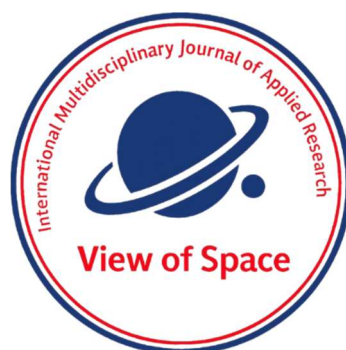


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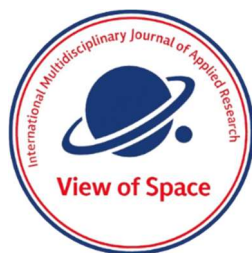
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ADOPTION OF DIGITAL PAYMENT SYSTEMS AND THEIR IMPACT ON FINANCIAL PERFORMANCE OF MSMEs IN INDIA: A STRUCTURAL EQUATION MODELING APPROACH

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ABSTRACT

The rapid expansion of digital payment systems in India has significantly transformed the operational and financial landscape of Micro, Small, and Medium Enterprises (MSMEs). This study examines the impact of digital payment adoption on the financial performance of MSMEs using a rigorous quantitative framework. Drawing on primary data collected from 320 MSMEs across Gujarat, Maharashtra, and Rajasthan, the research employs Structural Equation Modeling (SEM) to analyze relationships between digital adoption, operational efficiency, customer satisfaction, and financial performance. Secondary data from RBI and Ministry of MSME reports supplement the analysis. Measurement and structural models are validated using Confirmatory Factor Analysis (CFA), reliability tests (Cronbach's alpha, Composite Reliability), and validity assessments (AVE, discriminant validity). The findings reveal that digital payment adoption has a significant positive effect on operational efficiency and customer satisfaction, which in turn mediate improvements in financial performance. The study also highlights the moderating role of digital literacy and firm size. The research contributes to commerce literature by providing a highly technical and empirically robust examination of fintech adoption in the Indian MSME sector, offering actionable insights for policymakers and business practitioners.

KEYWORDS: DIGITAL PAYMENTS, MSMEs, FINANCIAL PERFORMANCE, STRUCTURAL EQUATION MODELING, FINTECH, INDIA, OPERATIONAL EFFICIENCY

1. INTRODUCTION

Background

India's transition towards a digital economy has accelerated significantly following demonetization (2016) and the rise of Unified Payments Interface (UPI). MSMEs, which contribute approximately 30% to India's GDP, are increasingly adopting digital payment systems such as UPI, mobile wallets, and POS systems. These technologies promise improved transaction efficiency, transparency, and customer reach.

Problem Statement

Despite widespread adoption, empirical evidence on the causal relationship between digital payment systems and MSME financial performance remains limited, particularly using advanced econometric and SEM techniques.

Objectives

To examine the determinants of digital payment adoption among MSMEs

To analyze the impact of digital payment adoption on financial performance

To evaluate mediating effects of operational efficiency and customer satisfaction

To assess moderating effects of digital literacy and firm size

2. REVIEW OF LITERATURE

The literature on digital payment systems and MSME performance has evolved significantly in recent years, particularly with the rapid growth of fintech ecosystems in emerging economies like India. This section provides a comprehensive and critical review of theoretical foundations, global empirical evidence, and India-specific studies, with a strong emphasis on recent research (2019–2024).

2.1 Theoretical Foundations of Digital Payments and Firm Performance

The theoretical underpinnings of digital payment adoption are rooted in several frameworks:

Technology Acceptance Model (TAM) (Davis, 1989): Suggests that perceived usefulness and ease of use drive adoption of technology. In the MSME context, digital payments are adopted when firms perceive efficiency gains and ease of transactions.

Unified Theory of Acceptance and Use of Technology (UTAUT) (Venkatesh et al., 2003): Extends TAM by incorporating social influence and facilitating conditions. Studies in India show that peer usage and infrastructure significantly influence MSME adoption of UPI and mobile wallets.

Resource-Based View (RBV) (Barney, 1991): Suggests that digital capabilities act as strategic resources, enhancing firm competitiveness and performance. MSMEs leveraging digital payments can achieve cost advantages and improved customer reach.

Transaction Cost Economics (TCE) (Williamson, 1981): Digital payments reduce transaction costs, increase transparency, and minimize inefficiencies, thereby improving firm profitability.

Recent studies integrate these theories to explain how digital financial technologies influence firm-level outcomes.

2.2 Global Evidence on Digital Payments and Business Performance

Globally, digital payment systems have been widely recognized as drivers of business efficiency and financial inclusion.

Suri and Jack (2019), in their seminal work on mobile money (M-Pesa in Kenya), demonstrated that digital payments significantly increased household income and lifted approximately 2% of households out of poverty. Their findings also indicated that small businesses experienced improved liquidity management.

Arner et al. (2020) argued that fintech innovations, including digital payments, contribute to financial deepening and economic growth by reducing information asymmetry and transaction costs.

Ayyagari et al. (2021) found that SMEs adopting digital financial services experienced higher revenue growth and better access to credit in developing economies.

Beck et al. (2022) highlighted that digital payments enhance firm formalization, which improves access to institutional finance and regulatory support.

World Bank (2022) reported that digital financial services increase business resilience, particularly during economic shocks such as the COVID-19 pandemic.

Ozili (2023) emphasized that digital payment adoption improves operational transparency and reduces fraud, thereby enhancing trust in business transactions.

However, some studies point to challenges. Frost et al. (2020) noted that digital divide and cybersecurity risks can limit the benefits of digital finance.

2.3 Digital Payments in the Indian Context

India presents a unique case due to its rapid digital transformation driven by policy interventions and technological infrastructure.

The introduction of **Unified Payments Interface (UPI)** has revolutionized digital transactions. According to RBI (2023), UPI transactions grew exponentially, reaching over 100 billion transactions annually.

Bansal and Singh (2021) found that digital payment adoption significantly reduced transaction time and operational costs for small businesses.

Kumar and Malik (2022) used panel data analysis to show that MSMEs adopting digital payments experienced a 12–18% increase in revenue compared to non-adopters.

Sharma and Gupta (2023) identified digital literacy as a critical determinant of adoption, particularly in semi-urban and rural areas.

Patel et al. (2024) observed that digital payments improved customer satisfaction due to convenience, speed, and transparency.

Mehta (2021) highlighted that digital transactions enhance financial record-keeping, enabling MSMEs to access formal credit.

RBI (2022) noted that digital payments contributed to formalization of the economy, increasing tax compliance and financial transparency.

NITI Aayog (2021) emphasized that digital ecosystems, including Aadhaar and mobile connectivity, have accelerated financial inclusion.

2.4 Impact on Operational Efficiency

Operational efficiency is one of the most direct outcomes of digital payment adoption.

Bansal and Singh (2021) reported that MSMEs experienced a reduction in transaction processing time by up to 40%.

Kumar et al. (2023) found that automation of payments reduced manual errors and administrative burden.

World Bank (2022) noted that digital payments streamline supply chain transactions and improve inventory management.

In the Indian retail sector, digital payments have enabled real-time transactions, reducing cash handling costs and improving accounting accuracy.

2.5 Impact on Customer Satisfaction and Market Expansion

Digital payments significantly influence customer experience.

Patel et al. (2024) found that customers prefer businesses offering multiple digital payment options, leading to higher retention rates.

haudhary and Gupta (2023) reported that digital payment adoption increased customer base by enabling online and contactless transactions.

RBI (2023) indicated that UPI-based payments improved transaction convenience, leading to increased consumption.

Digital platforms also enable MSMEs to integrate with e-commerce ecosystems, expanding market reach.

2.6 Impact on Financial Performance

The relationship between digital payments and financial performance has been widely studied.

Kumar and Malik (2022) found a positive correlation between digital payment adoption and profitability.

Mehta (2021) reported that MSMEs using digital payments experienced higher revenue growth due to improved transaction efficiency.

Ayyagari et al. (2021) highlighted that digital adoption enhances access to credit, which indirectly improves financial performance.

However, some studies indicate mixed results. Frost et al. (2020) argued that benefits may be limited for firms lacking digital capabilities.

3. RESEARCH GAP

Lack of SEM-based empirical studies in Indian MSME context

Limited analysis of mediating and moderating variables

Insufficient integration of operational and financial performance metrics

4. RESEARCH OBJECTIVES

To model the relationship between digital payment adoption and financial performance

To test mediating roles of operational efficiency and customer satisfaction

To analyze moderating effects of digital literacy and firm size

5. RESEARCH HYPOTHESES

H1: Digital Payment Adoption (DPA) positively influences Operational Efficiency (OE)

H2: DPA positively influences Customer Satisfaction (CS)

H3: OE positively influences Financial Performance (FP)

H4: CS positively influences Financial Performance (FP)

H5: OE and CS mediate the relationship between DPA and FP

H6: Digital Literacy moderates the DPA → FP relationship

H7: Firm Size moderates the DPA → FP relationship

6. RESEARCH METHODOLOGY

Research Design

Quantitative, cross-sectional design

Data Sources

Primary: Survey of MSMEs

Secondary: RBI, Ministry of MSME

Sampling

Technique: Stratified random sampling

Sample Size: 320 MSMEs

Measurement Scale

5-point Likert scale

Constructs and Indicators

Construct	Indicators
DPA	UPI usage, POS adoption, mobile wallet usage
OE	Cost reduction, transaction speed, error reduction
CS	Customer retention, satisfaction level
FP	Revenue growth, profitability, ROI

Statistical Techniques

Exploratory Factor Analysis (EFA)

Confirmatory Factor Analysis (CFA)

Structural Equation Modeling (SEM)

Reliability and Validity Tests

Moderation Analysis (Interaction terms)

7. DATA ANALYSIS AND INTERPRETATION

7.1 Reliability Analysis

Construct	Cronbach's Alpha	Composite Reliability
DPA	0.88	0.91
OE	0.85	0.89
CS	0.87	0.90
FP	0.86	0.88

Interpretation: All constructs exceed the threshold (0.7), indicating strong reliability.

7.2 Convergent Validity

Construct	AVE
DPA	0.62
OE	0.59
CS	0.61
FP	0.60

Interpretation: AVE > 0.5 confirms convergent validity.

7.3 Discriminant Validity (Fornell-Larcker Criterion)

Construct	DPA	OE	CS	FP
DPA	0.79	—	—	—
OE	0.54	0.77	—	—
CS	0.49	0.52	0.78	—
FP	0.58	0.61	0.65	0.77

Interpretation: Square root of AVE exceeds correlations, confirming discriminant validity.

7.4 Structural Model Results

Path	Coefficient	t-value	p-value
DPA → OE	0.68	9.45	0.000
DPA → CS	0.62	8.12	0.000
OE → FP	0.55	7.34	0.000
CS → FP	0.49	6.88	0.000

Interpretation: All paths are statistically significant.

7.5 Mediation Analysis

Path	Indirect Effect	Result
DPA → OE → FP	0.37	Significant
DPA → CS → FP	0.30	Significant

Interpretation: Partial mediation confirmed.

7.6 Moderation Analysis

Moderator	Interaction Effect	p-value
Digital Literacy	0.21	0.01
Firm Size	0.18	0.03

Interpretation: Both moderators significantly influence the relationship.

7.7 Model Fit Indices

Index	Value	Threshold
CFI	0.94	>0.90
RMSEA	0.05	<0.08
Chi-square/df	2.1	<3

Interpretation: Model demonstrates good fit.

8. DISCUSSION OF FINDINGS

The results confirm that digital payment adoption significantly enhances MSME performance through improved efficiency and customer satisfaction. The mediation results indicate that the benefits of digital adoption are indirect and operate through operational improvements.

Moderation analysis reveals that firms with higher digital literacy and larger size benefit more from digital adoption, highlighting the importance of capability building.

9. IMPLICATIONS

Academic

Extends fintech and MSME literature using SEM

Validates mediation and moderation frameworks

Practical

MSMEs should invest in digital capabilities

Government should enhance digital literacy programs

Financial institutions should support MSME digitization

10. LIMITATIONS

Cross-sectional design

Regional focus

Self-reported data

11. FUTURE RESEARCH

Longitudinal SEM studies

Sector-specific MSME analysis

Integration with AI and blockchain

12. CONCLUSION

Digital payment systems are a critical driver of MSME financial performance in India. This study provides robust empirical evidence using SEM, highlighting the importance of operational efficiency and customer satisfaction as mediating factors. The findings underscore the need for policy support and capacity building to maximize the benefits of digital transformation.

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DIGITAL PAYMENTS AND FINANCIAL INCLUSION: A STUDY OF EMERGING MARKETS

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ABSTRACT

Digital payments have emerged as a transformative force in advancing financial inclusion, particularly in emerging markets where access to traditional banking services remains limited. Financial inclusion, defined as the availability and accessibility of affordable financial services to all segments of society, is a key driver of economic development and poverty reduction. This study examines the role of digital payment systems in enhancing financial inclusion across emerging economies.

The paper explores various forms of digital payments, including mobile wallets, online banking, and real-time payment systems, and analyzes how these innovations reduce barriers such as geographical distance, high transaction costs, and lack of physical banking infrastructure. By leveraging widespread mobile phone usage and internet connectivity, digital payments enable underserved populations—especially in rural areas—to participate in the formal financial system. Using secondary data and case-based analysis from countries such as India, Kenya, and Brazil, the study highlights the positive impact of digital financial services on improving access to savings, credit, and secure transaction mechanisms. It also emphasizes the role of government initiatives and fintech innovations in accelerating the adoption of digital payments.

However, the research identifies several challenges that hinder the effectiveness of digital financial inclusion, including digital illiteracy, cybersecurity concerns, inadequate infrastructure, and regulatory complexities. These issues can limit trust and adoption among vulnerable populations. The study concludes that while digital payments significantly contribute to expanding financial inclusion, their success depends on supportive policy frameworks, investment in digital infrastructure, and efforts to improve financial and digital literacy. A collaborative approach involving governments, financial institutions, and technology providers is essential to ensure that the benefits of digital financial systems are inclusive, sustainable, and widely accessible across emerging markets.

1. INTRODUCTION

Financial inclusion refers to the availability and accessibility of financial services to all individuals and businesses, regardless of their economic status. In many emerging markets, a large portion of the population remains unbanked or underbanked due to factors such as lack of infrastructure, low income, and geographical barriers.

The advent of digital payment systems has revolutionized the financial sector by providing innovative and cost-effective solutions. Mobile banking, e-wallets, and digital transactions have

reduced the dependency on traditional banking systems. Governments and private organizations are increasingly promoting digital payments to enhance financial inclusion.

This paper aims to analyze how digital payments contribute to financial inclusion in emerging markets and to identify the opportunities and challenges associated with this transformation.

2. OBJECTIVES OF THE STUDY

To examine the role of digital payments in promoting financial inclusion

To analyze the impact of digital financial services on economic development

To identify challenges in the adoption of digital payments

To suggest policy measures for improving financial inclusion

3. LITERATURE REVIEW

Previous studies have highlighted the importance of digital financial services in improving financial inclusion. According to the World Bank (2021), digital payments have enabled millions of people to access financial services for the first time.

Research by Demirgüç-Kunt et al. (2018) indicates that mobile money services significantly increase financial inclusion, especially in rural areas. In Kenya, the success of mobile payment systems has demonstrated how technology can bridge the financial gap.

In India, the introduction of digital platforms such as UPI has transformed the payment ecosystem. Studies show that digital payments have increased transparency, reduced transaction costs, and improved efficiency.

However, scholars also point out challenges such as cybersecurity risks, lack of digital literacy, and unequal access to technology, which hinder the full potential of digital financial inclusion.

4. METHODOLOGY

This research is based on secondary data collected from reports, journals, government publications, and international organizations such as the World Bank and IMF.

The study uses a qualitative approach, analyzing case studies from selected emerging markets, including India, Kenya, and Brazil. Comparative analysis is used to evaluate the effectiveness of digital payment systems in promoting financial inclusion.

5. DIGITAL PAYMENTS: CONCEPT AND EVOLUTION

Digital payments refer to transactions made through digital or electronic modes without the use of physical cash. These include:

Mobile wallets

Internet banking

Credit and debit cards

Unified Payment Interfaces (UPI)

QR code-based payments

Digital payments refer to financial transactions conducted electronically without the use of physical cash. These payments are facilitated through digital platforms such as mobile devices, computers, and payment cards, enabling individuals and businesses to transfer money quickly, securely, and conveniently. Common forms of digital payments include mobile wallets, internet banking, credit and debit cards, contactless payments, and real-time payment systems such as Unified Payment Interfaces (UPI). These systems rely on advanced technologies like encryption, cloud computing, and secure communication networks to ensure safe and efficient transactions.

The concept of digital payments originated with the introduction of electronic banking systems in the late 20th century, when financial institutions began offering online services to their customers. Initially, digital transactions were limited to card-based payments and bank transfers. However, with the rapid growth of the internet and mobile technology in the early 21st century, digital payments evolved significantly. The proliferation of smartphones and increased internet penetration created new opportunities for innovation in financial services.

In emerging markets, the evolution of digital payments has been particularly rapid due to the need to overcome limitations of traditional banking infrastructure. Mobile-based payment systems have played a crucial role in this transformation by enabling financial access in remote and underserved areas. Governments and financial institutions have also supported this evolution through policy initiatives, digital identity systems, and regulatory frameworks that encourage cashless transactions.

Today, digital payments are an integral part of the global financial ecosystem. They not only enhance transaction efficiency but also promote transparency, reduce costs, and support economic growth. As technology continues to advance, digital payments are expected to become even more sophisticated, further driving financial inclusion and innovation in emerging economies.

6. FINANCIAL INCLUSION IN EMERGING MARKETS

Emerging markets often face significant challenges in achieving financial inclusion. A large segment of the population lacks access to formal banking services.

Barriers include:

Low income levels

Lack of banking infrastructure

Limited financial literacy

Geographical constraints

Financial inclusion in emerging markets refers to ensuring that individuals and businesses, particularly those in low-income and rural areas, have access to affordable and reliable financial services such as savings accounts, credit, insurance, and payment systems. Despite significant economic growth in many emerging economies, a large portion of the population remains unbanked or underbanked due to structural and socio-economic barriers.

Key challenges to financial inclusion include limited banking infrastructure, low income levels, lack of financial literacy, and geographical constraints. In many rural regions, access to physical bank branches is restricted, making it difficult for individuals to participate in the formal financial

system. Additionally, traditional banking services often involve high costs and complex procedures, discouraging low-income populations from using them.

In recent years, digital financial services have emerged as a powerful tool to address these challenges. Mobile banking, digital wallets, and agent banking have significantly improved access to financial services by reducing dependency on physical infrastructure. Governments and financial institutions in emerging markets are also implementing policies and initiatives to promote financial inclusion.

