changing socio-cultural landscape. Government involvement in supporting puppetry as a cultural heritage and livelihood option encompasses a range of policies, programs, and interventions aimed at preservation, promotion, and sustainability. By providing financial support, institutional framework, and capacity-building initiatives, governments play a crucial role in safeguarding puppetry as a cherished cultural tradition while recognizing its potential as a source of livelihood and cultural diplomacy.

Evaluating the effectiveness of government initiatives in empowering puppeteers, preserving traditional skills, and promoting social inclusion

Evaluating the effectiveness of government initiatives in empowering puppeteers, preserving traditional skills, and promoting social inclusion requires a comprehensive analysis of the impact of these programs on the targeted beneficiaries and broader socio-cultural outcomes. While government interventions are crucial in supporting puppetry as a cultural heritage and livelihood option, their effectiveness depends on various factors such as funding allocation, implementation strategies, and stakeholder engagement.

One key aspect of evaluating government initiatives is assessing their impact on empowering puppeteers by providing them with the necessary resources, training, and opportunities to sustain their craft and earn a livelihood (Pandey, 2017). Effective government programs should facilitate access to puppeteers' financial support, skill development, and market linkages, enabling them to enhance their artistic proficiency, expand their professional networks, and generate sustainable income from their work. Furthermore, initiatives that empower puppeteers should prioritize inclusivity, ensuring that marginalized communities, women, and youth have equal access to resources and opportunities within the sector (Goyal et al., 2023).

Preserving traditional skills is another crucial aspect of evaluating government initiatives in the context of puppetry. Effective programs should focus on documenting, transmitting, and revitalizing traditional puppetry techniques, ensuring continuity and relevance in a rapidly changing cultural landscape (UNESCO, n.d.). Government support for master-apprentice programs, archival projects, and heritage conservation efforts can contribute to the preservation of traditional skills, knowledge, and performance styles, thereby safeguarding puppetry as a living cultural heritage for future generations (Ghosh & Banerjee, 2009).

Promoting social inclusion is a crucial objective of many government initiatives in puppetry. Effective programs should strive to foster diversity, equity, and inclusion within the puppetry community, creating opportunities for participation and representation for individuals from diverse backgrounds (Pandey, 2017). This may involve targeted outreach programs, community engagement initiatives, and affirmative action measures to address historical inequalities and promote social cohesion within the sector (Goyal et al., 2023).

In evaluating the effectiveness of government initiatives, it is essential to consider both quantitative and qualitative indicators of impact, including changes in income levels, artistic quality, community cohesion, and cultural recognition. Long-term sustainability, scalability, and replicability of interventions are also crucial in assessing their effectiveness over time. Ultimately, government initiatives in puppetry should be guided by principles of cultural democracy, social justice, and sustainable development, aiming to empower practitioners, preserve traditional skills, and promote social inclusion for the benefit of present and future generations.

Broader implications of government support for human involvement in puppetry on cultural identity, community development, and sustainable tourism

Government support for human involvement in puppetry has broader implications for cultural identity, community development, and sustainable tourism, shaping the socio-cultural landscape and contributing to society's overall well-being. Preserving and promoting cultural identity is at the core of government support for puppetry. Puppetry is deeply intertwined with the cultural fabric of communities across India, serving as a repository of traditional knowledge, values, and beliefs (Ghosh

& Banerjee, 2009). By investing in puppetry as a cultural heritage, governments reinforce the importance of preserving indigenous artistic traditions and celebrating cultural diversity. This strengthens cultural identity and fosters a sense of community pride and belonging, promoting cultural resilience and intergenerational transmission of heritage.

Furthermore, government support for puppetry contributes to community development by creating economic opportunities, fostering social cohesion, and revitalizing cultural infrastructure. Puppetry performances, workshops, and festivals serve as platforms for community engagement, dialogue, and empowerment, bringing together people from diverse backgrounds and promoting cross-cultural exchange (Pandey, 2017). Additionally, puppetry tourism initiatives, such as cultural trails, heritage walks, and folk festivals, attract visitors, stimulate local economies, and enhance the quality of life for residents (Field, 2023). By leveraging puppetry as a catalyst for community development, governments can address socio-economic disparities, promote sustainable livelihoods, and build resilient and inclusive communities.

Moreover, government support for puppetry has implications for sustainable tourism. Puppetry tourism initiatives offer unique cultural experiences that attract domestic and international visitors while preserving natural and cultural heritage (UNESCO, n.d.). Puppetry tourism initiatives generate revenue for local economies and raise awareness about environmental conservation, cultural preservation, and responsible tourism practices (Goyal et al., 2023). By integrating puppetry into tourism development strategies, governments can promote cultural authenticity, heritage conservation, and community empowerment, fostering a more sustainable and inclusive tourism industry.