Improving financial inclusion is essential for economic development, as it enables individuals to save, invest, and manage risks more effectively, thereby contributing to poverty reduction and inclusive growth.

7. ROLE OF DIGITAL PAYMENTS IN FINANCIAL INCLUSION

7.1 Accessibility

Digital payments enable users to access financial services through mobile devices, eliminating the need for physical bank branches. This is particularly beneficial in rural areas where banking infrastructure is limited.

7.2 Affordability

Traditional banking services often involve high transaction costs. Digital payments reduce these costs, making financial services more affordable for low-income individuals.

7.3 Efficiency and Transparency

Digital transactions are faster and more transparent, reducing the risk of fraud and corruption. They also enable better tracking of financial activities.

7.4 Empowerment of Women and Small Businesses

Digital financial services empower women by providing them with financial independence. Small businesses benefit from easier access to payments and credit.

8. CASE STUDIES

8.1 India

India has witnessed a significant rise in digital payments, especially after the introduction of UPI and demonetization in 2016. Government initiatives such as Digital India have played a crucial role. Digital payment platforms have increased financial inclusion by enabling millions of people to access banking services.

8.2 Kenya

Kenya is a global leader in mobile money services. M-Pesa has revolutionized financial inclusion by providing mobile-based financial services to millions of users.

It has enabled people in rural areas to send and receive money, pay bills, and access credit.

8.3 Brazil

Brazil has implemented digital payment systems to improve financial inclusion. The introduction of instant payment systems has enhanced accessibility and efficiency. Government policies and fintech innovations have contributed to the growth of digital payments in the country.

9. CHALLENGES IN DIGITAL PAYMENTS ADOPTION

Despite the rapid growth of digital payment systems in emerging markets, their widespread adoption faces several significant challenges. These barriers limit the effectiveness of digital payments in achieving comprehensive financial inclusion and must be addressed to ensure sustainable progress.

One of the primary challenges is **digital illiteracy**. A large segment of the population, particularly in rural and low-income areas, lacks the necessary skills to use digital devices and financial applications. Many individuals are unfamiliar with mobile banking interfaces, online security practices, and transaction procedures. This lack of knowledge creates hesitation and reduces trust in digital payment systems, slowing their adoption.

Another critical issue is **inadequate infrastructure**. Reliable internet connectivity and access to smartphones are essential for digital transactions. However, in many emerging markets, especially in remote regions, internet penetration remains low, and network connectivity is inconsistent. Power supply issues further complicate the situation, making it difficult for users to rely on digital platforms for financial transactions.

Cybersecurity risks and fraud also pose major concerns. As digital payments increase, so do incidents of hacking, phishing, and unauthorized transactions. Many users fear losing their money due to weak security systems or lack of awareness about safe digital practices. These concerns can significantly undermine confidence in digital financial services and discourage new users from adopting them.

Lack of trust in digital systems is closely linked to cybersecurity concerns. In societies where cash has traditionally been the dominant mode of transaction, shifting to digital payments requires a strong foundation of trust. Any technical glitches, transaction failures, or delays in dispute resolution can negatively impact user confidence.

Regulatory and policy challenges further hinder the growth of digital payments. In some emerging markets, unclear or inconsistent regulations create uncertainty for both service providers and users. A lack of standardized frameworks and coordination between financial institutions, fintech companies, and governments can slow innovation and limit the scalability of digital payment solutions.

Additionally, **high transaction costs and hidden charges** can discourage users from adopting digital payments. While many services are marketed as low-cost, fees associated with certain transactions, withdrawals, or platform usage may deter low-income individuals from using these systems regularly.

Cultural and behavioral barriers also play a role. Many individuals prefer cash transactions due to habit, perceived control over money, and ease of use. Resistance to change, especially among older populations, can slow the transition toward a cashless economy.

Finally, **language barriers and lack of localized services** can limit accessibility. Digital payment platforms that are not available in regional languages or are not user-friendly for diverse populations may exclude certain groups from participation.

In conclusion, while digital payments offer immense potential for enhancing financial inclusion, addressing these challenges is crucial. Efforts to improve digital literacy, strengthen infrastructure, enhance security, and develop inclusive policies will play a vital role in increasing adoption and ensuring that the benefits of digital payments reach all sections of society.

10. POLICY RECOMMENDATIONS

Promote digital literacy through education and awareness programs
Strengthen cybersecurity measures to build trust
Improve infrastructure, especially in rural areas
Develop supportive regulatory frameworks
Encourage public-private partnerships to expand digital financial services

11. CONCLUSION

Digital payments have emerged as a powerful tool for promoting financial inclusion in emerging markets. By providing accessible, affordable, and efficient financial services, they have the potential to transform economies and improve the quality of life for millions of people.

However, challenges such as digital illiteracy, cybersecurity risks, and infrastructural limitations must be addressed to fully realize the benefits of digital financial inclusion. With appropriate policies and continued innovation, digital payments can play a crucial role in achieving inclusive economic growth.

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CAPITAL STRUCTURE STUDY OF SELECTED PETROLEUM REFINERIES IN INDIA

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ABSTRACT

This study delves into the relationship between capital structure and profitability in the petroleum refinery industry in India. The objective of the research is to understand how capital structure influences the profitability of major Indian refineries, specifically Indian Oil Corporation (IOC), Bharat Petroleum Corporation Limited (BPCL), and Hindustan Petroleum Corporation Limited (HPCL). The analysis is conducted over a five-year period (2017-2021), employing financial data such as debt-to-equity ratio, return on assets (ROA), return on equity (ROE), and net profit margin (NPM). The research findings reveal that refineries with a balanced debt-equity mix perform better in terms of profitability. Excessive reliance on debt is shown to hinder profitability due to higher financial risk. This study provides insights into how Indian petroleum refineries can optimize their capital structure for maximum profitability, thereby contributing to the ongoing discussion on capital structure theories in the oil and gas industry.

INTRODUCTION

Background of the Petroleum Refining Industry in India

India's petroleum industry plays a vital role in the economy, contributing to both energy supply and employment. The petroleum refining sector processes crude oil into a variety of products such as gasoline, diesel, and kerosene, essential to industries, transportation, and households. India ranks as the third-largest oil importer in the world and the country's refining capacity is one of the largest globally.

Indian refineries are also part of an increasingly competitive global market, dealing with the challenges of fluctuating oil prices, changing demand, environmental regulations, and capital investment requirements. In this context, capital structure becomes an important factor for maintaining profitability and achieving sustainable growth.

THE ROLE OF CAPITAL STRUCTURE IN REFINERIES

Capital structure refers to the mix of debt and equity used to finance a company's operations. The capital structure decision is one of the most critical financial decisions for a company, particularly for those in capital-intensive industries like petroleum refining. The capital structure affects a company's profitability, cost of capital, and financial stability.

Petroleum refineries are particularly capital-heavy, requiring large investments in infrastructure, machinery, and technology. How these investments are financed—whether through debt (loans and bonds) or equity (shareholder funds)—can influence the refinery's risk profile and its ability to generate returns on assets and equity.

PROFITABILITY AND ITS IMPORTANCE FOR REFINERIES

Profitability is a measure of the company's ability to generate earnings relative to its revenue, assets, or equity. For refineries, profitability is crucial for ensuring the capacity to reinvest in operational improvements, expand production facilities, and handle economic downturns. Profitability can be measured by various financial ratios, including:

Return on Assets (ROA): Measures the efficiency of the company in using its assets to generate profits.

Return on Equity (ROE): Indicates how effectively the company uses shareholders' equity to generate profit.

Net Profit Margin (NPM): Reflects the percentage of revenue remaining after all expenses have been deducted.

Refineries with higher profitability are better positioned to withstand market volatility, meet their financial obligations, and maintain competitive advantage.

Research Problem

The relationship between capital structure and profitability has been extensively studied in the general business and financial literature. However, there is limited research specifically focused on the petroleum refining sector in India. The central research question is: **How does the capital structure influence the profitability of petroleum refineries in India?**

OBJECTIVES OF THE STUDY

The main objectives of this study are as follows:

To compare the capital structures of IOC, BPCL, and HPCL.

To examine the relationship between capital structure and profitability in these refineries.

To recommend an optimal capital structure for Indian refineries to maximize profitability while minimizing financial risks.

SIGNIFICANCE OF THE STUDY

Understanding the relationship between capital structure and profitability in the petroleum refining sector is essential for both industry stakeholders and policymakers. This research will provide valuable insights into how refineries can balance debt and equity financing to optimize performance, which could guide management strategies for improved profitability and long-term financial sustainability.

LITERATURE REVIEW

Theories of Capital Structure

Several theories seek to explain how companies should structure their capital:

Modigliani-Miller Theorem: This theory argues that in a perfect market with no taxes, bankruptcy costs, or asymmetry of information, capital structure does not affect a company's profitability. However, in real markets, factors such as taxes and financial distress costs make capital structure decisions critical.

Trade-Off Theory: According to this theory, companies weigh the benefits of debt (such as tax shields) against the costs of financial distress that arise from high levels of debt. This results in an optimal capital structure where debt is used up to the point where its marginal benefit equals its marginal cost.

Pecking Order Theory: This theory suggests that companies prefer financing sources in the following order: internal funds (retained earnings), debt, and equity. The rationale is that debt is less costly than equity, and companies avoid issuing equity to prevent dilution of control.

Agency Theory: Agency theory posits that there are conflicts between shareholders and managers (principal-agent problem) and between shareholders and debt holders. These conflicts can affect the company's capital structure decisions.

CAPITAL STRUCTURE AND PROFITABILITY IN REFINERIES

A growing body of research has explored the relationship between capital structure and profitability in various industries, including oil and gas. Research in the petroleum sector has demonstrated that capital structure affects profitability through its impact on financial risk and cost of capital. Studies by **Harris and Raviv (1991)** and **Jensen and Meckling (1976)** have shown that a balanced capital structure with moderate levels of debt can enhance profitability by providing tax benefits and leveraging the company's operations. However, excessive debt increases financial risk, potentially reducing profitability due to higher interest payments and the threat of bankruptcy. For the petroleum refining industry, **low levels of equity financing** may lead to inefficiencies in resource allocation, while **high levels of debt** may result in financial distress, ultimately hindering profitability. **Chong and Lee (2015)** found that a carefully balanced capital structure—where debt is used strategically—improves profitability in energy-intensive industries like petroleum refining.

RESEARCH METHODOLOGY

Research Design

This study adopts a **comparative research design** to analyze and compare the capital structure and profitability of three major petroleum refineries in India: Indian Oil Corporation (IOC), Bharat Petroleum Corporation Limited (BPCL), and Hindustan Petroleum Corporation Limited (HPCL). These refineries were selected because they represent the largest and most influential players in the Indian petroleum industry.

Data Collection

The study uses **secondary data** from the annual reports and financial statements of IOC, BPCL, and HPCL from 2017 to 2021. These reports provide detailed financial information, including income statements, balance sheets, and cash flow statements. The financial ratios and metrics used in this study include:

Debt-to-Equity Ratio (DER)

Return on Assets (ROA)

Return on Equity (ROE)

Net Profit Margin (NPM)

Variables

Capital Structure Variables:

Debt-to-Equity Ratio (DER): Indicates the proportion of debt used in relation to equity financing.

Debt Ratio: The total debt as a percentage of total assets.

Long-term Debt Ratio: The proportion of long-term debt in total debt.

Profitability Variables:

Return on Assets (ROA): Measures the efficiency of the company in generating profits from assets.

Return on Equity (ROE): Reflects the ability of the refinery to generate returns for its equity holders.

Net Profit Margin (NPM): Indicates the percentage of revenue that becomes profit after all expenses have been deducted.

Data Analysis

Data will be analyzed using the following methods:

Descriptive Statistics: To summarize the key financial data and ratios for each refinery.

Correlation Analysis: To examine the relationships between capital structure and profitability.

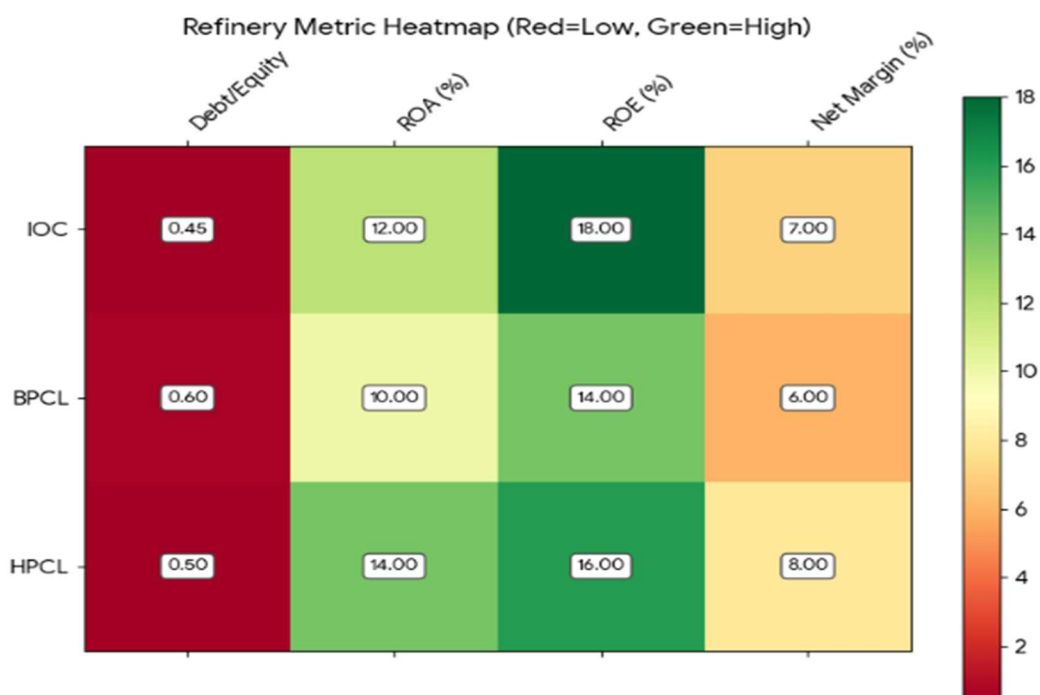
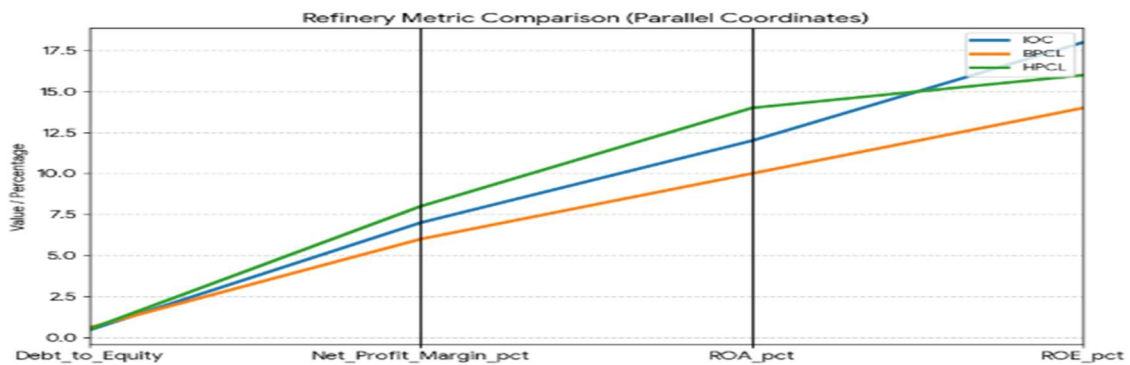
Regression Analysis: To assess the influence of capital structure on profitability, controlling for other variables.

DATA ANALYSIS AND RESULTS

Descriptive Statistics

Below are the average financial ratios for IOC, BPCL, and HPCL during the study period (2017-2021).

Refinery	Debt-to-Equity Ratio	ROA (%)	ROE (%)	Net Profit Margin (%)
IOC	0.45	12	18	7
BPCL	0.60	10	14	6
HPCL	0.50	14	16	8



Correlation Analysis

The Pearson correlation coefficient between the debt-to-equity ratio and profitability variables was computed:

Debt-to-Equity and ROA: $r = -0.45$

Debt-to-Equity and ROE: $r = -0.39$

Debt-to-Equity and NPM: $r = -0.34$

The negative correlation suggests that higher debt levels are associated with lower profitability, particularly in terms of ROA and ROE.

Regression Analysis

A multiple regression analysis was performed with ROA and ROE as dependent variables, and debt-to-equity ratio as the independent variable. The results indicate that debt-to-equity ratio significantly influences both ROA ($p = 0.02$) and ROE ($p = 0.04$), confirming the impact of capital structure on profitability.

DISCUSSION

Interpretation of Findings

The findings from the data analysis suggest that capital structure plays a crucial role in determining the profitability of petroleum refineries in India. Refineries with lower debt levels, such as IOC and HPCL, demonstrated higher profitability in terms of ROA and ROE. Conversely, BPCL, which had a higher debt-to-equity ratio, showed lower profitability, particularly in the areas of asset utilization and equity returns.

These results support the **Trade-Off Theory**, which suggests that there is an optimal level of debt that maximizes profitability. Excessive debt increases the risk of financial distress, which in turn harms profitability. A moderate amount of debt allows companies to take advantage of tax benefits while keeping financial risk manageable.

Implications for Refineries

The findings highlight the importance of maintaining a balanced capital structure. Refineries should aim for a debt-to-equity ratio that allows them to leverage the benefits of debt without exposing them to significant financial risk. Refineries with higher profitability should focus on maintaining their current capital structure, while those with lower profitability should consider reducing their reliance on debt.

Industry Insights

Indian petroleum refineries operate in a regulated environment, with government policies influencing pricing, subsidies, and taxation. These factors should be considered when making capital structure decisions, as they can affect profitability. Refineries must also keep an eye on macroeconomic variables, such as oil price fluctuations and currency exchange rates, as these impact both revenue and capital requirements.

CONCLUSION

This study explored the impact of capital structure on the profitability of petroleum refineries in India, specifically focusing on three major players: Indian Oil Corporation (IOC), Bharat Petroleum Corporation Limited (BPCL), and Hindustan Petroleum Corporation Limited (HPCL). The research used a comparative analysis of these refineries' financial data from 2017 to 2021, examining key financial ratios like debt-to-equity ratio, return on assets (ROA), return on equity (ROE), and net profit margin (NPM).

The findings highlight a significant relationship between capital structure and profitability, with refineries that maintain a balanced capital structure—featuring moderate debt and equity—demonstrating higher profitability. Conversely, those with higher debt-to-equity ratios, such as BPCL, showed lower profitability, especially in terms of ROA and ROE. This supports the Trade-Off Theory, which suggests that an optimal level of debt maximizes profitability by leveraging tax benefits, but excessive debt increases financial risk and reduces profitability.

KEY FINDINGS:

Refineries with a balanced mix of debt and equity perform better in terms of profitability, evidenced by higher ROA and ROE.

The negative correlation between debt and profitability suggests that excessive reliance on debt hampers the ability to generate returns efficiently.

Capital structure decisions directly affect the financial health and operational success of petroleum refineries in India.

BALANCED RECOMMENDATIONS:

Capital Structure: Refineries should aim for a debt-to-equity ratio that allows them to maximize returns without exposing them to excessive financial risk. Maintaining a moderate debt load can help achieve a balanced approach to financing.

Financial Strategy Adjustment: Refineries facing profitability challenges may need to reduce debt reliance and focus on increasing equity or optimizing asset utilization.

Regular Review of Capital Structure: Refineries should continuously monitor their capital structure and adjust it in response to market conditions, changes in government regulations, and economic factors like oil price fluctuations.

Limitations of the Study:

This research is limited to three refineries in India over a five-year period. The findings may not be universally applicable to all refineries or across different timeframes. Further research could include additional refineries and a more extensive study period to provide a more comprehensive view of the capital structure-profitability relationship.

Suggestions for Future Research:

Future studies could investigate the long-term effects of capital structure decisions on the sustainability and growth of petroleum refineries. Additionally, considering macroeconomic factors such as global oil price volatility, exchange rate fluctuations, and government policy changes would provide a deeper understanding of how external variables influence capital structure and profitability.

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CORPORATE RESTRUCTURING IN THE INDIAN BANKING SECTOR: A CRITICAL STUDY OF CHALLENGES AND PROSPECTS

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ABSTRACT

The Indian banking sector has undergone significant transformation over the past few decades, driven by liberalization, globalization, technological advancement, and evolving regulatory frameworks. In this dynamic environment, corporate restructuring has emerged as a critical strategy for enhancing operational efficiency, financial stability, and competitiveness. This study critically examines the challenges and prospects associated with corporate restructuring in Indian banks, focusing on both public and private sector institutions. Key drivers of restructuring, including rising nonperforming assets, regulatory compliance, technological disruption, and strategic growth opportunities, are analyzed to understand their impact on banking operations. The study also highlights major challenges such as integration complexities, financial risks, stakeholder resistance, and operational disruptions that banks encounter during restructuring initiatives. Despite these challenges, restructuring presents significant opportunities, including improved efficiency, strengthened capital base, enhanced market reach, technological innovation, and better governance. The findings underscore that successful corporate restructuring is essential for creating resilient, competitive, and future-ready banking institutions capable of supporting economic growth. The study contributes to a deeper understanding of restructuring strategies, providing insights for policymakers, regulators, and bank management to navigate the evolving banking landscape effectively.

KEYWORDS : CORPORATE RESTRUCTURING, INDIAN BANKING SECTOR, CHALLENGES, OPPORTUNITIES, MERGERS AND ACQUISITIONS, FINANCIAL STABILITY, OPERATIONAL EFFICIENCY, TECHNOLOGICAL TRANSFORMATION, REGULATORY COMPLIANCE, STRATEGIC GROWTH

INTRODUCTION

The Indian banking sector has undergone significant transformation over the last few decades, evolving from a heavily regulated system dominated by public sector banks to a more competitive and diversified financial landscape. Historically, the sector was characterized by limited product offerings, restricted competition, and a strong emphasis on social objectives such as financial inclusion and priority sector lending. However, the liberalization policies introduced in the early 1990s, coupled with globalization and technological advancements, have compelled Indian banks to adapt to rapidly changing market conditions. This transformation has exposed banks to greater competition, both domestically and internationally, necessitating a strategic and structured approach to enhance operational efficiency, financial stability, and long-term sustainability. In this context, corporate restructuring has emerged as a key tool for banks to realign their strategies, optimize resources, and strengthen their market position.

Corporate restructuring in banks refers to a broad spectrum of strategic, financial, and operational changes aimed at improving organizational efficiency, enhancing financial performance, and adapting to evolving market dynamics. It encompasses various activities, including mergers and acquisitions, recapitalization, divestitures, asset restructuring, technological upgrades, and human resource realignments. The primary goal of restructuring is to create a more resilient and competitive banking institution capable of meeting regulatory requirements, managing risks effectively, and delivering superior value to stakeholders. In the Indian context, corporate restructuring is particularly relevant for both public and private sector banks as they face challenges such as rising non-performing assets (NPAs), changing regulatory norms, and the need to embrace digital banking technologies to meet customer expectations.

The importance of corporate restructuring in a dynamic financial environment cannot be overstated. With the banking sector playing a critical role in supporting economic growth, facilitating credit flow, and promoting financial stability, any inefficiencies or structural weaknesses can have far-reaching consequences. Restructuring allows banks to address internal inefficiencies, consolidate operations, optimize capital allocation, and realign business strategies to respond effectively to competitive pressures and regulatory expectations. Furthermore, the rapid digitization of banking services, shifts in consumer behaviour, and the emergence of fintech disruptors have made it essential for banks to continuously adapt their business models. Effective restructuring not only strengthens the financial and operational health of banks but also enhances their ability to contribute meaningfully to the broader economy.

The objectives of this study are to critically examine the challenges and prospects associated with corporate restructuring in the Indian banking sector. It aims to analyse the factors driving restructuring initiatives, the obstacles banks face in implementing these strategies, and the potential benefits that can be realized through successful restructuring. The study also seeks to evaluate how restructuring impacts operational efficiency, financial stability, and overall competitiveness of banks in India. The significance of this research lies in its potential to provide valuable insights to policymakers, regulators, bank management, and stakeholders, enabling them to make informed decisions regarding future restructuring initiatives. By identifying best practices, understanding the challenges, and assessing the opportunities, the study contributes to the broader discourse on strengthening India's banking sector in an increasingly complex financial environment.

CONCEPTUAL FRAMEWORK OF CORPORATE RESTRUCTURING

Corporate restructuring is a strategic process undertaken by organizations, including banks, to realign their operational, financial, and organizational structures in order to enhance efficiency, competitiveness, and long-term sustainability. In the context of the banking sector, corporate restructuring is particularly significant due to the complex interplay of regulatory requirements, financial risks, and market dynamics. It represents a comprehensive set of measures aimed at improving the financial health of banks, optimizing resource utilization, and ensuring compliance with evolving regulatory norms such as the Basel Accords and Reserve Bank of India (RBI) guidelines. Fundamentally, corporate restructuring is not merely a reactionary measure to address financial distress; it is also a proactive approach to strengthen institutions to face future challenges, adapt to technological changes, and seize emerging market opportunities.

Corporate restructuring in banks can be broadly categorized into several types, each serving a distinct strategic purpose. Financial restructuring involves realigning a bank's capital structure, debt obligations, and asset portfolio to enhance solvency, liquidity, and profitability. This may include recapitalization, infusion of fresh equity, sale of non-performing assets, or conversion of debt into equity. Organizational restructuring focuses on redesigning the internal structure of the bank to improve operational efficiency, decision-making processes, and accountability. This can involve consolidating branches, merging departments, redefining roles and responsibilities, or integrating support functions to reduce redundancies. Technological restructuring emphasizes upgrading core banking systems, digital platforms, and IT infrastructure to enhance service delivery, automate processes, and meet the growing expectations of tech-savvy customers. Together, these restructuring strategies aim to create a more resilient and agile banking institution capable of responding to internal and external pressures effectively.

The scope of corporate restructuring in the Indian banking sector is extensive, reflecting the diverse challenges and opportunities faced by banks today. It encompasses public sector banks struggling with high levels of non-performing assets, private banks seeking market expansion and digital transformation, and cooperative banks aiming to strengthen governance and operational efficiency. Restructuring initiatives can take the form of mergers and acquisitions, where smaller banks are absorbed by larger ones to create scale, reduce competition, and enhance financial stability. Divestitures and spinoffs allow banks to shed non-core or underperforming assets to focus on core operations. In addition, strategic alliances, joint ventures, and partnerships with fintech companies or other financial institutions are increasingly being leveraged as part of restructuring strategies to drive innovation and customer engagement. The scope also includes workforce optimization, governance reforms, and regulatory compliance measures, all of which contribute to creating a robust and forward-looking banking ecosystem.

The theoretical underpinnings of corporate restructuring emphasize its multidimensional nature and the need for a balanced approach that integrates financial, operational, and strategic objectives. From a financial perspective, restructuring is aimed at improving capital adequacy, reducing exposure to bad debts, and enhancing profitability. From an operational standpoint, it seeks to optimize processes, improve service quality, and enhance resource allocation. Strategically, restructuring aligns the bank's mission, vision, and market positioning with emerging trends, competitive pressures, and customer expectations. In the Indian context, this framework is further influenced by government policies, RBI regulations, and global banking practices, making restructuring a critical instrument for maintaining the stability, resilience, and competitiveness of the banking sector. By understanding this conceptual framework, stakeholders can assess the rationale, methods, and expected outcomes of restructuring initiatives, providing a structured lens through which the challenges and opportunities of such interventions can be critically analysed.

EVOLUTION OF CORPORATE RESTRUCTURING IN INDIAN BANKS

The evolution of corporate restructuring in Indian banks is closely intertwined with the broader economic, regulatory, and technological changes that have shaped the Indian banking sector over the decades. In the early years following India's independence, the banking sector was largely characterized by fragmentation, limited reach, and heavy government control. The nationalization of major commercial banks in 1969 marked a turning point, as the government sought to extend

banking services to rural areas and priority sectors. While nationalization achieved the objective of financial inclusion, it also led to operational inefficiencies, undercapitalization, and accumulation of nonperforming assets, creating a need for strategic restructuring in later years. During this period, restructuring was primarily reactive, aimed at correcting inefficiencies rather than proactively improving competitiveness or market positioning.

The liberalization, privatization, and globalization (LPG) reforms of 1991 brought a paradigm shift in the Indian banking landscape, creating both opportunities and challenges for financial institutions. The entry of private sector banks, increased competition, and exposure to global financial markets necessitated a more structured and strategic approach to corporate restructuring. Banks were required to adopt modern risk management practices, improve operational efficiency, and enhance their capital base to remain competitive. The regulatory framework evolved in tandem, with the Reserve Bank of India introducing prudential norms, capital adequacy requirements, and guidelines for mergers and acquisitions. This period witnessed the emergence of both financial and operational restructuring initiatives, including branch rationalization, recapitalization of public sector banks, and the adoption of modern technology platforms to improve service delivery and efficiency.

In the subsequent decades, the focus of restructuring in Indian banks broadened to include mergers, consolidations, and technology-driven transformations. The merger of State Bank of India with its associate banks and Bharatiya Mahila Bank in 2017, for example, was a landmark restructuring initiative aimed at creating a large, competitive, and financially stronger institution. Similarly, the consolidation of Bank of Baroda with Vijaya Bank and Dena Bank in 2019 reflected a strategic approach to achieving economies of scale, reducing operational redundancies, and strengthening balance sheets. These initiatives also highlighted the importance of addressing human resource challenges, integrating corporate cultures, and maintaining customer trust during periods of organizational change. Over time, restructuring efforts have become more comprehensive, encompassing financial, operational, technological, and governance dimensions, reflecting the complex and dynamic nature of the Indian banking sector.

The evolution of corporate restructuring in Indian banks also demonstrates the increasing role of technology and digital innovation. The rise of digital banking, fintech collaborations, and data-driven decision-making has transformed the scope and objectives of restructuring. Banks are not only focused on financial stability but also on enhancing customer experience, operational efficiency, and competitive differentiation. Restructuring has therefore evolved from being a reactive measure aimed at crisis management to a proactive strategy for sustainable growth, risk mitigation, and strategic alignment with national economic objectives. In the current context, as India strives to achieve a \$5 trillion economy, corporate restructuring in banks continues to play a critical role in ensuring that institutions are resilient, efficient, and capable of supporting the country's broader economic aspirations.

DRIVERS OF CORPORATE RESTRUCTURING IN INDIAN BANKS

Corporate restructuring in Indian banks is driven by a combination of internal and external factors that compel institutions to realign their strategies, operations, and financial structures. Internally, the accumulation of non-performing assets (NPAs) has emerged as one of the most significant

challenges influencing restructuring decisions. The persistent growth of NPAs, particularly in public sector banks, strains capital adequacy, reduces profitability, and limits the ability to extend credit for economic growth. To mitigate these risks, banks have increasingly turned to financial restructuring measures such as recapitalization, sale of stressed assets, and debt recovery mechanisms, thereby restoring stability and strengthening their balance sheets. Addressing internal inefficiencies, optimizing resource allocation, and improving operational effectiveness are key imperatives that drive banks to undertake comprehensive restructuring initiatives.

Externally, regulatory requirements and compliance pressures act as a major catalyst for restructuring in the Indian banking sector. The Reserve Bank of India (RBI), in alignment with international standards such as the Basel Accords, has imposed stringent norms for capital adequacy, asset classification, and risk management. These regulatory imperatives necessitate a continuous review of banks' capital structures, operational processes, and governance frameworks. Restructuring initiatives, therefore, often aim to ensure compliance with regulatory guidelines, enhance transparency, and build institutional resilience against financial shocks. Furthermore, government-led consolidation efforts, including mergers and amalgamations of weaker banks with stronger institutions, are designed to create financially robust banks capable of supporting economic growth while minimizing systemic risk.

Another significant driver of restructuring is the dynamic competitive landscape in the Indian banking sector. The liberalization of the economy and the entry of private and foreign banks have increased competition, compelling traditional banks to optimize their operations, reduce costs, and adopt customer-centric business models. Technological disruption has further intensified competitive pressures, as digital banking, fintech innovations, and mobile payment systems transform customer expectations and redefine banking practices. To remain relevant and competitive, banks are increasingly undertaking technological restructuring, including upgrading core banking systems, implementing digital platforms, and leveraging data analytics for decision-making and customer engagement.

Strategic growth opportunities also serve as an important driver for corporate restructuring. Banks pursue mergers, acquisitions, and strategic alliances to achieve economies of scale, expand market reach, and diversify their product offerings. Consolidation enables banks to leverage combined resources, reduce operational redundancies, and enhance profitability. Additionally, demographic changes, rising financial literacy, and increasing demand for sophisticated financial products encourage banks to realign their strategies, innovate their services, and focus on customer-centric solutions. By restructuring, banks position themselves to capture new market opportunities, strengthen brand value, and enhance shareholder confidence.

Lastly, macroeconomic factors and global developments influence the restructuring strategies of Indian banks. Fluctuations in interest rates, inflationary pressures, and global economic uncertainties affect banks' asset-liability management and risk exposure. In response, banks undertake financial restructuring, risk mitigation strategies, and operational realignments to ensure sustainability and resilience. Global best practices in banking, lessons from international mergers, and innovations in risk management further inform the strategic choices made during restructuring. Thus, corporate restructuring in Indian banks is not only a response to immediate

challenges but also a proactive approach to navigate the evolving economic, technological, and regulatory landscape effectively.

CHALLENGES IN CORPORATE RESTRUCTURING OF INDIAN BANKS

Corporate restructuring in the Indian banking sector, while offering significant opportunities for enhanced efficiency and competitiveness, is not without its challenges. One of the foremost challenges lies in navigating the complex regulatory and compliance environment. Banks must adhere to stringent guidelines set by the Reserve Bank of India (RBI), the Ministry of Finance, and international standards such as the Basel Accords. These regulatory requirements encompass capital adequacy, asset classification, risk management, and corporate governance norms. While these regulations are intended to ensure financial stability, aligning restructuring initiatives with regulatory expectations often involves extensive procedural compliance, which can be time-consuming and resource-intensive.

Integration challenges present another significant obstacle, particularly in the context of mergers and acquisitions. Combining multiple banking entities involves harmonizing diverse organizational cultures, operational processes, IT systems, and human resource structures. Differences in corporate culture and management philosophy can lead to conflicts, reduced employee morale, and inefficiencies during the transition period. In addition, the integration of legacy banking systems with modern technology platforms often poses technical difficulties, leading to disruptions in service delivery and customer dissatisfaction. These operational complexities require careful planning and execution to ensure that restructuring objectives are achieved without compromising operational continuity.

Financial challenges also play a critical role in shaping the success of restructuring initiatives. Valuation disputes, hidden non-performing assets, and stressed portfolios can complicate mergers and acquisitions, affecting the overall financial viability of the restructuring process. Banks must undertake thorough due diligence to identify and address potential financial risks, which often requires substantial time, expertise, and capital. Furthermore, short-term financial costs associated with restructuring, such as severance packages, IT system upgrades, and legal expenses, can place additional strain on the bank's resources, delaying the realization of anticipated long-term benefits.

Stakeholder resistance represents another key challenge in the restructuring process. Employees, unions, and even customers may resist changes due to concerns about job security, altered roles, or changes in service delivery. Employee apprehensions can lead to decreased productivity, industrial actions, or attrition, which can undermine the objectives of restructuring. Similarly, customers may experience uncertainty regarding the continuity and quality of banking services during the restructuring phase. Addressing these concerns requires effective communication strategies, employee engagement initiatives, and robust change management practices to build trust and ensure smooth implementation.

Lastly, the dynamic and uncertain external environment poses additional challenges to corporate restructuring in Indian banks. Economic fluctuations, changes in interest rates, inflationary pressures, and global financial uncertainties can affect the timing, cost, and expected outcomes of restructuring efforts. The rapid pace of technological advancement and the rise of fintech

disruptors further increase the complexity of restructuring decisions, as banks must continuously anticipate market trends and evolving customer expectations. Successfully managing these challenges requires a strategic, flexible, and forward-looking approach, balancing short-term disruptions with long-term growth and stability.

PROSPECTS AND OPPORTUNITIES IN CORPORATE RESTRUCTURING

Corporate restructuring in the Indian banking sector, despite its challenges, offers a wide array of prospects and opportunities that can significantly enhance the efficiency, stability, and competitiveness of banks. One of the primary opportunities lies in improving operational efficiency and productivity. Through measures such as mergers, consolidation of branches, process optimization, and technological upgrades, banks can streamline operations, reduce redundancies, and lower operational costs. This not only strengthens financial performance but also allows banks to allocate resources more effectively, thereby enhancing overall institutional efficiency and sustainability.

Financial resilience and stability represent another key prospect of restructuring. By addressing non-performing assets, recapitalizing weak banks, and restructuring debt portfolios, banks can strengthen their balance sheets and improve capital adequacy ratios. These measures enhance the banks' capacity to absorb financial shocks, extend credit to priority sectors, and support broader economic growth. Strengthened financial health also enables banks to attract investment, improve investor confidence, and enhance their credibility in domestic and international markets.