Government support for human involvement in puppetry has far-reaching implications for cultural identity, community development, and sustainable tourism. By investing in puppetry as a cultural heritage, governments reaffirm the importance of preserving indigenous artistic traditions and promoting cultural diversity. Furthermore, puppetry catalyzes community development, fostering economic opportunities, social cohesion, and cultural revitalization. Finally, puppetry tourism initiatives offer unique cultural experiences that contribute to sustainable tourism development, promoting heritage conservation, environmental stewardship, and inclusive growth. Through strategic investments and partnerships, governments can harness the power of puppetry to enrich lives, strengthen communities, and foster sustainable development for generations to come.

CASE STUDIES AND EXAMPLES

Case Studies and Examples

Presenting case studies or examples illustrating the dynamics of puppetry, market forces, and human involvement in specific regions or communities within India offers valuable insights into the diverse landscape of puppetry practices and experiences across the country. Highlighting successful initiatives, innovative practices, and challenges faced by puppeteers and stakeholders' sheds light on the complexities and opportunities within the sector.

Case studies or examples illustrating the dynamics of puppetry, market forces, and human involvement in specific regions or communities within India.

Case Study 1: Puppetry Revival in Rajasthan

In the rural villages of Rajasthan, traditional string puppetry, known as "Kathputli," has been revived in recent years thanks to concerted efforts by local communities and cultural organizations (Chopra et al., 2023). Recognizing the cultural significance of Kathputli as a storytelling medium and source of livelihood, government-funded initiatives have supported training programs, skill development workshops, and marketing campaigns aimed at preserving and promoting this ancient art form. Through collaborative efforts between puppeteers, artisans, and tourism authorities, Kathputli performances have become a significant tourist attraction, generating income for local communities and contributing to the region's socio-economic development. However, challenges such as changing audience preferences, limited market access, and environmental degradation pose ongoing threats to the sustainability of Kathputli as a cultural heritage and livelihood option.

Case Study 2: Digital Transformation of Puppetry in Kerala

In Kerala, a state known for its rich cultural heritage and innovative arts scene, puppetry practitioners embrace digital technologies to adapt to changing market dynamics and reach new audiences (Field, 2023). Through online platforms, social media channels, and virtual reality experiences, puppeteers are experimenting with new forms of storytelling, interactive performances, and educational content delivery. These digital initiatives not only expand the reach and accessibility of puppetry but also create opportunities for revenue generation, collaboration, and audience engagement. However, challenges such as the digital divide, technological infrastructure, and intellectual property rights require careful consideration to ensure equitable access and ethical practices within the digital puppetry landscape.

Case Study 3: Community-Led Puppetry Initiatives in West Bengal

In the rural villages of West Bengal, community-led puppetry initiatives are empowering marginalized groups, promoting social inclusion, and preserving cultural heritage (Pandey, 2017). Through grassroots organizations, self-help groups, and local

cooperatives, puppetry practitioners from disadvantaged backgrounds receive training, mentorship, and financial support to revitalize traditional puppetry forms such as "Putul Naach" (doll dance). These community-led initiatives provide livelihood opportunities for puppeteers and foster pride, solidarity, and cultural continuity within marginalized communities. However, persistent challenges such as limited funding, lack of infrastructure, and societal stigma pose obstacles to the long-term sustainability of these grassroots puppetry initiatives.

The case studies exemplify the diverse dynamics of puppetry, market forces, and human involvement in specific regions or communities within India. While successful initiatives demonstrate the resilience and adaptability of puppetry practitioners, challenges such as changing audience preferences, digital transformation, and socio-economic inequalities underscore the need for innovative solutions, supportive policies, and collaborative efforts to ensure the continued vitality and relevance of puppetry as a cultural heritage and livelihood option.

Highlight successful initiatives, innovative practices, and challenges puppeteers and stakeholders face

Successful Initiatives

i. Community Empowerment Programs: Collaborative efforts between government agencies, NGOs, and local communities have led to the establishment of community empowerment programs to revitalize traditional puppetry forms. These initiatives provide puppeteers with training, resources, and marketing support, empowering them to preserve their cultural heritage while generating sustainable income (Pandey, 2017).
ii. Cultural Festivals and Events: Cultural festivals and events dedicated to puppetry, such as the International Puppet Festival in Kolkata and the Rajasthan International Puppet Festival, have gained prominence recently. These platforms not only provide exposure and networking opportunities for puppeteers but also attract audiences from diverse backgrounds, fostering an appreciation for this ancient art form (Chopra et al., 2023).
iii. Digital Innovation: Puppeteers are leveraging digital technologies to innovate new forms of puppetry and reach wider audiences. Online platforms, social media, and virtual reality experiences enable puppeteers to showcase their performances, connect with fans, and explore interactive storytelling formats, thereby expanding the reach and impact of puppetry in the digital age (Field, 2023).