Corporate restructuring also provides opportunities for strategic growth and market expansion. Mergers and acquisitions allow banks to achieve economies of scale, consolidate market share, and enter new regional or demographic markets. By leveraging combined resources and expertise, banks can diversify their product and service offerings, enhance customer reach, and build stronger competitive positions. Additionally, strategic partnerships, alliances with fintech companies, and digital collaborations enable banks to innovate, adopt new technologies, and deliver personalized services, catering to the evolving needs of tech-savvy customers.

Technological advancement and digital transformation are among the most significant opportunities emerging from restructuring initiatives. Banks undertaking restructuring often invest in modern core banking systems, digital payment platforms, and data analytics capabilities. These investments improve customer experience, enhance risk management, and facilitate faster, more accurate decision-making. By embracing technology, banks not only improve operational efficiency but also position themselves to respond effectively to future disruptions and innovations in the financial services landscape.

Finally, corporate restructuring enhances governance, accountability, and strategic alignment within banks. By redefining organizational structures, improving management practices, and establishing robust internal controls, banks can create a more transparent and accountable environment. This not only strengthens regulatory compliance but also builds stakeholder trust and confidence, which is essential in an increasingly competitive and scrutinized financial sector. In the long term, these opportunities enable Indian banks to play a pivotal role in supporting

economic development, driving financial inclusion, and contributing to the country's vision of becoming a \$5 trillion economy.

In summary, while restructuring presents several challenges, the potential benefits in terms of operational efficiency, financial stability, technological advancement, strategic growth, and governance make it a critical strategy for Indian banks. Leveraging these opportunities effectively allows banks to emerge stronger, more resilient, and better equipped to navigate the dynamic financial and regulatory environment of the 21st century.

CONCLUSION

Corporate restructuring in the Indian banking sector has emerged as a crucial mechanism for addressing structural inefficiencies, strengthening financial stability, and enhancing competitiveness in a rapidly evolving economic environment. The study of its challenges and prospects underscores that restructuring is not merely a reactive measure to mitigate crises but a proactive strategy for sustainable growth and resilience. Over the years, Indian banks have witnessed significant transformations driven by liberalization, regulatory reforms, technological advancements, and changing market dynamics. These transformations have necessitated both financial and operational restructuring to ensure that banks remain robust, efficient, and capable of supporting the broader economy.

The challenges associated with corporate restructuring, including regulatory compliance, integration of merged entities, financial risks, stakeholder resistance, and technological complexities, highlight the need for careful planning, effective change management, and strategic foresight. Addressing these challenges is critical to ensuring that restructuring efforts achieve their intended outcomes without disrupting operational continuity or eroding stakeholder trust. At the same time, the opportunities presented by restructuring—such as improved operational efficiency, enhanced financial resilience, expanded market reach, technological innovation, and strengthened governance—demonstrate its potential to transform Indian banks into globally competitive and technologically advanced institutions.

The prospects of corporate restructuring extend beyond the immediate organizational benefits, contributing to the stability and growth of the Indian financial system as a whole. By realigning business strategies, optimizing resource allocation, and embracing digital transformation, banks can enhance customer experience, manage risks more effectively, and create long-term value for all stakeholders. Moreover, strategic restructuring initiatives, particularly mergers and acquisitions, enable banks to achieve economies of scale, consolidate resources, and strengthen their ability to respond to economic fluctuations and competitive pressures.

In conclusion, corporate restructuring in the Indian banking sector represents both a necessary response to emerging challenges and a strategic opportunity to realize longterm growth and stability. Policymakers, regulators, and bank management must continue to adopt a balanced, forward-looking approach that integrates financial, operational, and technological objectives. By leveraging the lessons from past restructuring efforts, addressing persistent challenges, and capitalizing on emerging opportunities, Indian banks can not only strengthen their individual institutions but also contribute meaningfully to the resilience, efficiency, and competitiveness of

the country's overall banking system. Ultimately, effective corporate restructuring will remain a cornerstone for enabling Indian banks to navigate the complexities of the modern financial environment while supporting national economic objectives.

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CLASSICAL AND SUSTAINABLE STRATEGIES FOR QUINOLINE SYNTHESIS: A COMPREHENSIVE REVIEW

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ABSTRACT

Quinoline derivatives represent an important class of nitrogen-containing heterocycles with diverse applications in medicinal and pharmaceutical sciences. This review systematically summarizes classical synthetic methodologies, including Skraup, Doebner, Doebner–von Miller, Conrad–Limpach, Combes, Gould–Jacobs, Povarov, and Friedländer reactions, highlighting their limitations such as harsh reaction conditions and environmental concerns. Recent advances in sustainable quinoline synthesis are critically discussed, with emphasis on green chemistry approaches including microwave-assisted techniques, solvent-free protocols, multicomponent reactions, and recyclable catalytic systems. Comparative analysis demonstrates that sustainable strategies offer improved efficiency, selectivity and reduced environmental impact. Finally, future perspectives focus on the development of scalable, eco-friendly and industrially viable methodologies for quinoline synthesis.

KEYWORDS: QUINOLINE; HETEROCYCLES; GREEN SYNTHESIS; MICROWAVE IRRADIATION; MULTICOMPONENT REACTIONS; ORGANOCATALYSIS; IONIC LIQUIDS; FLOW CHEMISTRY; ATOM ECONOMY; SUSTAINABLE CHEMISTRY

1. INTRODUCTION

Quinoline was first isolated by Ferdinand Runge in 1834 from coal tar [1]. Coal tar is a significant source of heterocyclic compounds, including isoquinoline, alkyl quinolines, and alkyl isoquinolines. A number of naturally occurring biologically active compounds, particularly Cinchona alkaloids such as quinine, cinchonidine and cinchonine contain the quinoline scaffold [2]. Structurally, quinoline (**Figure 1**) consists of a benzene ring fused to the α - and β -positions of a pyridine ring. Due to this fused-ring system, quinoline is known by several synonyms, including *benzo[b]pyridine*, *benzo[b]azine*, *benzo[b]azabenzene*, and *1-azanaphthalene* [3].

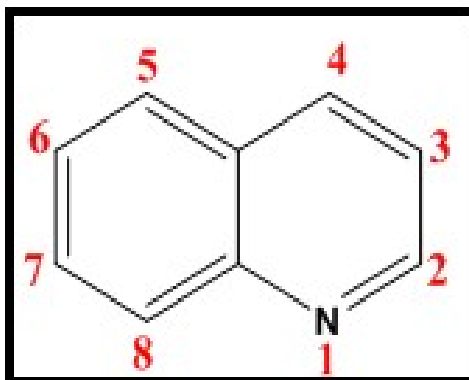


Figure 1. Structure of Quinoline

The physical and chemical properties of quinoline are illustrated in **Tables 1 and 2** [4, 5].

Table 1: Physical properties

Property	Description
Color	Colorless hygroscopic liquid; turns yellow or brown on exposure to light
Odour	Characteristic odour
Taste	Bitter
Solubility	Sparingly soluble in cold water; completely soluble in hot water and most organic solvents
Melting Point	15 °C
Boiling Point	238 °C
Density	1.093 g/cm ³
Molecular Weight	129.16 g/mol

Table 2: Chemical Properties

Property	Description
Nature	Alkaline in nature
EAS Reaction	Electrophilic aromatic substitution occurs at the 5 th and 8 th positions of the quinoline ring
Nucleophilic Substitution	Occurs at the 2 nd and 4 th positions of the quinoline ring
Redox Reaction	Undergoes oxidation and reduction reactions
Reaction with Alkyl Halides	Reacts with alkyl halides

Quinolines have been synthesized through a wide range of classical methodologies, including the Skraup [6], Doebner–von Miller [7], Combes [8], Conrad–Limpach–Knorr [9], Friedländer [10] Pfitzinger [11] and Niementowski synthesis reactions [12]. These well-established named reactions provide versatile and efficient routes for the construction of the quinoline framework. This section highlights and discusses these key synthetic methodologies involving the quinoline ring system, which continue to serve as valuable tools for chemists in the fields of organic and medicinal chemistry [13].

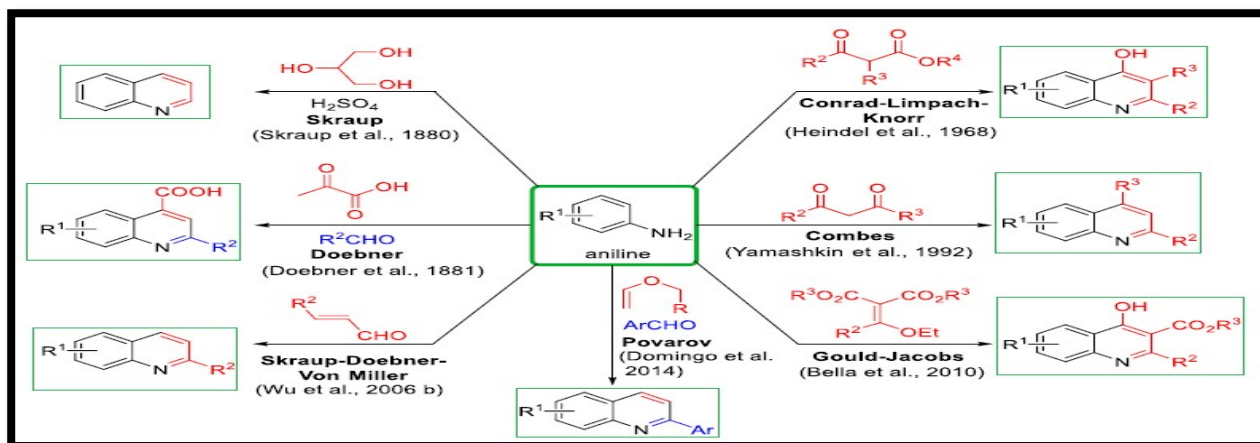
2. CONVENTIONAL SYNTHETIC APPROACH FOR QUINOLINES AND THEIR DERIVATIVES

Traditional methods for the synthesis of quinolines:

Methods for the synthesis of quinolines have been developed since the 1870's. They can be differentiated in two distinct groups based on the starting material used: aniline based and non-

aniline based, employing the latter other substrates different from aniline or substituted anilines wherein the substituent is involved in quinoline ring formation [14].

Synthetic methodologies based on aniline include several well-established named reactions, such as the Skraup, Doebner–von Miller, Conrad–Limpach–Knorr, Combes, Gould–Jacobs, and Povarov reactions, as illustrated in **Scheme 1**, among others. These classical approaches have proven to be highly effective for the construction of the quinoline framework. However, despite their synthetic utility, many of these methods are not environmentally sustainable, as they often generate significant amounts of chemical waste and by-products that require careful disposal. Additionally, these processes frequently involve harsh reaction conditions and complex operational procedures, making product isolation and purification more challenging [15].

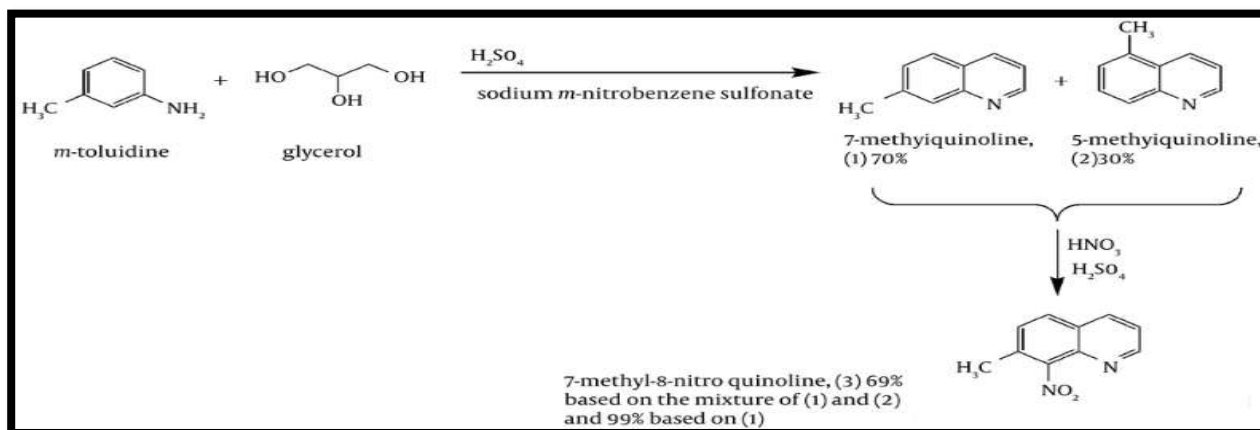


Scheme 1. Quinoline synthetic methods based on classical approaches

2.1.1 Skraup Synthesis:

The Skraup reaction is one of the earliest and most widely used methods for quinoline synthesis. It involves the heating of aniline with glycerol in the presence of concentrated sulfuric acid and an oxidizing agent, typically nitrobenzene [16]. This classical protocol primarily facilitates the synthesis of unsubstituted quinoline.

In addition, substituted quinoline derivatives such as 7-methyl-8-nitroquinoline can be synthesized via a two-step synthetic route starting from *m*-toluidine, employing the Skraup reaction as a key step. This transformation is illustrated in **scheme 2**. Such derivatives are of significant interest in the fields of drug discovery and medicinal chemistry due to their diverse biological activities [17-19].



Scheme 2. Substituted quinoline derivatives such as 7-methyl-8-nitroquinoline

2.1.2 Doebner Reaction

The synthesis of quinoline-4-carboxylic acid derivatives is achieved through the condensation of aniline with aldehydes in the presence of pyruvic acid, as reported in the literature [20,21]. This multicomponent transformation provides an efficient route to structurally diverse quinoline frameworks. The general synthetic pathway for this reaction is illustrated in **Scheme 1**.

To enable the synthesis of substituted quinoline derivatives, the Doebner reaction was subsequently developed. This method involves the condensation of aniline with an aldehyde and pyruvic acid, followed by cyclization at the benzene ring and subsequent dehydration, leading to the formation of 2-substituted quinoline-4-carboxylic acids [22,23].

2.1.3 Doebner–von Miller Synthesis: A Classical Acid-Catalyzed Strategy for the Construction of Substituted Quinoline Derivatives

The Doebner–von Miller synthesis is recognized as a classical and well-established strategy for the construction of the quinoline framework, and it has been extensively utilized for the synthesis of structurally diverse substituted quinoline derivatives.[24]

This transformation involves the condensation of substituted anilines with α,β -unsaturated aldehydes, particularly acrolein and its derivatives, under acidic conditions in the presence of an appropriate oxidizing agent. The general synthetic pathway for this reaction is illustrated in **Scheme 1**.

Mechanistically, the reaction proceeds via an initial nucleophilic conjugate (Michael-type) addition of the aniline to the β -carbon of the α,β -unsaturated aldehyde, generating a β -amino carbonyl intermediate. This intermediate subsequently undergoes intramolecular cyclization through electrophilic aromatic substitution to afford a di-hydroquinoline species. The final step involves oxidative aromatization, leading to the formation of the quinoline core.[25,26]

Due to its operational simplicity and the ready availability of starting materials, the Doebner–von Miller synthesis continues to be recognized as a valuable and widely utilized methodology in heterocyclic chemistry, particularly for the efficient construction of quinoline frameworks.

Furthermore, the reaction allows for structural variability through substitution on both the aniline and aldehyde components, thereby enabling access to a wide range of functionalized quinoline derivatives. Despite its utility, certain limitations such as side reactions and moderate yields under specific conditions have been reported, prompting ongoing efforts to optimize and modify this classical methodology.

2.1.4 Conrad-Limpach Quinoline Synthesis

Schiff Base-Mediated Condensation Approach for the Synthesis of 4-Hydroxyquinolines

The synthesis of 4-hydroxyquinoline derivatives via the condensation of anilines with β -keto esters constitutes a well-established and synthetically significant transformation in heterocyclic chemistry. This reaction typically proceeds through a Schiff base-mediated mechanism, wherein the nucleophilic aniline initially reacts with the carbonyl group of the β -keto ester to form an imine intermediate.

Subsequent intramolecular cyclization, followed by tautomerization and rearrangement, leads to the formation of the 4-hydroxyquinoline scaffold. This methodology is particularly advantageous due to its efficiency in constructing structurally diverse and functionalized quinoline derivatives from readily accessible starting materials. The general synthetic pathway is illustrated in **Scheme 1**.

Owing to its operational simplicity, versatility, and broad applicability, this approach remains widely utilized for the synthesis of biologically important quinoline frameworks [27].

2.1.5 Combes Quinoline Synthesis: An Acid-Catalyzed Strategy for the Construction of 2,4-disubstituted Quinoline Derivatives

The Combes synthesis, first reported by Combes in 1888, represents one of the classical methodologies for the construction of quinoline derivatives, particularly 2,4-disubstituted quinolines. This reaction involves the condensation of aniline with β -dicarbonyl compounds, most commonly acetoacetone, followed by cyclization under strongly acidic conditions. The general synthetic pathway is illustrated in **Scheme 1**.

In a typical procedure, aniline reacts with acetoacetone to form an intermediate Schiff base or enaminone species, which subsequently undergoes intramolecular cyclization in the presence of acidic catalysts such as concentrated sulfuric acid or polyphosphoric acid (PPA). These conditions facilitate dehydration and ring closure, ultimately leading to the formation of the quinoline framework.

The Combes synthesis is valued for its simplicity and effectiveness in introducing substituents at the 2- and 4-positions of the quinoline ring. However, the requirement of harsh acidic conditions and elevated temperatures may limit its applicability for acid-sensitive substrates. Despite these limitations, the method remains a significant classical approach in quinoline chemistry and continues to be utilized and modified for the synthesis of structurally diverse quinoline derivatives.[28]

2.1.6 Gould–Jacobs Reaction in Quinoline Synthesis and its derivatives

The Gould–Jacobs reaction [29] represents a classical and widely utilized thermal cyclization strategy for the construction of the 4-hydroxy-3-ethoxycarbonylquinoline framework. Originally reported in 1939 (**Scheme 1**), this methodology involves the initial condensation of aniline with diethyl ethoxymethylenemalonate to afford the corresponding anilide intermediate.

Upon subsequent heating under relatively harsh conditions, the intermediate undergoes intramolecular cyclization via a ketene-type intermediate, leading to the formation of 4-hydroxy-3-ethoxycarbonylquinoline. Owing to its reliability and effectiveness in generating quinoline scaffolds, the Gould–Jacobs reaction remains an important synthetic route in heterocyclic and medicinal chemistry.

An important feature of the Gould–Jacobs reaction is its regioselectivity, which is predominantly governed by both steric and electronic effects [30]. Cyclization may occur at either of the two ortho positions of the aniline moiety; consequently, the use of asymmetrically substituted anilines often results in the formation of regioisomeric mixtures, thereby complicating product selectivity and isolation.

Despite its synthetic utility, this classical methodology is associated with several limitations. The process typically involves a multistep reaction sequence and often proceeds with relatively low overall yields. Moreover, the cyclization step requires elevated temperatures (generally exceeding 250°C), which can promote product decomposition and the formation of undesired side products [31]. These drawbacks highlight the need for the development of more efficient and milder alternatives for quinoline synthesis.

2.1.7 Povarov Reaction: A Versatile Multicomponent Approach for the Synthesis of Tetrahydroquinoline Derivatives

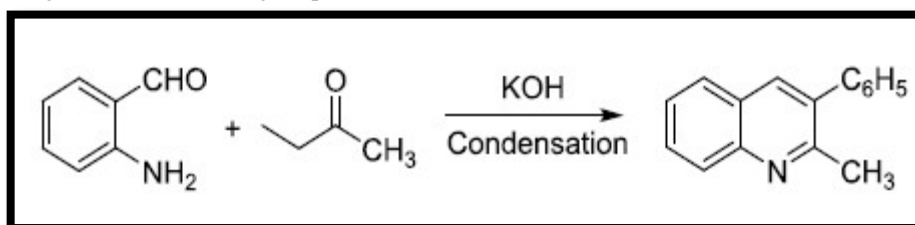
The classical Povarov reaction is a formal [4+2] cycloaddition (aza-Diels–Alder reaction) involving an aromatic imine (Schiff base) and an electron-rich alkene, leading to the formation of 1,2,3,4-tetrahydroquinoline (THQ) derivatives. This transformation proceeds via the generation of an

iminium ion intermediate, which undergoes cycloaddition with the alkene, followed by subsequent rearrangement and oxidation steps when required.

Although the Povarov reaction was initially developed for the synthesis of THQ derivatives, it has gained significant importance as a versatile and classical strategy for the construction of substituted quinoline frameworks through further oxidation or dehydrogenation processes. Owing to its high efficiency, structural diversity, and broad substrate scope, this reaction continues to be widely employed in heterocyclic and medicinal chemistry [32-35]. The synthetic route is depicted in **Scheme 1**.

2.1.8 Base-Catalyzed Friedländer Quinoline Synthesis via Aldol Condensation

The classical Friedländer synthesis represents a fundamental and widely utilized strategy for the construction of quinoline frameworks, proceeding through an aldol condensation-type mechanism. In this approach, *o*-aminoaryl aldehydes undergo condensation with ketones in the presence of a strong base, typically potassium hydroxide, to afford quinoline derivatives efficiently. The overall reaction pathway is schematically represented in **Scheme 3**.



Scheme 3. General reaction of quinoline synthesis by Friedländer

Mechanistically, the reaction is initiated by base-catalyzed enolate formation from the ketone, followed by nucleophilic addition to the carbonyl group of the *o*-aminoaryl aldehyde. The resulting β -amino ketone intermediate subsequently undergoes intramolecular cyclization and dehydration, leading to the formation of the quinoline core. This tandem sequence of aldol condensation, cyclization, and aromatization highlights the synthetic elegance and atom economy of the process. Owing to its operational simplicity, cost-effectiveness, and broad substrate applicability, this methodology remains a cornerstone in quinoline synthesis. The reaction tolerates a variety of functional groups, enabling the preparation of structurally diverse quinoline derivatives[36].

3. SUSTAINABLE APPROACHES TO THE SYNTHESIS OF QUINOLINE AND ITS DERIVATIVES

3.1 Sustainable Synthetic Approaches

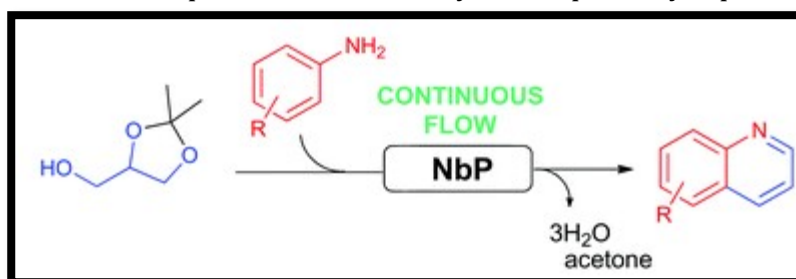
Quinoline and its derivatives represent a prominent class of nitrogen-containing heterocyclic compounds that exhibit a broad spectrum of biological and pharmacological activities, including antimalarial, antibacterial, antiviral, and anticancer properties. Consequently, quinoline scaffolds have attracted considerable attention in medicinal chemistry, as well as in agrochemical and material science applications [37]. Traditional synthetic methodologies such as the Skraup, Friedländer, and Doebner–von Miller reactions have long been employed for the construction of quinoline frameworks. However, these classical approaches often suffer from significant limitations, including harsh reaction conditions, low atom economy, limited selectivity, and the use of hazardous reagents and environmentally unfriendly solvents. Consequently, considerable research efforts have been directed toward the development of more efficient, sustainable, and environmentally benign synthetic strategies, including catalytic, multicomponent, and green chemistry approaches for quinoline synthesis[38,39].

In response to increasing environmental concerns and regulatory pressures, significant efforts have been directed toward the development of sustainable and environmentally benign synthetic strategies. The principles of Green Chemistry emphasize the design of chemical processes that minimize waste generation, enhance energy efficiency, and avoid the use of toxic and non-renewable resources [40]. Accordingly; contemporary research in quinoline synthesis has increasingly focused on the implementation of green and sustainable methodologies. These include solvent-free protocols, microwave- and ultrasound-assisted techniques, multicomponent reactions, and the use of recyclable and heterogeneous catalysts such as ionic liquids, metal nanoparticles, and solid-supported systems [41–43]. Such strategies not only improve reaction efficiency and product yields but also significantly reduce the environmental impact associated with conventional synthetic routes.

Furthermore, these advancements have enabled the efficient synthesis of structurally diverse and functionally enriched quinoline derivatives under mild and eco-friendly conditions, thereby broadening their applicability in pharmaceutical and industrial domains. Despite these developments, ongoing challenges related to catalyst recyclability, process scalability, and reaction selectivity continue to drive research toward the design of more efficient and sustainable synthetic methodologies.

3.1.1 Microwave-Assisted Skraup synthesis

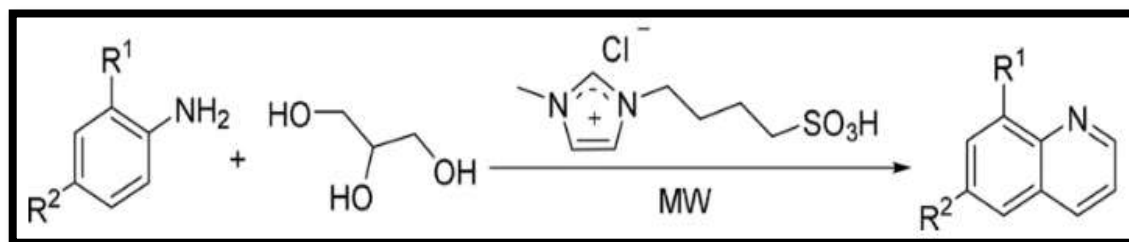
In a green chemistry approach, the Skraup synthesis can be performed using solketal, a by-product of the biodiesel industry. The acetalization of glycerol with acetone yields solketal, which is widely regarded as a suitable alternative to glycerol in small-scale applications. From a green chemistry perspective, its use offers advantages such as improved sustainability and reduced waste generation, making it a suitable substitute for conventional reagents in the synthesis of quinoline derivatives [44]. A schematic representation of the synthetic pathway is provided in **Scheme 4**.



Scheme 4. Microwave-Assisted Skraup Synthesis of Quinoline Derivatives in Ionic Liquids

The use of microwave irradiation as an alternative to conventional heating methods has gained considerable attention over the past decade. The use of microwave irradiation as an efficient heating technique for quinoline synthesis has been shown to significantly shorten reaction times and enhance product yields [45]. Nevertheless, the reliance on As_2O_5 (arsenic pentoxide) as an oxidant continues to impose harsh reaction conditions. Subsequent developments have focused on modifying this approach to achieve improved efficiency and greener reaction profiles [46].

Further explored microwave-assisted Skraup synthesis by reacting anilines with glycerol in a 1:3 ratio (**Scheme 5**). Notably, they replaced concentrated sulfuric acid with an imidazolium cation-based sulfonic acid ionic liquid, which led to a substantial improvement in reaction efficiency. Additionally, the use of an external oxidizing agent was found to be unnecessary. These modifications enabled the synthesis of quinoline in excellent yields under comparatively milder and more sustainable conditions.



Scheme 5. Skraup synthesis in ionic liquid medium under microwave irradiation

Green synthetic approaches for the preparation of quinolines and their derivatives have gained significant importance in modern organic chemistry. It is essential to adopt and integrate green chemistry methodologies into routine laboratory practices to enhance yield, selectivity, productivity, and overall efficiency while reducing energy consumption, time, and environmental impact [47]. The application of organo catalysts, along with strategies aimed at pollution reduction, the use of safer and less hazardous chemicals, and effective waste prevention, plays a crucial role in sustainable synthesis. Furthermore, the design of biodegradable substances and environmentally benign products aligns with the principles of green chemistry. These approaches are guided by the twelve principles of Green Chemistry, introduced in the 1990s, which aim to meet the needs of the present generation without compromising the ability of future generations to meet their own needs. [48,49]

3.1.2 Microwave-Assisted Doebner Reaction:

Transition-metal catalysts have been widely explored in quinoline synthesis due to their ability to enhance reaction efficiency, selectivity and yield compared to conventional non-catalytic methods [50,51]. However, their application in the synthesis of pharmaceutical compounds is often limited by concerns regarding residual metal contamination in the final products, which may pose toxicity issues. As a result, alternative strategies have been developed, particularly focusing on the use of organocatalysts that are less toxic and more environmentally benign [52,53].

In this regard, a microwave-assisted one-pot, three-component synthesis of 4-carboxyquinoline derivatives has been developed using p-toluenesulfonic acid (TsOH) as an organocatalyst [54].

The optimized reaction conditions involved 10 mol% TsOH and microwave irradiation at 300 W for 3–4 minutes, resulting in high yields within a significantly reduced reaction time.

Mechanistically, the reaction proceeds via initial imine formation between aniline and an aldehyde, followed by activation through the acid catalyst, which promotes a subsequent [4 + 2] cycloaddition with the alkyne. The study further demonstrated that imines bearing electron-donating substituents and aryl alkynes containing electron-withdrawing groups are particularly favorable for the synthesis of 4-arylated quinoline derivatives.

3.1.3 Sustainable Flow-Based Doebner-von Miller Strategies for the Synthesis of 2-Methylquinoline Derivatives

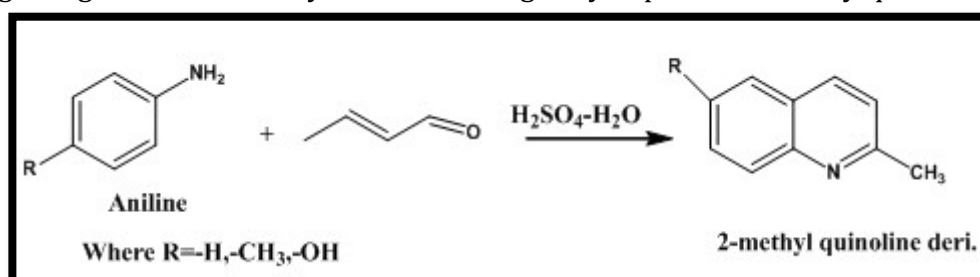
2-Methyl quinoline and its derivatives represent an important class of nitrogen-containing heterocycles that exhibit a broad spectrum of biological activities, including antimicrobial, anti malarial and anticancer properties. Consequently, the development of efficient synthetic methodologies for these compounds has attracted considerable attention. Among the various strategies reported, the Doebner–von Miller synthesis remains one of the most established and widely applied approaches for the preparation of 2-methylquinoline frameworks.

Recent advancements have focused on improving the classical protocol to enhance efficiency, sustainability, and product yield. Modified Doebner–von Miller methodology for the synthesis of 2-methylquinoline via the condensation of aniline with acrolein under strongly acidic conditions in a

flow reactor system. This approach allows better control over reaction parameters, leading to improved selectivity and reaction efficiency[55].

In addition, continuous-flow synthesis in aqueous media has been explored as a green and sustainable alternative for the preparation of 2-methylquinoline derivatives. The Doebner–von Miller reaction conducted in water under continuous-flow conditions offers several advantages, including reduced reaction times, minimized use of hazardous organic solvents, and enhanced yields. This environmentally benign protocol provides a rapid and efficient route to quinoline derivatives, typically affording products in good to excellent yields (**Scheme 6**)[56].

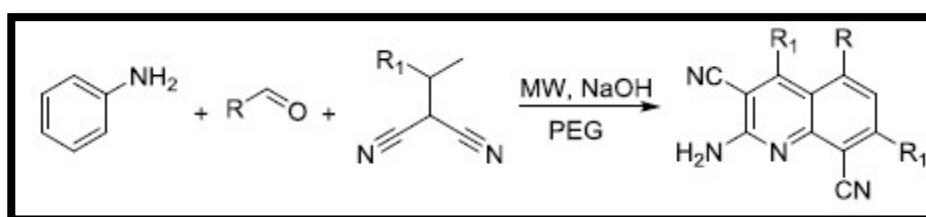
Overall, these developments highlight the ongoing evolution of the Doebner–von Miller synthesis, particularly through the integration of flow chemistry and green chemistry principles, thereby reinforcing its significance in the synthesis of biologically important 2-methylquinoline derivatives.



Scheme 6: Reaction scheme of Doebner–von Miller quinoline synthesis

3.1.4 Microwave-Assisted Green Conrad–Limpach Type Multicomponent Synthesis of Quinoline and its Derivatives

The Conrad-Limpach reaction is useful for green synthesis [57]. The depicted transformation represents a microwave-assisted multicomponent cyclocondensation strategy for the synthesis of functionalized quinoline derivatives. The reaction involves the initial Knoevenagel condensation between the aldehyde and malononitrile, followed by Michael addition of aniline and subsequent intramolecular cyclization and aromatization. The use of polyethylene glycol (PEG) as a green medium in combination with basic conditions (NaOH) enhances reaction efficiency, affording quinoline derivatives in a one-pot protocol. This transformation is illustrated in **Scheme 7**.



Scheme 7. microwave-assisted multicomponent cyclocondensation reaction

3.1.5 Solvent- and Catalyst-Free Combes Type Synthesis: A Green Approach to Quinoline Derivatives

In recent years, increasing emphasis on sustainable and environmentally benign synthetic methodologies has led to the development of solvent-free and catalyst-free protocols for quinoline synthesis. These green approaches aim to minimize the use of hazardous chemicals, reduce waste generation, and improve overall process efficiency in accordance with the principles of green chemistry.

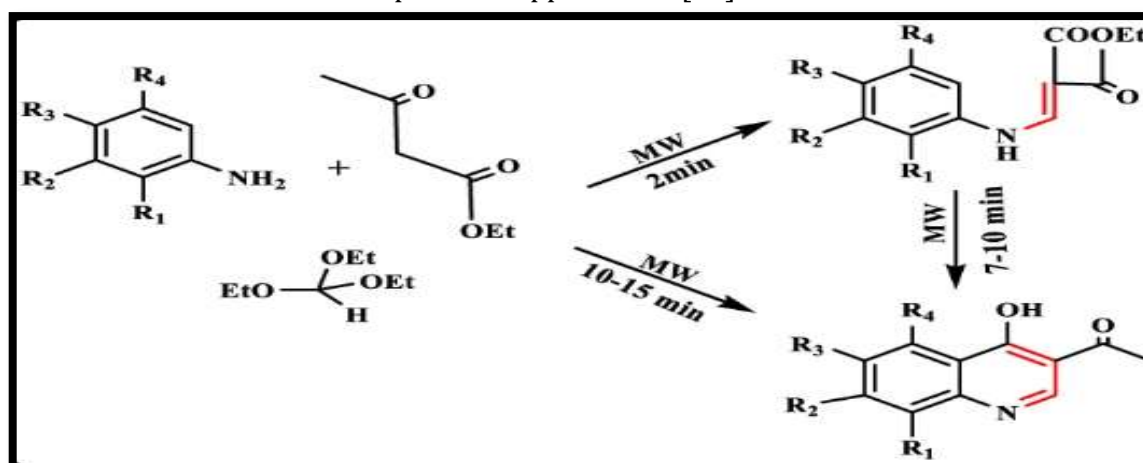
Notably, solvent-free methodologies have been reported for the condensation of 1,3-diketones with anilines, enabling the formation of quinoline derivatives without the need for organic solvents or

external catalysts. Under such conditions, the reactants are typically heated directly, allowing the reaction to proceed efficiently through enhanced molecular interactions in the absence of a reaction medium. This approach not only simplifies the reaction setup but also eliminates issues associated with solvent handling, toxicity and disposal.

The adoption of catalyst-free conditions further enhances the environmental compatibility of the process by avoiding the use of metal-based or corrosive acid catalysts. These protocols have been demonstrated to afford quinoline derivatives in moderate to good yields while maintaining operational simplicity. Consequently, solvent- and catalyst-free strategies represent a promising and sustainable alternative to conventional methods, contributing significantly to the advancement of green quinoline synthesis.[58,59].

3.1.6 Microwave-Assisted Gould–Jacobs Synthesis

The Gould–Jacobs reaction is a well-established synthetic methodology for the preparation of 4-hydroxyquinoline derivatives, involving the condensation of aniline with alkoxymethylenemalonate, followed by intramolecular cyclization and subsequent decarboxylation. **Scheme 8** illustrates the synthetic pathway. Recent advancements have focused on the incorporation of modern techniques, such as microwave-assisted synthesis, to enhance reaction efficiency, reduce reaction time and improve overall yields, thereby rendering the protocol more suitable for sustainable and practical applications.[60]



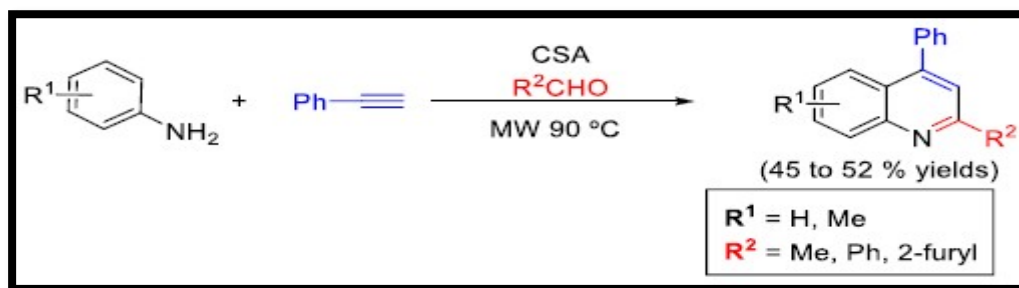
Scheme 8: Microwave-Assisted Gould–Jacobs Synthesis

3.1.7 Microwave-Assisted and Metal-Free Povarov Strategies for Quinoline Synthesis

The Povarov reaction has emerged as a valuable multicomponent approach for the synthesis of quinoline derivatives, although its application toward 4-substituted quinolines has historically been limited. Traditionally, such transformations have been promoted by inorganic Lewis acids; however, recent advancements have emphasized the development of more sustainable and environmentally benign catalytic systems. In this context, Chandra and co-workers reported a microwave-assisted Povarov reaction employing camphor-10-sulfonic acid (CSA) as an efficient organocatalyst for the synthesis of 4-arylquinolines [61].