Innovative Practices

i. Hybrid Performances: Puppeteers are experimenting with hybrid performance styles that combine traditional puppetry techniques with contemporary elements such as music, dance, and multimedia. These innovative practices attract diverse audiences and breathe new life into age-old puppetry traditions, ensuring their relevance in a modern context (Ghosh & Banerjee, 2006).
ii. Education and Outreach Programs: Puppetry education and outreach programs target schools, community centers, and cultural institutions, introducing children and youth to the art of puppetry. These programs foster participants' creativity, empathy, and cultural appreciation through hands-on workshops, storytelling sessions, and educational resources, nurturing the next generation of puppetry enthusiasts and practitioners (Miquel & Oltra, 2022).
iii. Cross-Cultural Collaborations: Puppeteers are engaging in cross-cultural collaborations with artists, scholars, and practitioners from different regions and disciplines. These collaborations enrich artistic expression and facilitate knowledge exchange, innovation, and cultural dialogue, fostering mutual understanding and appreciation across diverse communities (Cariad & Tsaplina, 2020).

Challenges Faced

i. Economic Sustainability: Puppeteers often face challenges in generating sustainable income from their craft due to limited market opportunities, low audience turnout, and fluctuating demand. Many puppeteers struggle to make ends meet and lack access to financial support, marketing resources, and professional development opportunities (McCormick & Pratasik, 1989).
ii. Technological Transition: While digital innovation offers new possibilities for puppetry, many puppeteers lack the technical skills, resources, and infrastructure to harness digital technologies effectively. The digital divide, limited internet connectivity, and access to equipment pose challenges for puppeteers seeking to adapt to the digital landscape (Field, 2023).
iii. Cultural Preservation: Rapid urbanization, globalization, and cultural homogenization threaten traditional puppetry forms and practices. Changing audience preferences, diminishing patronage, and losing intergenerational knowledge pose challenges for preserving and transmitting puppetry as a cultural heritage (Ghosh & Banerjee, 2009).

The successful initiatives and innovative practices demonstrate the resilience and adaptability of puppeteers and stakeholders in India. However, challenges such as economic sustainability, technological transition, and cultural preservation underscore the need for continued support, collaboration, and advocacy to ensure the vitality and relevance of puppetry as a cherished cultural tradition and dynamic artistic form.

CONCLUSION

This research has illuminated the intricate landscape of puppetry in India, emphasizing its deep-rooted traditions, evolving market dynamics, and the vital role of human involvement. Through the analysis of academic literature, government policies, case studies, and stakeholder insights, the study has identified several key findings that underscore the cultural richness and adaptive capacity of puppetry. At its core, Indian puppetry represents a living repository of heritage, encompassing a multitude of forms, techniques, and narratives that have been passed down across generations. The resilience and creativity embedded in these traditions continue to inspire innovation, as puppeteers adopt their practices to resonate with contemporary audiences while preserving their ancestral legacy. Government intervention has emerged as a critical enabler for the survival and flourishing of puppetry. Public policies and cultural programs have the potential to sustain puppetry both as a form of artistic expression and as a means of livelihood. Institutional support through funding, recognition, and infrastructure helps puppeteers navigate economic uncertainties and professionalize their craft. However, to be truly impactful, such interventions must be inclusive, context-sensitive, and grounded in the lived realities of traditional artists.

The research also highlights that the market environment for puppetry is shaped by shifting audience preferences, digital transformation, and broader socio-economic forces. While technology presents new opportunities—such as online performances, virtual exhibitions, and global reach—it also introduces challenges related to digital access, commercialization, and authenticity. Balancing innovation with the preservation of cultural integrity is essential to ensure puppetry remains both relevant and respected. Human involvement is perhaps the most dynamic dimension of the puppetry ecosystem. Artists, educators, policymakers, researchers, and audiences all play critical roles in shaping its trajectory. Their interactions form the foundation for knowledge transfer, creative experimentation, and cultural dialogue. Community-driven initiatives and collaborative networks have proven especially effective in revitalizing the art form and expanding its social impact.