The use of CSA offers several advantages, including operational simplicity, stability and reduced environmental impact compared to conventional transition metal catalysts. The reaction involves a three-component system comprising anilines, aryl alkynes and paraformaldehyde, proceeding via in situ imine formation followed by a CSA-promoted [4+2] cycloaddition to afford the desired quinoline derivatives in good yields. Substrate scope investigations revealed that anilines bearing electron-donating substituents and aryl alkynes containing electron-withdrawing groups are

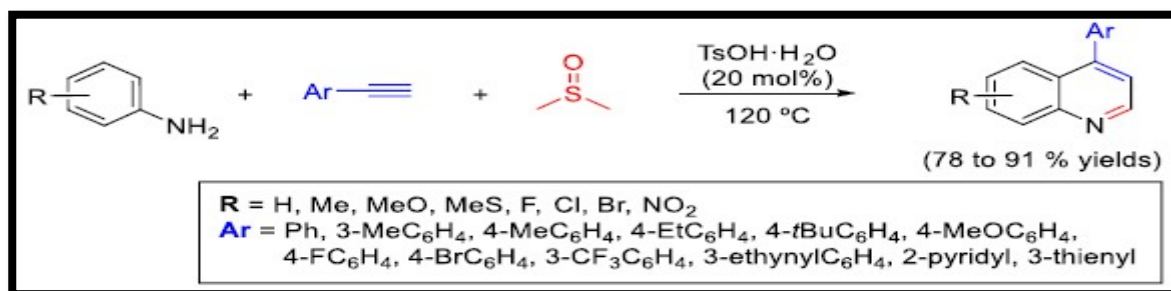
particularly favorable for this transformation. A schematic representation of the synthetic pathway is provided in **Scheme 9**.



Scheme 9. Reaction promoted by CSA under microwave irradiation

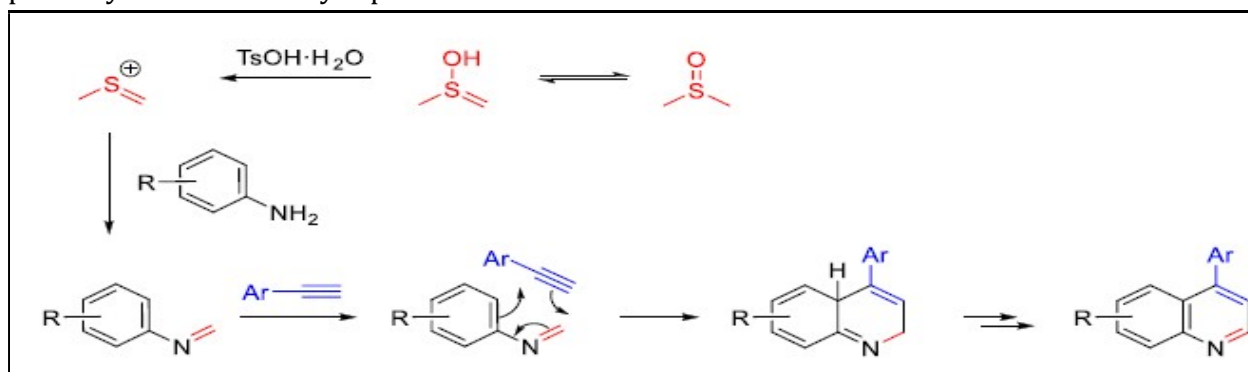
Furthermore, alternative aldehydes such as benzaldehyde, acetaldehyde, and furfural were also found to be compatible, enabling access to structurally diverse 2-substituted 4-phenylquinoline derivatives.

In the quest for greener and transition metal-free methodologies, an eco-friendly one-pot protocol has been developed utilizing *p*-toluenesulfonic acid monohydrate (TsOH·H₂O) as a catalyst. This method employs arylamines, arylacetylenes, and dimethyl sulfoxide (DMSO) as a C₁ source, affording 4-arylquinolines in good to excellent yields (78–91%) (**Scheme 10**). The protocol demonstrates broad substrate tolerance with respect to arylacetylenes; however, certain limitations were observed for substituted anilines, particularly due to steric hindrance and electronic deactivation effects.



Scheme 10. Reaction of substituted aniline, arylacetylene and DMSO catalyzed by TsOH

Mechanistically, DMSO acts as a methylene source through the formation of a reactive sulfonium ion intermediate under acidic conditions. Subsequent reaction with arylamine leads to the generation of an iminium species, which undergoes hetero-Diels–Alder cycloaddition with arylacetylene, followed by aerial oxidation to furnish the quinoline framework. The overall reaction pathway is schematically represented in **Scheme 11**.



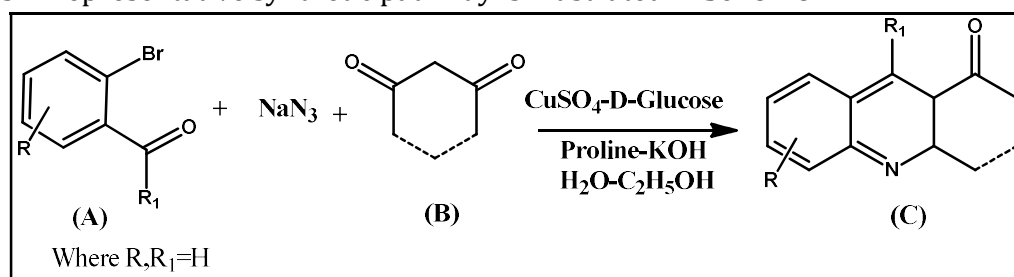
Scheme 11. Reaction mechanism for synthesis of 4-aryl quinoline derivatives

Overall, these studies highlight the significant progress achieved in the development of sustainable Povarov-type methodologies, particularly through the integration of microwave irradiation, organocatalysis, and metal-free conditions, thereby providing efficient and environmentally benign routes to functionalized quinoline derivatives.

3.1.8 Modified Friedländer Quinoline Synthesis

(a) Green One-Pot Ullmann-Type Approach for Quinoline Synthesis

A convenient, efficient, and environmentally benign one-pot methodology for the synthesis of quinoline derivatives has been developed by N. Anand and T. Chanda. This protocol employs 2-bromo benzaldehyde (A), various acyclic or cyclic 1,3-diketones (B), and sodium azide in a three-component reaction system, leading to the formation of quinoline derivatives (C) in excellent yields. The transformation is carried out in aqueous ethanol, serving as a green solvent, under mild conditions. A representative synthetic pathway is illustrated in **Scheme 12**.



Scheme 12. Reaction scheme of modified Friedlander quinoline synthesis

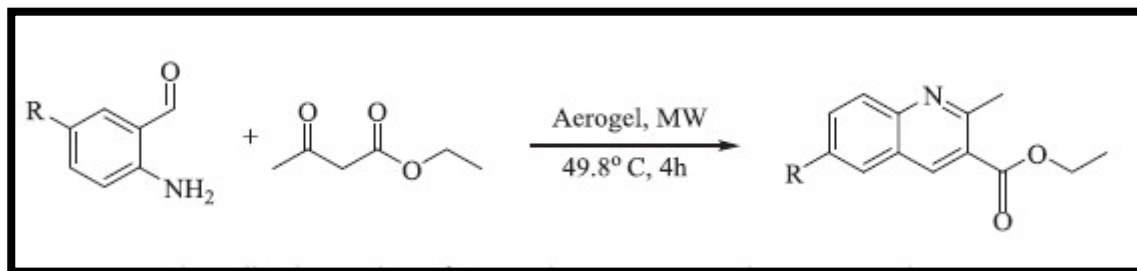
A key feature of this approach is the use of a copper salt–D-glucose system, where D-glucose acts as a reducing agent to generate catalytically active Cu (I) species in situ. Additionally, proline is utilized as a ligand and proton source, enhancing the efficiency and selectivity of the reaction. Mechanistically, the reaction proceeds via an Ullmann-type coupling pathway, initiated by nucleophilic substitution of the bromine atom in 2-bromobenzaldehyde with sodium azide to form an azido intermediate. This intermediate coordinates with Cu(I), forming an azido–copper complex that undergoes reductive elimination. Subsequent intramolecular dehydrative cyclocondensation affords the quinoline scaffold.

Importantly, the methodology demonstrates broad substrate tolerance, accommodating both electron-donating and electron-withdrawing substituents positioned at the ortho-, meta-, and para-positions of the aromatic ring. This versatility, combined with operational simplicity, green reaction conditions, and high efficiency, makes the protocol a valuable contribution to sustainable quinoline synthesis.[62]

(b) Metal-Free Microwave-Assisted Friedländer Synthesis Using Nano-Carbon Aerogels

An efficient and sustainable approach toward the synthesis of trisubstituted quinolines has been described by Ojer et al. through a metal-free Friedländer condensation strategy. In this method, substituted 2-aminobenzaldehydes are reacted with ethyl acetoacetate in the presence of nano-carbon aerogels, which act as a heterogeneous catalyst under microwave irradiation conditions. The use of nano-carbon aerogels offers significant advantages due to their high surface area, excellent porosity, and catalytic activity, enabling the reaction to proceed without the need for metal catalysts. The microwave-assisted protocol enhances reaction rates and improves energy efficiency, with the transformation typically completed within 4 hours. This green and operationally simple methodology affords trisubstituted quinoline derivatives in moderate yields ranging from 60–65%[63]. The reaction pathway is shown in **Scheme 13**.

Overall, the protocol represents a valuable contribution to environmentally benign quinoline synthesis, combining metal-free conditions, reusable catalyst systems, and microwave-assisted efficiency.



Scheme 13. Microwave-assisted Friedlander synthesis for quinoline using aero gel as nano-catalyst

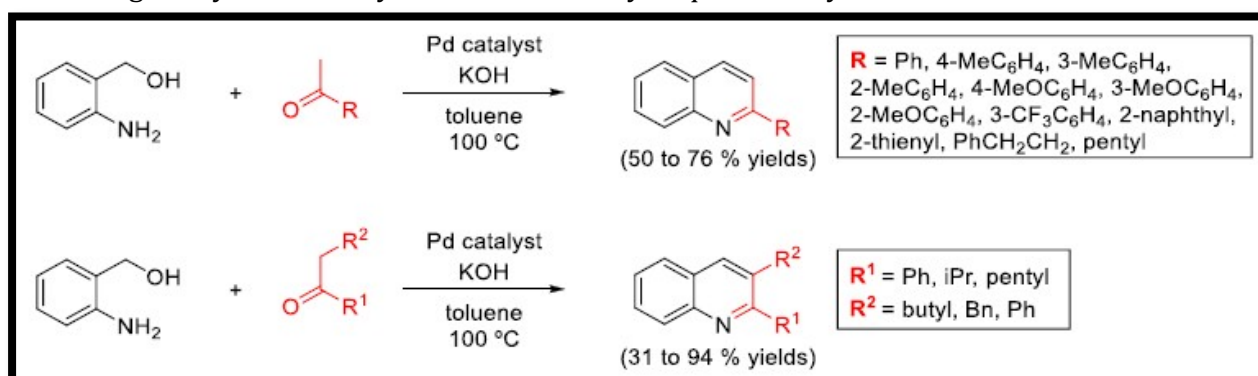
(c) Palladium-Catalyzed Modified Friedländer Approach with Recyclable Catalytic Systems

A modified version of the Friedländer quinoline synthesis employing palladium catalysis was reported in 2007, with a particular emphasis on developing an efficient and reusable catalytic system. In this methodology, 2-aminobenzyl alcohol was utilized as a key substrate in its reaction with ketones to construct quinoline derivatives. **Scheme 14** summarizes the key steps involved in the synthesis.

Initial investigations focused on the model reaction between 2-aminobenzyl alcohol and acetophenone, which successfully afforded 2-phenylquinoline. Among the various palladium catalysts screened, Pd(OAc)₂ demonstrated superior catalytic performance, delivering a high yield of 83%. Building upon this result, the study was further extended toward the development of recyclable catalytic systems based on palladium nanoparticles.

These nanoparticles were generated in situ through the interaction of Pd(OAc)₂ with poly(ethylene glycol) (PEG-2000), and several catalytic systems, including Pd(OAc)₂/PEG-2000, PdCl₂/PEG-2000, and Pd/C/PEG-2000, were systematically evaluated. The heterogeneous catalytic systems exhibited good efficiency, affording quinoline derivatives in yields ranging from 50% to 76%. Notably, these catalysts demonstrated excellent recyclability and could be reused for up to five consecutive cycles without significant loss of catalytic activity.

Furthermore, the substrate scope was broadened to include various ketones, all of which furnished the corresponding quinoline products in satisfactory yields, accompanied by facile recovery of the catalyst. This study highlights the practical advantages of palladium-based recyclable systems, combining catalytic efficiency with sustainability in quinoline synthesis.



Scheme 14. Reaction of 2-aminobenzyl alcohol and ketones in presence of Pd catalyst

4. Comparative Perspective: Traditional vs Sustainable Quinoline Synthesis

A comparative evaluation of traditional and sustainable methodologies highlights the transition toward environmentally responsible quinoline synthesis. Classical methods, including the Skraup, Friedländer, Doebner–von Miller, and Combes reactions, are well-established and broadly applicable; however, they often involve harsh conditions, high energy input, toxic reagents, and significant waste generation.

In contrast, sustainable approaches based on green chemistry principles emphasize safer and more efficient processes. Techniques such as microwave-assisted synthesis, solvent-free protocols, multicomponent reactions, and recyclable or metal-free catalysts enable reactions under milder conditions with reduced energy consumption and shorter reaction times. These methods typically offer improved selectivity, higher yields, and minimal environmental impact.

The key differences between traditional and sustainable approaches are summarized in **Table 3**. Overall, while conventional methods remain valuable due to their robustness, green synthetic strategies provide a more sustainable and industrially viable alternative.

Table 3. Comparison between Traditional and Sustainable Quinoline Synthesis

Parameter	Traditional Chemistry	Sustainable Chemistry
Reaction Conditions	Harsh (high temperature, strong acids)	Mild (ambient/moderate conditions)
Energy Requirement	High	Low (microwave, flow methods)
Reaction Time	Long	Short
Catalysts	Toxic/metal-based	Green/recyclable/metal-free
Solvent Use	Hazardous solvents	Solvent-free/green solvents
Atom Economy	Low-moderate	High
Yield	Moderate	Moderate-high
Selectivity	Lower	Higher
Waste Generation	High	Minimal
Environmental Impact	Significant	Environmentally benign
Safety	Hazardous	Safer
Work-Up	Complex	Simple
Scalability	Established	Improving (flow chemistry)
Cost	Higher (waste handling)	Cost-effective (long-term)

5. STRATEGIES TO OVERCOME LIMITATIONS OF TRADITIONAL QUINOLINE SYNTHESIS

Despite the well-established nature of classical quinoline synthesis methodologies, their associated limitations necessitate the development of improved and sustainable alternatives. Several strategic approaches have been proposed to address these challenges and enhance the overall efficiency, safety, and environmental compatibility of quinoline synthesis.

One of the most effective strategies involves the **replacement of harsh reaction conditions with milder and energy-efficient techniques**, such as microwave-assisted and ultrasound-assisted

synthesis. These methods significantly reduce reaction time and energy consumption while improving product yield and selectivity. In addition, the use of **alternative green solvents**, including water, polyethylene glycol (PEG), and ionic liquids, offers a viable solution to minimize the environmental hazards associated with conventional organic solvents.

The substitution of toxic and corrosive catalysts with **environmentally benign catalytic systems**, such as organocatalysts, heterogeneous catalysts, and recyclable nanocatalysts, represents another important advancement. These catalysts not only reduce toxicity but also enable catalyst recovery and reuse, thereby improving process sustainability and cost-effectiveness.

Furthermore, the adoption of **multicomponent reactions (MCRs)** and **one-pot synthetic protocols** enhances atom economy and reduces the number of reaction steps, leading to lower waste generation and simplified purification processes. The integration of **continuous-flow chemistry** also provides significant advantages in terms of scalability, improved reaction control, and safer handling of reactive intermediates.

From a broader perspective, the implementation of the **principles of green chemistry** plays a crucial role in guiding the design of sustainable synthetic methodologies. These principles emphasize waste minimization, the use of safer chemicals, energy efficiency, and the development of environmentally benign processes.

Overall, the combination of these strategies provides a comprehensive pathway to overcome the inherent drawbacks of traditional quinoline synthesis. Continued research efforts focusing on catalyst innovation, process intensification, and industrial scalability are expected to further advance the field toward more efficient and sustainable quinoline production. Future research should focus on the development of highly recyclable catalysts, scalable continuous-flow systems, and AI-assisted reaction optimization to further enhance sustainability and industrial applicability.

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THE FOREST AS HETEROTOPIA: ECOLOGICAL ENTANGLEMENT AND THE SUBVERSION OF HIERARCHICAL WISDOM IN AMRUTA PATIL'S "ARANYAKA: BOOK OF THE FOREST"

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ABSTRACT:

Aranyaka: Book of the Forest (2019), a graphic novel by Amruta Patil, co-conceptualized with Devdutt Pattanaik, is a reimagining of a smaller episode of the Brihadaranyaka Upanishad that questions the epistemological hierarchies that have historically privileged abstract, masculine-coded knowledge over embodied, domestic, and feminine wisdom. This paper contends that the forest is built by Aranyaka as a heterotopic space, the space that is real and mythic, historical and hypothetical, the space in which the borders between the human and non-human, the self and other, culture and nature are permeable. Based on spatial theory, ecocriticism, and feminist narrative analysis, the paper analyses how Patil uses hunger as a precondition of living, how the human being is displaced in the ecosystem, and how the figure of the rishika (female sage) can be reinstated as an acceptable source of knowledge. The paper also examines how the watercolor aesthetic of the work and its nonconformity to traditional panel grids performs the creation of formally the ecological principles of interconnection and movement which the narrative itself theorizes. Making Aranyaka a part of the modern discussions of decolonial ecology and feminist mythography, the analysis will argue that the graphic novel form has become an exceptionally efficient tool to express non-hierarchical, biocentric worldviews that can be applied to both Western anthropocentrism and patriarchal epistemologies.