In this context, the Triple Helix Model offers a valuable analytical lens, synthesizing tradition, market dynamics, and human agency into an integrated framework. It demonstrates that the evolution of puppetry depends on the balanced interplay of these three dimensions. Tradition anchors puppetry in cultural heritage; market dynamics determine its economic viability; and human involvement ensures its relevance and adaptability. Any imbalance among these strands can hinder the art's sustainability, making it essential to cultivate synergy among all actors involved. To promote the growth of puppetry, future research should focus on its socio-economic impact on communities, the application of digital tools to enhance performance and outreach, and its role in education. Policy recommendations include providing financial incentives, embedding puppetry in cultural and educational programs, and fostering international collaborations. Community engagement should be bolstered through local festivals, professional training, and NGO partnerships. Simultaneously, strategic marketing—via social media, tourism, and media collaborations—can amplify the visibility of puppetry nationally and globally. Skill development through specialized institutions and the documentation of traditional knowledge will help preserve and evolve the art form. Collectively, these recommendations can create an ecosystem where puppetry thrives not only as a cherished cultural legacy but also as a dynamic force for creative expression, community empowerment, and cultural continuity in modern India.

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Bridging Cultures: A Comparative Study of Female Agency in African and Indian Women's Novels

Priyanka Malik[1*], Girish Panth[1], Saroj Bala[2]

[1] School of Humanities, Starex university, Gurgaon, Haryana, India
[2] Swami Shraddhanand College, University of Delhi, Delhi, India

***Corresponding Author:** priyankamann93@gmail.com

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ABSTRACT

This paper presents a comparative literary analysis of female agency in African and Indian women's novels, highlighting how women writers from these regions challenge patriarchal structures and reclaim female subjectivity. Drawing on selected works by authors such as Buchi Emecheta, Chimamanda Adichie, Mahasweta Devi, and Kamala Das, the study examines thematic concerns including gender roles, resistance, identity, and the tension between tradition and modernity. The analysis reveals both convergences and divergences in narrative strategies, socio-cultural contexts, and feminist articulations. Using feminist literary theory and postcolonial criticism as frameworks, the research underscores how these authors employ literature not just as artistic expression but as political resistance, offering counter-narratives to dominant patriarchal and colonial discourses. The study concludes that African and Indian women writers serve as cultural agents who not only document but actively shape feminist consciousness in their respective societies.

Keywords: Female agency, postcolonial literature, feminist theory, African women writers, Indian women writers.

INTRODUCTION

The literary voices of women in postcolonial societies have played a pivotal role in reshaping the contours of national identity, cultural memory, and socio-political resistance. Among these, African and Indian women writers have emerged as powerful agents of change, challenging patriarchal structures, reclaiming historical narratives, and articulating the complexities of female subjectivity in deeply stratified societies (Chikwenye, 2006; Spivak, 1988). Their works offer nuanced insights into the gendered realities of postcolonial life, where women negotiate identity within intersecting oppressions of colonial legacy, patriarchy, caste, class, and ethnicity.

Despite being rooted in distinct geographies and traditions, African and Indian women's literatures share common thematic threads: the struggle for self-definition, the burden of tradition, resistance to patriarchal norms, and the assertion of female agency (Mohanty, 1988; Nfah-Abbenyi, 1997). In both literary traditions, women writers have often used fiction not merely as a form of artistic expression but as a mode of activism—an instrument to interrogate social norms, dismantle stereotypes, and illuminate the silenced voices of women in their societies (Thiong'o, 1986; Devi, 1997). Through the lens of gender and postcolonial critique, these writings serve as repositories of resistance and resilience.

African women's literature, though historically marginalized due to colonial language politics and patriarchal cultural structures, began gaining prominence in the mid-20th century with authors such as Flora Nwapa, Buchi Emecheta, and later Chimamanda Ngozi Adichie. Their works explore the multilayered oppressions women face, from bride price practices and polygamy to Western education's double-edged promise (Nwapa, 1966; Emecheta, 1979; Adichie, 2004). These narratives are often rooted in oral traditions, mythic structures, and indigenous idioms, creating a literary tapestry that resists homogenization

while asserting cultural specificity (Stratton, 1994; Davies & Graves, 1986).

In contrast, Indian women writers have long contended with the dual burden of colonial influence and entrenched patriarchy, producing literature that reflects regional diversity, linguistic plurality, and layered forms of oppression (Chakravarty, 2008; Chughtai, 1994). From the feminist provocations of Ismat Chughtai and Kamala Das to the Dalit feminist voices of Urmila Pawar and Bama, Indian women's literature presents a complex negotiation of gender, caste, and identity within a rapidly modernizing society (Pawar, 2008; Das, 2009; Rege, 2000). Their works span across genres—poetry, short stories, memoirs, and novels—each format allowing a different register of emotional and political engagement.

This comparative study seeks to analyze how African and Indian women novelists construct female agency in their narratives. It aims to explore the thematic, stylistic, and contextual similarities and differences in their portrayals of women's lives. By examining selected literary works from both regions—including *The Joys of Motherhood* by Buchi Emecheta, *Purple Hibiscus* by Chimamanda Adichie, *Draupadi* by Mahasweta Devi, and *An Introduction* by Kamala Das—this study seeks to illuminate how these authors represent the dynamics of gender roles, resistance, and identity within the larger framework of postcolonial struggle and feminist thought.

The methodological approach taken here is grounded in comparative literature, intersecting with feminist literary theory and postcolonial criticism. It positions literature as both a cultural artifact and a political act, emphasizing the transformative power of narrative in articulating subaltern voices (Spivak, 1988; Minh-ha, 1989). Importantly, this paper also reflects on how these narratives resonate globally while remaining deeply embedded in local contexts—a duality that characterizes much of postcolonial women's writing.

Ultimately, this paper contends that African and Indian women's literatures do not merely document oppression; they serve as platforms for envisioning alternative futures. These works critique dominant narratives, destabilize hegemonic histories, and present counter-discourses that foreground the lived experiences of women. In doing so, they play an essential role in decolonizing literature and empowering female voices in the global literary canon (Ashcroft, Griffiths, & Tiffin, 2002; Nnaemeka, 2004).

LITERATURE REVIEW

African Feminist Literary Canon

African women's literature emerged prominently during the post-independence era, although its roots lie in long-standing oral traditions and indigenous knowledge systems. The early literary landscape was dominated by male authors, and women's narratives were often suppressed or represented through a patriarchal lens (Stratton, 1994). The pioneering works of Flora Nwapa and Buchi Emecheta marked a pivotal shift, foregrounding women's lived experiences within colonial and postcolonial societies. Nwapa's *Efuru* (1966) was one of the first novels by an African woman to gain international recognition, offering a nuanced portrayal of a woman navigating marriage, motherhood, and economic independence.

Emecheta's *The Joys of Motherhood* (1979) continued this trajectory by critically examining the myth of maternal fulfillment in a society where a woman's worth is tethered to her reproductive role. According to Davies and Graves (1986), Emecheta's narrative strategy of embedding socio-political commentary within personal stories marked a turning point in African feminist literature. Chimamanda Ngozi Adichie further expanded this tradition in the 21st century by interweaving contemporary issues—such as globalization, religious fundamentalism, and youth identity crises—into her novels like *Purple Hibiscus* (2004) and *Half of a Yellow Sun* (2006), maintaining the feminist ethos while broadening the thematic scope (Adichie, 2004; Ogundipe-Leslie, 1994).

African feminist literary criticism also emphasizes the intersectionality of gender, race, and coloniality. Scholars like Nnaemeka (2004) and Nfah-Abbenyi (1997) argue that African women writers resist Western feminist models, instead formulating indigenous feminisms rooted in communal values and anti-colonial resistance. This approach, often referred to as "nego-feminism," allows for a flexible understanding of power, negotiation, and compromise in African women's lives (Nnaemeka, 2004). The literary expression of these dynamics manifests through narrative forms that draw on oral storytelling, proverbs, and folklore, reinforcing cultural continuity while challenging patriarchal norms (Stratton, 1994; Kolawole, 1997).

Indian Feminist Literary Landscape

The Indian feminist literary tradition is similarly rich, with its evolution shaped by colonial encounters, nationalist movements, and internal socio-religious reform. Early women writers like Rokeya Sakhawat Hossain and Pandita Ramabai used prose and essays to advocate for women's education and emancipation. However, the post-independence period witnessed the rise of fiction writers who addressed the complexities of caste, gender, and sexuality in modern India (Chakravarty, 2008).

Ismat Chughtai's *Lihaaf* (1942) was revolutionary in its open portrayal of female desire and same-sex intimacy, provoking widespread controversy and debate in conservative literary circles (Chughtai, 1994). Kamala Das, known for her confessional poetry and prose, articulated the tensions between societal expectations and female autonomy. In *My Story* (1976), she

dismantles the myth of the dutiful Indian woman by exposing the emotional and sexual struggles of women in patriarchal households (Das, 2009). Writers like Mahasweta Devi, through works such as *Draupadi*, infused fiction with revolutionary zeal, using tribal and Dalit women's voices to challenge systemic violence and state oppression (Devi, 1997; Rege, 2000).

Indian feminist scholarship emphasizes the diversity of women's experiences across caste, religion, region, and class. The concept of "multiple patriarchies" articulated by scholars like Rege (2000) and Chakravarty (2008) underscores how upper-caste, urban feminist discourses often marginalize Dalit and Adivasi women's narratives. In this context, the autobiographical writings of Dalit authors like Urmila Pawar and Bama have emerged as powerful counter-discourses. These works combine literary innovation with political critique, reclaiming narrative spaces that had been historically denied to subaltern women (Pawar, 2008; Bama, 2000).