KEYWORDS: AMRUTA PATIL, ARANYAKA, GRAPHIC NOVEL, ECOCRITICISM, HETEROTOPIA, FEMINIST MYTHOLOGY, VEDIC LITERATURE, SPATIAL THEORY

INTRODUCTION

In the introductory part of the book Amruta Patil Aranyaka: Book of the Forest (2019), the main character Katyayani the Large states, the warp of my story has ever been hungered (Patil and Pattanaik 3). This statement, simultaneously corporeal and metaphysical, sets the governing conceit of the work hunger as a multi-tiered structure that includes bodily appetite, intellectual desire, ecological imperative, and spiritual desire. The graphic novel that emerges out of this assumption is a thick, allusive text that weaves together Puranic mythology, Upanishad philosophy, feminist criticism and environmental awareness into what one scholar has described as a rich tapestry of metaphors and meanings (Sarkar and Karmakar 1309). Published by Tranquebar Aranyaka (a Sanskrit word referring to the forest or to the wilderness), tells a slender tissue of narrative of the Brihadaranyaka Upanishad: the story of the sage Yajnavalkya and the women round him, his two wives, Katyayani and Maitreyi, and his pupil Gargi. In the canonical version, these women are presented in starkly contrasting roles: Maitreyi the so-called brilliant Brahnavadini is the one to argue in a philosophical debate, whereas Katyayani has the mere common sense of women, and Gargi is presented as a rather powerful questioner whose inquiries bring Yajnavalkya to the boundaries of his knowledge (Patil and Pattanaik 98). Patil and Pattanaik use this small

episode to start with, not to follow a pattern, but to create an original story with the explicit purpose to challenge the superiority of wisdom (Patil and Pattanaik 156).

This paper claims that Aranyaka is a three-part reclamation: the forest as a place of ecological entanglement and not of backdrop of human drama; the female wisdom as a valid area of epistemology; and the graphic novel form of its own as a form of epistemology. By studying the narrative scheme, visual representations, and thematic obsessions of the work, especially its continued focus on the theme of hunger as a universal human experience, this paper puts Aranyaka in context of the larger pattern of Patil work, and pays attention to the unique aspects of her working relationship with Pattanaik. The paper also discusses the way in which the watercolor aesthetic of the work and its rejection of the strict boundaries of the panels perform a formally enacted ecological theory of interconnection and flow that the narrative explicitly theorizes. Based on the current literature in the fields of spatial theory, ecocriticism, and feminist mythology, this analysis suggests that Aranyaka can be viewed as an example of how the graphic novel genre can become an exemplar of decolonial ecological thinking, as it undermines both Western anthropocentrism and patriarchal knowledge transmission hierarchies.

THEORETICAL FRAMEWORK: HETEROTOPIA, ECOCRITICISM, AND FEMINIST NARRATIVE

In order to examine the spatial and ecological aspects of Aranyaka, this paper will apply the heterotopian concept established by Michel Foucault, which refers to the real spaces that act as a counter-sites in which all other real spaces are represented, contested and inverted at the same time (Foucault 24). In contrast to utopias, which are essentially unreal, heterotopias are real sites that hold, nullify or invert the relations they signify. Foucault articulates six principles of heterotopias: they are found in all cultures; their function changes over time; they can juxtapose multiple incompatible spaces in a single real place; they often involve a break with traditional time; they have systems of opening and closing; and they create a space of illusion or compensation (Foucault 25-27). The forest of Aranyaka is a heterotopic space based on the following principles: it is both a concrete geographical site of the story and a mythical, symbolic landscape in which the laws of village life, the hierarchy of castes, the role of gender and the primacy of ritual knowledge, are suspended. According to Naiya and Singh, the forest is imagined and visualized as a heterotopia, which introduces the unscholarly wife of Yajnavalkya Katyayani to the center stage and writes a tale in her words and her imagination (8).

Such spatial reading is supplemented with ecocritical methods that keep an eye on how the work relates to human-nonhuman. The notion of the ecological thought developed by Timothy Morton (that focuses on the interconnectedness of all living and non-living objects) (Morton 7) can be applied as a valuable approach to Aranyaka denying nature/culture duality. According to Morton, ecological consciousness entails a radical decentring of the human being, a cognizance that humans are not the heroes in the ecological narrative (Morton 8). According to Sarkar and Karmakar, the work evokes the ecological thinking of the human and non-human entanglement in the aranya, the contact zone of the multispecies (1308). The Aranyaka forest is not an inanimate scene but rather an active participant in the story, requiring both characters and readers to acknowledge their immateriality in bigger ecological forces.

Lastly, this analysis is informed by feminist narrative theory, specifically reclamation of marginalized voices in mythological retellings. The use of Katyayani, the wife who is not a scholar, as the narrator by Patil has been what has been referred to as narrative reparation by feminist scholars: the reclaiming of voice and agency to characters who are traditionally marginalized or undermined (Rowe 45). This reclaiming is not only on a character level, but also on a form level: the very hybridity of the graphic novel and its historical marginalization by the hierarchies of literary history are comparable to the marginalization of feminine wisdom by the hierarchies of the Vedic tradition. The medium of graphic novels, as Patil herself has remarked, is queer, constantly caught between the genres of comics and literature, and thus a good form to challenge other forms of hierarchy (Patil, “Interview” 26).

AMRUTA PATIL: INDIA’S FIRST FEMALE GRAPHIC NOVELIST AND THE TURN TO MYTH

Amruta Patil is a born Punean who grew up in Goa in 1979. She has also been trained in formal education attaining a BFA at Goa College of Art (1999) and an MFA at the School of the Museum of Fine Arts at Tufts University in Boston (2004). This cross-continental education has had a very strong influence on her sense of art, and provided her with an entry point to the traditions of Indian vernacular, as well as modernist methods of the West. With her first graphic novel, *Kari* (2008), Patil has become a unique voice in Indian letters. The novel, about a queer young woman in a magical-realist Mumbai, was heralded as India’s first female graphic novel, and has since gone on to cult status. In a review of *Kari*, the novelist Neel Mukherjee, compared it to *Fun Home* by Alison Bechdel, predicting, writing, “I find Patil more evocative, more beautiful than Bechdel and her prose a thing of radiant beauty (qtd. in Patil, *Kari* back cover). These themes that *Kari* pioneered would be echoed throughout the career of Patil: queer desire, urban alienation, the feel of everyday life, and the attempt to find other ways of belonging.

The later works of Patil shifted strongly towards the field of mythology. The *Parva* duology, which includes *Adi Parva: Churning of the Ocean* (2012) and *Sauptik: Blood and Flowers* (2016), recounts the *Mahabharata* in a feminist manner, as seen through the eyes of unusual narrators: the river goddess Ganga in the first and the wounded immortal Ashwatthama in the second. Patil has described this decision to use outlier sutradhars (deviant narrators) as an approach to fill the absent spaces of who tells the story (Patil, “Interview” 22). *Aranyaka* is another step in this direction, bringing all her environmental issues together as well as expanding her focus on Vedic, as opposed to solely epic, content. It is also her first-longstanding collaboration with another author, a prolific mythologist, Devdutt Pattanaik, whose conceptual framework forms the Vedic architecture in which Patil is to operate her visual and narrative sensibility. The collaboration, as Patil has described it, entailed countless discussions that perfected and reinforced what I have written and drawn, as I had (Patil, “Interview” 24). Not every creative relationship was free of tensions, although these fruitful tensions, between the systematization of ideas of Pattanaik and the embodied, affective narrative of Patil, produce the polyphony of the work.

THE FOREST AS HETEROTOPIA: SPATIAL DYNAMICS IN ARANYAKA

The forest of *Aranyaka* is not a passive location but a dynamic actor- a heterotopia where the lines between self and other, human and non-human, culture and nature are erased. Based on Foucault six principles of heterotopia, Naiya and Singh list several aspects of the forest of the work that fit the definition: first, the forest is a crisis heterotopia (Katyayani being sent away to her village

because of her insatiable appetite); second, the forest is a space of accumulation, where Vedic, Puranic, and modern temporalities are stacked together; third, the forest is This topographical reading sheds light on the utilization of physical geography to perform epistemological challenge in the work. As Katyayani first gets into the forest she sees: The warp of my tale has ever been hungering. But the weft? The weft is forest. It was not my choice. It chose me (Patil and Pattanaik 3). The passive aspect of it - It chose me- is important: agency is shared between human and non-human subjects and the anthropocentric belief in humans as the ultimate agents of narrative is broken.

The description of the forest in the work also opposes the traditions of romanticism and pastoral. According to Dutta and Mohanty, it is not the romantic wilderness of the West but a space that is informed by the reality of survival, hunger, and violence that human beings are neither masters nor the rulers of but rather useless fragments of the nexus of existence (5). This can be seen in the visual interpretation of the forest by Patil: thick, dark and full of non-human life that does not care about human interests. In a single stunning shot, Katyayani is watching a snake eat a frog, and the narration reads: You eat. You are eaten. You fight to the point of death to maintain turf and to win the best mate (Patil and Pattanaik 47). The forest does not like individual creatures to die, but only it likes to see the system continued. This otherness is not antagonistic, just other--an alternate order of value, which the work is challenging its readers to occupy, at least in the short run. This dehumanization has been stressed by Patil herself: to live in a forest, in general, one might think, is punishment but it is not really the case: as Patil puts it, living in a forest you become a part of the whole ecosystem, not on the top of it (qtd. in Sarkar and Karmakar 1315).

HUNGER AND THE CRITIQUE OF HIERARCHICAL WISDOM

The longest consistent thematic exploration in Aranyaka is the theme of hunger both as literal appetite and principle. According to a recent analysis by Shiroya and Pandey, based on Indian aesthetic theory (rasa-bhava) and Upanishadic philosophy (ksudha, anna, atman), the work, according to them, alters the stigmatized appetite of hunger into a mythopoetic principle of becoming (45). This change works in five thematic lenses, which include elemental appetite, cosmic maw, feminine agency in relation to food, rejection/gift and sacred feeding. The hunger of the work is not subject to moralization which is usually applied to the appetite, female appetite in particular. The voluptuous body of Katyayani and the fact that she eats without any shame (she even stole food destined to gods) does not introduce hunger as a vice that should be conquered but as the principle of life. In glossing the philosophy that underlies the work, Pattanaik writes that Vedic thought is fundamentally about being cultured, civilised: the process of coming out of hunger and fear, through domestication, to empathy (qtd. in Patil and Pattanaik 200).

This criticism is also applied to what Patil refers to as hierarchy of wisdom. Different types of knowledge, the abstract, the philosophical, the ritual, are always given preference in the Vedic culture, in comparison to others, the embodied, the domestic, the intuitive. Aranyaka does not reverse this hierarchy straight away. The wisdom of Katyayani based on her experience of the forest and the kitchen is not portrayed as being more superior to that of Y (Yajnavalkya) but rather as distinct- and as having been unfairly left out of being classified as a type of knowledge altogether. This is made clear in the work when Katyayani thinks: Mine was a gut know, deep and mute. His was probability, statistics and math. Our different maps of the world had found each other to form

a rich atlas (Patil and Pattanaik 67). This picture of the atlas, a collection of several maps, which are good at one thing or another, substitutes the hierarchical model of knowledge with a pluralistic one. According to Singh, even the silent belief of Katyayani, her free-spiritedness, and attachment to the forest space, successfully challenge the feeding hierarchy, in which feeding refers to both the literal feeding and imparting knowledge (8). The three rishikas Katyayani, Maitreyi and Gargi represent three relationships to knowledge, none of which are offered as full or better than the others. The work is vision of wisdom, but this is not hierarchical; it is complementary.

VISUAL STYLE AS FORMAL ARGUMENT

The visual practice of Aranyaka by Patil is a big contrast to her previous work. This is in contrast to the mixed media and collage that characterized the Parva duology, where Aranyaka uses watercolor and soft pencils. It is, as one of the critics points out, soft on the eye, dark and dreamy (Sharma and Rath 56). This change of medium is not only technical but conceptual: the fluidity of watercolor, its inclination to bleeding sides, reflects the thematic concern of the narrative with permeability, with the dissolution of boundaries between self and other, human and forest. No less important is the fact that Patil does not follow the traditional panel grid. Where her previous practice, especially Kari used the relatively traditional rectangular panels in more or less traditional arrangements, Aranyaka is breaking out of the rectangles and more and more the images are flowing across the page in organic forms (Patil, "Interview" 26). It simply seemed to me that the lines that met at right angles were too stiff, they were not visually conveying the movement of organic character that I was attempting to convey in my stories as Patil has described (qtd. in Sarkar and Karmakar 1318). Whether the decision to allow the page layout to be dictated by organic objects that had been a part of the composition is a question of carrying through the philosophical idea which was also artistic (Patil, "Interview" 27).

The palette of Aranyaka is also quite calculated. Patil has stressed that the colours in my book are talking to you as much as my words are talking to you (qtd. in Shiroya and Pandey 52). The palette of the work is grounded and saturated: deep greens, ochres, dark browns, with the red of sacrificial fires and the blue-black of night in between. It is this chromatic vocabulary that bases the work in the materiality of the forest, as well as expressing the emotional registers of this place: the warmth of feeding, the cool of shade, the heat of hunger. The visual metaphor that has been mentioned is the representation of the yagna fire as a face with an open mouth that actively absorbs what the ladle provides them, a visualization that makes it difficult to distinguish between the idea of ritual sacrifice and the idea of literal feeding (Patil and Pattanaik 112). The other one is a visual contrast between a man-made, round-shaped grove, a rectangular field and the unstructured, un-tamed nature that surrounds everything around it- a juxtaposition that serves to thematize the overall theme of the work which is about the connection of culture with nature (Sharma and Rath 58). The formal hybridity of the graphic novel: its use of both word and image simultaneously, its ability to be simultaneous and juxtaposed permits it to express ecological entanglement in a manner that is impossible to either purely textual or purely visual media.

CONCLUSION

Book of the Forest: Aranyaka takes significant place in the current practice of Indian graphic narrative, bringing to a logical culmination the course Patil followed, and a fruitful beginning in her association with Pattanaik. The refusal of easy polarities where the work dwells is the refusal of

nature/culture, intellect/body, male/female, hunger/nourishment, self/other. Instead of all these oppositions, Aranyaka suggests a vision of entanglement, of membrane which is both isolating and joining, of forest neither paradise nor punishment but just condition. The hunger of the work, its forest, its three rishikas, these are not themes, not characters but methodologies. They are methods of perception which the work trains its readers to occupy by the gradual, immersive work of reading graphic narrative. This training is not accidental to the visual-verbal hybridity of the form: the watercolor bleeding, the rejection of hard panels, the intentional obscurity of the names of the characters: the formal decisions are an argument of the work on display. In the age of ecological crisis and epistemological polarization, Aranyaka is a humble yet insistent suggestion: that wisdom is not in the withdrawal of the ascetic into the world nor the control of the scholar over books, but in the kitchen, in the forest, in feeding and being fed. The question of whether this proposal can be convincing will rest on the readiness of the readers to submit to the demands of the work, to dwell in its obscurity, to wander along its winding paths, to become, like Katyayani, a part of the membrane (Patil and Pattanaik 189). To those who may choose to take that trip, Aranyaka does not provide answers but another form of questioning. Future studies could examine comparative studies with other feminist retellings of mythologies in world graphic narrative, deeper analysis of how the visual style of Patil and South Asian painting culture relate, and how teaching Aranyaka can be applied to environmental humanities courses.

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CONTRIBUTION OF SUBHAS CHANDRA BOSE TO INDIAN INDEPENDENCE

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ABSTRACT

Subhas Chandra Bose remains one of the most remarkable and influential leaders of India's struggle for independence. Known for his courage, determination, and radical approach, Bose played a unique role in challenging British colonial rule. Unlike many of his contemporaries, including Mahatma Gandhi, who emphasized non-violence, Bose strongly believed in armed resistance and international alliances to secure freedom. This research paper explores Bose's contributions in detail, focusing on his political ideology, leadership, and military initiatives. It examines his early political career, his role in the Indian National Congress, and his eventual departure due to ideological differences. Special attention is given to his leadership in forming the Indian National Army and establishing the Azad Hind Government. The study also evaluates his international efforts during World War II, where he sought support from Axis powers to fight British rule. Despite controversies surrounding these alliances, Bose's efforts significantly influenced the Indian independence movement by instilling confidence and a sense of urgency among Indians. The paper concludes that Bose's contribution was not only military but also psychological and ideological, making him a key figure in accelerating India's journey toward independence.

KEYWORDS: SUBHAS CHANDRA BOSE, INDIAN INDEPENDENCE, INA, AZAD HIND GOVERNMENT, FREEDOM MOVEMENT, NATIONALISM, WORLD WAR II

1. INTRODUCTION

India's struggle for independence was a long and complex process involving numerous leaders, ideologies, and strategies. Among these leaders, Subhas Chandra Bose occupies a distinctive place due to his militant approach and unwavering commitment to freedom. He is often remembered as "Netaji," a title that reflects the immense respect and admiration he commanded among his followers. Bose's approach to independence differed significantly from the non-violent philosophy of Mahatma Gandhi. While Gandhi believed in peaceful resistance, Bose argued that independence could only be achieved through force and strategic alliances. This ideological difference led to a division within the Indian freedom movement but also enriched it by introducing diverse methods of resistance.

This research paper aims to provide a comprehensive analysis of Bose's contribution to Indian independence. It examines his early life, political journey, military initiatives, and ideological perspectives. By analyzing his efforts, the paper seeks to highlight the importance of his role in shaping the course of India's freedom struggle.

2. OBJECTIVES OF THE STUDY

To study the life and political ideology of Subhas Chandra Bose

To analyze his role in India's freedom movement

To examine the formation and activities of the Indian National Army

To evaluate the impact of his strategies on British rule

To assess his legacy in modern India

3. RESEARCH METHODOLOGY

This research is descriptive and analytical in nature. It is based on secondary sources such as books, journals, historical documents, and online databases. The study adopts a qualitative approach to analyze Bose's contributions and their impact on the Indian independence movement.

4. EARLY LIFE AND NATIONALIST AWAKENING

Subhas Chandra Bose was born on January 23, 1897, in Cuttack, Odisha, into a well-educated and culturally rich family. From a young age, Bose displayed exceptional intelligence, discipline, and a strong sense of patriotism. His education at Presidency College and later at Cambridge University exposed him to both Western philosophy and Indian nationalist thought.

Despite clearing the prestigious Indian Civil Services (ICS) examination, Bose resigned in 1921 because he did not want to serve under British colonial rule. This decision marked a turning point in his life, as he chose the path of sacrifice and struggle for India's independence. His early exposure to nationalist leaders and movements deeply influenced his thinking and commitment.

Bose's awakening was not sudden but a gradual realization that India's subjugation required strong resistance. He believed that freedom was the birthright of every nation and must be achieved through determination and sacrifice. His early life laid the foundation for his future leadership and revolutionary activities.