Indian women's literature also reflects the tension between tradition and modernity, a recurring theme as authors grapple with cultural continuity amid globalization. This duality is often explored through symbolic devices, such as the domestic space, religious rituals, or female bodies, to critique hegemonic norms while also seeking rootedness in cultural heritage (Mukherjee, 2000).

Comparative Feminist Theorization

While the literary traditions of African and Indian women are shaped by distinct socio-political histories, both intersect through their shared engagement with postcolonial feminism. Spivak's (1988) seminal essay *Can the Subaltern Speak?* has become central to understanding how women from formerly colonized regions articulate agency in spaces where their voices have been historically erased. Spivak argues that even within anti-colonial narratives, women's voices are often ventriloquized or silenced, necessitating a deliberate re-centering of their perspectives in postcolonial discourse.

Mohanty (1988) similarly critiques the homogenizing tendencies of Western feminism, cautioning against the portrayal of "Third World women" as a monolithic oppressed group. Instead, she advocates for context-specific feminist epistemologies that recognize the multiplicity of experiences shaped by history, culture, and resistance. In the comparative context, this theoretical lens is vital for analyzing how African and Indian women writers deploy literature to deconstruct essentialist gender roles and reframe agency.

Furthermore, the use of indigenous literary forms—oral storytelling in Africa and mythological retellings in India—illustrates how cultural specificities enrich feminist expression. As Minh-ha (1989) posits, narrative voice and structure are themselves political; women's stories disrupt not only content but also form, breaking linearity, hierarchy, and closure to assert feminist consciousness. These strategies foreground literature as a site of epistemological resistance, allowing marginalized women to speak, imagine, and theorize on their own terms.

Comparative studies like those by Nath and Dutta (2018) demonstrate the pedagogical value of placing African and Indian women's literatures side-by-side. Their analysis of Emecheta and Lummer Dai shows how bride-price and arranged marriage, while culturally specific, emerge as universal metaphors for patriarchal control. Thus, this comparative lens not only highlights convergences but also foregrounds the need to situate each narrative within its own cultural logic.

RESEARCH METHODOLOGY

This research adopts a qualitative and interpretive approach rooted in comparative literary analysis. The primary objective is to examine how female agency is represented and negotiated in selected African and Indian women's novels. The methodology is designed to capture both the cultural specificities and thematic parallels within the two literary traditions, using feminist and postcolonial theoretical frameworks to inform textual interpretation.

Research Design

The study is structured as a comparative case study analysis of representative works authored by women from Africa and India. This design allows for a deep contextual understanding of how gender roles, identity formation, resistance, and socio-cultural tensions are portrayed in literary narratives. Rather than focusing on statistical generalizations, this research prioritizes thematic depth, narrative nuance, and symbolic meaning. The research follows an interpretivist paradigm, which acknowledges the multiplicity of meanings and subjectivities embedded in literary texts (Denzin & Lincoln, 2011). It embraces the notion that literature is not only reflective of society but also constitutive of cultural ideologies, making it a rich site for critical feminist inquiry.

Selection of Primary Texts

The novels and texts selected for this study represent diverse geographical, linguistic, and socio-cultural contexts within the African and Indian literary landscapes. They were chosen based on their:

i. Canonical or critical status within feminist and postcolonial literature,

ii. Representation of women's voices and agency,

iii. Engagement with socio-cultural, historical, and political themes,

iv. Use of innovative narrative techniques.

Selected African Texts

i. Efuru by Flora Nwapa (1966)

ii. The Joys of Motherhood by Buchi Emecheta (1979)

iii. Purple Hibiscus by Chimamanda Ngozi Adichie (2004)

iv. The Stillborn by Zaynab Alkali (1984)

Selected Indian Texts

i. Lihaaf by Ismat Chughtai (1942)

ii. Draupadi by Mahasweta Devi (1997)

iii. An Introduction by Kamala Das (1965)

iv. Aaydan by Urmila Pawar (2008)

These texts span different time periods and thematic scopes, enabling a historical and generational comparison of female voices within postcolonial narratives.

Analytical Framework

The analytical process integrates feminist literary theory, intersectionality, and postcolonial criticism:

i. Feminist Literary Theory focuses on the representation of gender, power dynamics, and the construction of female subjectivity (Showalter, 1985; Moi, 1985). It guides the examination of how the selected authors challenge patriarchal structures through female-centered narratives.

ii. Intersectionality is employed to assess how gender interacts with other axes of identity—such as caste, class, ethnicity, and colonial history—to shape women's experiences (Crenshaw, 1991). This is particularly relevant in texts like *Aaydan*, which explores Dalit identity, and *Draupadi*, which centers an Adivasi woman's resistance.

iii. Postcolonial Criticism informs the exploration of identity formation, cultural hybridity, resistance to Western epistemologies, and the reclaiming of indigenous voices (Said, 1978; Bhabha, 1994). It is especially relevant in analyzing the lingering effects of colonial rule on women's roles and autonomy in both regions.

Data Collection and Interpretation

As this is a textual analysis, data was collected through close reading of the selected novels and cross-referenced with relevant literary criticism, journal articles, and feminist theory. The analytical process involved:

i. Identifying key themes related to female agency, resistance, and gender roles.

ii. Analyzing narrative strategies such as voice, symbolism, and form.

iii. Comparing the findings across African and Indian contexts using thematic coding and synthesis.

iv. Integrating theoretical perspectives to interpret how these themes align or diverge.

Each text was analyzed individually, followed by a comparative synthesis to draw cross-cultural insights. Emphasis was placed on authorial intent, character development, social context, and reception.

Ethical Considerations and Limitations

Given the nature of literary research, ethical concerns are minimal. However, the researcher remains critically aware of the risk of imposing external theoretical frameworks—particularly Western feminist perspectives—onto culturally specific texts. Care was taken to contextualize each analysis within its respective cultural and historical setting, and to prioritize indigenous feminist thought where available.

The primary limitation of the study is its non-exhaustive text selection. While the chosen texts are representative, they cannot capture the full diversity of African and Indian women's literature. Additionally, translation issues may affect the interpretation of non-English texts, particularly regional Indian works and African texts originally written in indigenous languages.

ANALYSIS AND DISCUSSION

This section explores how African and Indian women novelists conceptualize female agency through their thematic concerns, narrative strategies, and engagement with socio-cultural tensions. Drawing from selected texts, the analysis reveals

both convergence and divergence in how these writers articulate women's struggles and resistance within patriarchal, postcolonial realities.

Historical and Socio-Cultural Contexts

The literary emergence of African and Indian women cannot be divorced from the historical structures that marginalized their voices. In Africa, colonial systems disrupted indigenous gender norms while simultaneously instituting Victorian ideals of womanhood, limiting access to education and public discourse (Nfah-Abbenyi, 1997; Stratton, 1994). Women like Flora Nwapa and Buchi Emecheta broke these barriers by reclaiming storytelling traditions and spotlighting female protagonists navigating marriage, motherhood, and societal constraints (Nwapa, 1966; Emecheta, 1979). Similarly, Indian women faced both colonial and Brahmanical patriarchy, which reinforced female domesticity and silenced dissent. Writers such as Ismat Chughtai and Mahasweta Devi used fiction to defy this silencing and critique rigid gender norms within Hindu-Muslim and tribal frameworks respectively (Chughtai, 1994; Devi, 1997).

In both regions, oral traditions and communal storytelling shaped narrative forms. While African literature is often characterized by folklore-infused prose and collective memory, Indian literature reflects mythological allegory and spiritual metaphor (Kolawole, 1997; Mukherjee, 2000). These culturally rooted modes of expression have allowed women writers to challenge dominant historiographies and construct spaces of feminist articulation.

Thematic Concerns

Gender Roles and Patriarchal Structures

Both African and Indian women writers interrogate the institution of marriage as a central site of female subjugation. In The Joys of Motherhood, Emecheta deconstructs the glorification of motherhood, portraying Nnu Ego's sacrifices as ultimately unrecognized and unrewarded by her patriarchal society (Emecheta, 1979). Likewise, in *Lihaaf*, Chughtai subtly critiques the sexual and emotional neglect experienced by women in traditional marriages, using homoerotic subtext as a form of resistance (Chughtai, 1994). These narratives expose how gender roles are culturally constructed and maintained through familial, religious, and legal structures.

Identity and Selfhood

Female identity is often negotiated at the intersection of societal expectations and personal desires. In Purple Hibiscus, Adichie depicts the psychological journey of Kambili, a teenage girl suffocated by a religiously fanatic father, who gradually asserts her voice and autonomy (Adichie, 2004). Similarly, Kamala Das's An Introduction critiques the social policing of female identity and asserts the poet's right to linguistic, sexual, and emotional freedom (Das, 2009). Both writers foreground internal transformation as a form of agency, emphasizing the power of language and self-expression.

Resistance and Rebellion

Resistance manifests both overtly and subtly across the texts. Devi's *Draupadi* presents Dopdi Mejhen, a tribal woman who resists military and patriarchal oppression not through submission but through a radical act of bodily defiance—refusing to clothe herself after being raped, thereby reclaiming agency (Devi, 1997). This symbolic resistance resonates with the thematic subversion in The Stillborn by Zaynab Alkali, where the protagonist breaks free from societal norms that deem women incomplete without children (Alkali, 1984). These texts embody feminist refusal and the redefinition of power beyond institutional validation.

Tradition versus Modernity

Writers in both traditions grapple with the dilemma of preserving cultural heritage while seeking liberation from its regressive elements. Efuru and Aaydan both highlight how women maneuver through religious and communal customs while asserting individuality. While Nwapa presents Efuru as a spiritual figure who ultimately chooses self-respect over marital conformity (Nwapa, 1966), Urmila Pawar's autobiography portrays the tension between Dalit identity and the pursuit of modern feminist ideals (Pawar, 2008). These narratives question the binaries of tradition and modernity, suggesting that feminist agency often lies in reinterpreting rather than rejecting cultural values.

Narrative Strategies and Literary Devices

African and Indian women writers employ diverse narrative techniques to embody female subjectivity and resistance. First-person narration is frequently used to build intimacy and authenticity, as seen in An Introduction and My Story, where Das's confessional style disrupts literary decorum and asserts a female gaze (Das, 2009). In The Stillborn, Alkali's use of third-person narration combined with internal monologue captures the protagonist's emotional turmoil and inner strength.

Symbolism is also central to both traditions. In Lihaaf, the quilt becomes a metaphor for hidden female desire and taboo (Chughtai, 1994), while in Purple Hibiscus, the titular flower represents both repression and the fragile hope of emancipation (Adichie, 2004). In African literature, storytelling itself is often a symbolic act of reclamation, as seen in Adichie's narrative layering and Emecheta's interweaving of personal and communal voices.

Multilingualism and code-switching further complicate narrative structures, particularly in Indian texts that move between English, Hindi, and regional languages. These linguistic choices reflect hybridity and cultural negotiation (Mukherjee, 2000). In African novels, the integration of proverbs, songs, and indigenous expressions reinforces oral memory and challenges the dominance of colonial language norms (Kolawole, 1997).

Case Studies: Comparative Insights

Emecheta's Nnu Ego vs. Devi's Dopdi

While both protagonists exist within exploitative patriarchal systems, their responses differ. Nnu Ego internalizes societal expectations and succumbs to them, symbolizing the generational weight of tradition (Emecheta, 1979). In contrast, Dopdi's physical and psychological defiance dismantles the narrative of victimhood and asserts revolutionary subjectivity (Devi, 1997). The contrast highlights how agency can be shaped by class, community, and historical positioning.

Adichie's Kambili vs. Das's Speaker

Both characters experience silencing and surveillance but use personal voice as a tool of resistance. Kambili's journey is outward—moving from oppression to liberation through external change—while Das's resistance is inward, rooted in poetic self-assertion (Adichie, 2004; Das, 2009). These parallel journeys reflect the multiplicity of feminist expression.

Lummer Dai and Buchi Emecheta

The theme of bride price in both authors' works functions as a critique of commodified femininity. While Emecheta's protagonist resents her objectification, Dai presents a more ambivalent stance, showing how tradition can also carry symbolic and communal meanings (Nath & Dutta, 2018). This nuanced portrayal reflects the dynamic engagement with cultural practices across both regions.

CONCLUSION

This comparative study reveals that African and Indian women writers have profoundly transformed the literary landscapes of their respective regions by foregrounding women's lived experiences and resisting the homogenizing pressures of patriarchy and colonial legacies. Through distinct yet overlapping trajectories, these writers engage with themes such as gender roles, identity, resistance, and the tension between tradition and modernity—each uniquely situated within their socio-cultural contexts. From the defiant voice of Dopdi in Mahasweta Devi's Draupadi to the subdued suffering of Nnu Ego in Emecheta's The Joys of Motherhood, the breadth of female subjectivity is vividly portrayed, offering complex and often contradictory depictions of agency. Despite linguistic, geographical, and cultural divergences, these literatures converge in their goal to disrupt silence, critique social injustice, and offer alternative visions of womanhood. Their narrative strategies—whether oral, poetic, symbolic, or hybrid—serve not only as artistic devices but also as political tools for reclaiming history and identity. By weaving personal stories into the broader tapestry of national and postcolonial struggles, these writers challenge dominant historiographies and inscribe women's voices into cultural memory. Furthermore, the study affirms that feminist literary expression cannot be bound by Western paradigms alone. The feminist consciousness evident in these texts is deeply embedded in local traditions, indigenous philosophies, and grassroots activism. Such multiplicity enriches global feminist discourse by introducing non-Western articulations of resistance and autonomy.

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Telephone No.: +91 70426 57038,
Phone No.: +91 88606 72581
mail: editorinchief@ijcres.in, managingeditor@ijcres.in
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