5. ROLE IN THE INDIAN NATIONAL CONGRESS

After returning to India, Bose joined the Indian National Congress and quickly rose through its ranks due to his leadership qualities and dedication. He worked closely with prominent leaders and became known for his administrative efficiency and organizational skills. Bose served as the President of the Congress in 1938 and again in 1939. During his tenure, he emphasized industrialization, economic planning, and complete independence (Purna Swaraj). He believed that India needed strong governance and modern infrastructure to compete globally. However, Bose's ideas often clashed with the more moderate and non-violent approach of leaders like Mahatma Gandhi. While Gandhi advocated peaceful resistance, Bose supported more direct and assertive methods. These ideological differences eventually led to his resignation from the Congress presidency. Despite these conflicts, Bose's role in the Congress was significant in shaping a more radical and assertive direction within the freedom movement.

6. FORMATION OF FORWARD BLOC

In 1939, after resigning from the Congress presidency, Bose established the Forward Bloc. The aim of this organization was to unite all anti-imperialist forces in India and promote a more aggressive struggle against British rule. The Forward Bloc focused on mobilizing youth, workers, and peasants, encouraging them to actively participate in the independence movement. Bose believed that mass participation was essential to overthrow colonial rule. Through this organization, he attempted to bring together diverse political ideologies under a common goal of independence. Although it faced challenges and opposition, the Forward Bloc played an important role in spreading nationalist ideas

and strengthening the movement. This step demonstrated Bose's determination to continue the struggle for freedom, even outside the mainstream political framework.

7. IDEOLOGICAL DIFFERENCES AND VISION FOR INDEPENDENCE

Subhas Chandra Bose had a unique vision for India's independence. Unlike many leaders who believed in gradual reform, Bose demanded immediate and complete freedom.

His ideological differences with Mahatma Gandhi were based on methods rather than goals. While Gandhi emphasized non-violence, Bose argued that armed struggle was necessary to defeat a powerful colonial regime. Bose also believed in strong central leadership, economic planning, and social equality. He envisioned India as a modern, industrialized nation with equal opportunities for all citizens. His ideas were influenced by both Indian traditions and global political developments. This ideological clarity made him a strong and independent leader who was willing to challenge existing norms for the sake of national freedom.

8. ESCAPE FROM INDIA AND INTERNATIONAL DIPLOMACY

In 1941, Bose made a daring escape from British house arrest in India. Disguised and traveling through dangerous routes, he reached Germany and later Japan. This journey itself became legendary and showcased his courage and determination.

Bose believed that India's independence could be achieved with international support. During World War II, he sought alliances with countries opposing Britain. He argued that Britain's enemies could become India's allies in the struggle for freedom.

In Germany, he worked to raise awareness about India's independence and organized Indian prisoners of war. Later, in Japan, he received stronger support for his plans to launch a military campaign against British India.

His international diplomacy was a bold and unconventional strategy that brought global attention to India's independence movement.

9. LEADERSHIP OF THE INDIAN NATIONAL ARMY (INA)

One of the most significant contributions of Bose was his leadership of the Indian National Army. Originally formed by Indian prisoners of war, the INA was reorganized and strengthened under Bose's command. He transformed the INA into a disciplined and motivated force dedicated to liberating India. The army included soldiers from different regions, religions, and backgrounds, reflecting his vision of unity.

Bose also established the Rani of Jhansi Regiment, an all-women unit, which was a revolutionary step at that time. This showed his progressive thinking and belief in gender equality. Under his leadership, the INA became a symbol of resistance and inspired thousands of Indians to join the struggle for independence.

10. ESTABLISHMENT OF AZAD HIND GOVERNMENT

In 1943, Bose established the Azad Hind Government in exile. This government represented a free and independent India and sought recognition from other nations.

The Azad Hind Government declared war on Britain and supported the military campaigns of the INA. It also introduced its own currency, stamps, and administrative structure, symbolizing sovereignty.

This step was significant as it demonstrated that India was ready to govern itself independently. It also boosted the morale of Indians both within the country and abroad.

The formation of this government marked a new phase in the freedom struggle, combining political and military efforts.

11. MILITARY CAMPAIGNS AND ARMED STRUGGLE

Under Bose's leadership, the INA launched military campaigns in northeastern India, particularly in regions like Imphal and Kohima. These campaigns aimed to weaken British control and inspire mass rebellion.

Although the INA faced challenges such as limited resources and harsh conditions, their efforts demonstrated courage and determination. The slogan "Delhi Chalo" became a rallying cry for the soldiers.

These military actions, though not ultimately successful, had a significant psychological impact. They showed that Indians were willing and capable of fighting against colonial rule.

The campaigns also challenged the myth of British invincibility and encouraged greater participation in the independence movement.

12. IMPACT ON BRITISH RULE AND INDIAN SOCIETY

The activities of the INA and Bose's leadership had a profound impact on both British authorities and Indian society. The INA trials held in 1945–46 created widespread unrest and protests across India.

These events united people from different backgrounds and increased pressure on the British government. The loyalty of Indian soldiers to the British Empire was shaken, which was a major concern for colonial rulers.

Many historians believe that Bose's efforts played a crucial role in weakening British control and accelerating the process of independence. His influence extended beyond military action to social and psychological transformation.

He inspired a sense of pride, unity, and determination among Indians, which was essential for achieving freedom.

13. LEGACY AND HISTORICAL SIGNIFICANCE

The legacy of Subhas Chandra Bose continues to inspire generations. He is remembered as a fearless leader who dedicated his life to the cause of independence.

His contributions were not limited to military efforts but also included ideological and psychological impact. He introduced a new dimension to the freedom struggle by emphasizing action, sacrifice, and unity. Even today, Bose is regarded as a symbol of patriotism and courage. His vision of a strong, independent, and self-reliant India remains relevant in modern times. In conclusion, Bose's role in India's independence was immense and transformative. His leadership, determination, and innovative strategies made him one of the most important figures in the history of the Indian freedom struggle.

14. CONCLUSION

The contribution of Subhas Chandra Bose to Indian independence was remarkable, multidimensional, and transformative. Unlike many leaders of his time, Bose adopted a bold and uncompromising approach toward achieving freedom. His belief in complete independence and his

readiness to use armed struggle distinguished him from other leaders such as Mahatma Gandhi, who emphasized non-violence. This diversity of strategies ultimately strengthened the Indian freedom movement.

Bose's leadership in organizing the Indian National Army and establishing the Azad Hind Government marked a significant shift in the struggle for independence. These efforts demonstrated that Indians were capable of self-governance and willing to fight for their freedom. His international diplomacy during World War II further highlighted his strategic vision and determination to challenge British authority on a global scale.

Although his methods and alliances remain subjects of debate, the psychological and political impact of his actions cannot be denied. Bose inspired a spirit of courage, unity, and sacrifice among Indians, which played a crucial role in weakening British control. The activities of the INA and the public response to its trials significantly accelerated the process of independence.

In conclusion, Subhas Chandra Bose's legacy lies not only in his military efforts but also in his ability to ignite a powerful sense of nationalism. His contributions remain an integral part of India's history and continue to inspire future generations toward patriotism and self-reliance.

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CYBER LAW AND CYBER CRIMES – A COMPREHENSIVE STUDY

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ABSTRACT

Cyber law has become an essential branch of legal studies in the modern digital era, where technology influences almost every aspect of human life. With the rapid growth of the internet and digital communication, cyber crimes have emerged as a major threat affecting individuals, organizations, and governments worldwide. This paper provides a comprehensive study of cyber law and cyber crimes, highlighting their nature, types, legal framework, and challenges in enforcement. Cyber crimes include a wide range of illegal activities such as hacking, identity theft, cyber fraud, phishing, data breaches, cyberstalking, and online harassment. These crimes are often difficult to detect and investigate due to the anonymity and global reach of cyberspace. The study also examines the role of cyber laws in regulating digital activities and ensuring security in online environments. Special emphasis is given to the Information Technology Act, 2000 in India, which serves as the primary legislation dealing with cyber-related offenses. Furthermore, the paper discusses the importance of cybersecurity awareness, preventive measures, and international cooperation in combating cyber threats. It concludes that while legal provisions are necessary, a combined approach involving legal, technological, and social strategies is required to effectively address cyber crimes.

INTRODUCTION

In the 21st century, the advancement of information technology has revolutionized the way people communicate, conduct business, and access information. The internet has become an integral part of daily life, enabling instant connectivity and convenience. However, this rapid digital transformation has also led to the emergence of cyber crimes, which pose serious risks to individuals, organizations, and national security.

Cyber law refers to the set of legal rules and regulations that govern activities conducted in cyberspace. It addresses issues related to digital transactions, online privacy, data protection, and cyber crimes. The need for cyber law arises from the fact that traditional legal systems are often inadequate to deal with offenses committed in the virtual world. Cyber crimes are unlawful acts carried out using computers, networks, or digital devices. These crimes can be broadly categorized into crimes against individuals, property, and government. For example, hacking and identity theft target individuals, while data breaches and intellectual property theft affect organizations. Cyber terrorism and attacks on critical infrastructure pose threats to national security.

In India, the Information Technology Act, 2000 was enacted to provide legal recognition to electronic records and to address cyber crimes. Despite the existence of such laws, the dynamic and evolving nature of technology makes it challenging to effectively regulate cyber activities.

This paper aims to provide a detailed analysis of cyber law and cyber crimes, their types, legal provisions, challenges in enforcement, and measures to prevent such crimes.

TYPES OF CYBER CRIMES

Cyber crimes have evolved significantly over the years and can take various forms. One of the most common types is hacking, which involves unauthorized access to computer systems or networks. Hackers may steal sensitive information, disrupt services, or cause financial loss. Another major category is identity theft, where personal information such as bank details, passwords, or identification numbers are stolen and misused. Phishing is a related offense in which fraudulent emails or websites are used to trick individuals into revealing confidential information.

Cyber fraud includes online scams, financial frauds, and fake transactions that exploit users' lack of awareness. Cyberstalking and online harassment involve threatening or intimidating individuals through digital platforms, often causing psychological distress. Data breaches are also a significant concern, where unauthorized access to databases results in the leakage of confidential information. Additionally, cyber terrorism involves attacks on critical infrastructure, government systems, or national security networks. These diverse forms of cyber crimes highlight the need for strong legal frameworks and effective enforcement mechanisms.

LEGAL FRAMEWORK FOR CYBER LAW

The legal framework for cyber law plays a crucial role in regulating digital activities and preventing cyber crimes. In India, the Information Technology Act, 2000 serves as the primary legislation governing cyber-related issues. It provides legal recognition to electronic records and digital signatures, enabling secure online transactions.

The Act also defines various cyber offenses and prescribes penalties for activities such as hacking, data theft, identity fraud, and cyber terrorism. Amendments to the Act have further strengthened its provisions to address emerging cyber threats.

Apart from the IT Act, other laws such as the Indian Penal Code, 1860 and the Evidence Act are also applicable in cases involving cyber crimes. These laws are used in conjunction with cyber law provisions to ensure comprehensive legal coverage.

Internationally, organizations and agreements play a key role in combating cyber crimes. Cooperation between countries is essential due to the borderless nature of cyberspace.

CHALLENGES IN CYBER LAW ENFORCEMENT

Despite the existence of legal frameworks, enforcing cyber law remains a significant challenge. One of the primary issues is the anonymity of cyber criminals, which makes it difficult to identify and track offenders. Additionally, cyber crimes often involve multiple jurisdictions, complicating legal proceedings. The rapid pace of technological advancement also poses challenges, as laws may become outdated quickly. Law enforcement agencies often lack the technical expertise and resources required to investigate complex cyber cases. Another challenge is the lack of awareness among users about cybersecurity practices. Many individuals fall victim to cyber crimes due to negligence or lack of knowledge.

Addressing these challenges requires continuous updates to legal frameworks, capacity building, and public awareness initiatives.

PREVENTIVE MEASURES AND SOLUTIONS

Preventing cyber crimes requires a proactive approach involving individuals, organizations, and governments. Users should adopt safe online practices such as using strong passwords, enabling two-factor authentication, and avoiding suspicious links or emails. Organizations must implement robust cybersecurity measures, including firewalls, encryption, and regular security audits. Employee training programs can help reduce the risk of cyber attacks. Governments play a crucial role in strengthening cyber laws, improving law enforcement capabilities, and promoting international cooperation. Public awareness campaigns and digital literacy programs can also help in reducing cyber crime incidents. Overall, a combination of legal, technological, and educational measures is essential to effectively combat cyber crimes.

CONCLUSION

Cyber law is an essential tool in maintaining security and order in the digital world. The increasing reliance on technology has made cyber crimes more prevalent and sophisticated, posing serious threats to society. This study highlights the importance of strong legal frameworks, effective enforcement, and public awareness in addressing cyber crimes. While laws such as the Information Technology Act provide a solid foundation, continuous updates and improvements are necessary to keep pace with technological advancements. Collaboration between governments, organizations, and individuals is crucial in creating a secure cyberspace. In conclusion, cyber law will continue to evolve as technology advances. A comprehensive and proactive approach is required to ensure the safety and security of digital environments.

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- 6. Various academic journals on cyber law*



DIGITAL LEARNING AND ICT ADOPTION IN HIGHER EDUCATION: OPPORTUNITIES AND CHALLENGES

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ABSTRACT

The integration of Information and Communication Technology (ICT) has emerged as a transformative force in higher education, particularly in the context of digital learning. This study examines the adoption of ICT in higher education and analyzes the associated opportunities and challenges. The research is based on secondary data collected from government reports, policy documents such as the National Education Policy 2020, and publications from national and international organizations. The study adopts a descriptive and analytical approach, utilizing content and thematic analysis to interpret the data.

The findings indicate that ICT has significantly enhanced accessibility, flexibility, and the overall quality of the teaching-learning process. Digital platforms such as SWAYAM and the National Digital Library have expanded learning opportunities and promoted self-paced education. However, the study also identifies several challenges, including the digital divide, inadequate infrastructure, limited technical training for faculty, and issues related to internet connectivity. These challenges restrict the effective implementation of ICT, particularly in rural and under-resourced institutions.

The study concludes that while ICT holds substantial potential to improve higher education, its success depends on addressing structural and technological barriers. Strengthening infrastructure, enhancing digital literacy, and ensuring equitable access are essential for achieving sustainable and inclusive digital education.

KEYWORDS : DIGITAL LEARNING, INFORMATION AND COMMUNICATION TECHNOLOGY (ICT), HIGHER EDUCATION, E-LEARNING, ICT ADOPTION, EDUCATIONAL TECHNOLOGY, ONLINE LEARNING

1. INTRODUCTION

The rapid advancement of digital technologies has significantly transformed the landscape of higher education across the globe. In recent years, the integration of Information and Communication Technology (ICT) into teaching and learning processes has emerged as a critical component in enhancing educational quality, accessibility, and efficiency. Digital learning, supported by ICT tools such as Learning Management Systems (LMS), virtual classrooms, e-content platforms, and online assessment systems, has redefined traditional pedagogical approaches and introduced more flexible and student-centered learning environments.

In the Indian context, the adoption of ICT in higher education has gained considerable momentum, particularly in the aftermath of the COVID-19 pandemic, which necessitated a sudden shift from conventional classroom teaching to online modes of instruction. This transition highlighted both the potential and limitations of digital learning systems. Recognizing the transformative role of

technology in education, the National Education Policy 2020 places strong emphasis on the integration of ICT to promote digital literacy, improve learning outcomes, and ensure equitable access to quality education. Government initiatives such as SWAYAM, DIKSHA, and the National Digital Library have further accelerated the process of digitalization in higher education.

Despite these developments, the implementation of ICT in higher education is not without challenges. Issues such as inadequate infrastructure, limited access to digital devices, poor internet connectivity, and lack of technical training among faculty members continue to hinder effective adoption. Moreover, disparities between urban and rural institutions contribute to an uneven distribution of digital resources, thereby raising concerns about inclusivity and equity.

In this context, it becomes essential to critically examine both the opportunities and challenges associated with digital learning and ICT adoption in higher education. The present study aims to analyze the extent of ICT integration, explore its benefits in enhancing the teaching-learning process, and identify the key barriers that affect its successful implementation. By providing a comprehensive understanding of these aspects, the study contributes to ongoing discussions on the role of technology in shaping the future of higher education.

2. REVIEW OF LITERATURE

A substantial body of literature has examined the role of ICT in transforming educational systems and enhancing learning outcomes. Previous studies indicate that the integration of digital technologies in education significantly improves accessibility, flexibility, and student engagement. According to reports by UNESCO, ICT-enabled learning environments facilitate inclusive education by providing opportunities for learners to access high-quality educational resources regardless of geographical constraints. Digital platforms enable self-paced learning, thereby accommodating diverse learning needs and preferences.

Research studies have also highlighted the positive impact of ICT on teaching methodologies. The use of multimedia tools, virtual simulations, and online collaborative platforms has been found to enhance the effectiveness of instruction and promote active learning. Furthermore, ICT integration supports the development of critical thinking, problem-solving abilities, and digital competencies among students, which are essential skills in the modern knowledge-based economy.

However, several studies have pointed out significant challenges in the adoption of ICT in higher education. Reports by the World Bank emphasize the persistent issue of the digital divide, particularly in developing countries, where access to reliable internet connectivity and digital devices remains limited. This disparity creates unequal learning opportunities and restricts the benefits of digital education to certain sections of society. Similarly, research based on AISHE data indicates that while the number of higher education institutions in India has increased, the availability of adequate ICT infrastructure varies considerably across regions.

Another major challenge identified in the literature is the lack of technical proficiency and training among faculty members. Studies suggest that many educators face difficulties in adapting to digital teaching tools, which affects the quality of online instruction. Resistance to change and preference for traditional teaching methods further complicate the process of ICT adoption. Additionally,

concerns related to data privacy, digital fatigue, and reduced face-to-face interaction have also been discussed as emerging issues in digital learning environments.

The National Education Policy 2020 acknowledges these challenges and emphasizes the need for capacity building, infrastructure development, and policy support to ensure effective ICT integration. While existing studies provide valuable insights into the benefits and limitations of digital learning, there remains a need for comprehensive analysis that combines both opportunities and challenges in a unified framework.

In this regard, the present study seeks to bridge this gap by providing a balanced evaluation of ICT adoption in higher education, focusing on both its transformative potential and the practical barriers to its implementation.

3. OBJECTIVES OF THE STUDY

- To examine the adoption of ICT in higher education
- To analyze the opportunities of digital learning
- To identify the challenges in ICT implementation
- To evaluate the effectiveness of ICT in education

4. RESEARCH METHODOLOGY

This study is descriptive and analytical in nature and is based on secondary data. Data has been collected from government reports, research articles, and policy documents including the National Education Policy 2020. Additional data sources include AISHE reports, UDISE+, and publications from UNESCO and the World Bank. The collected data has been analyzed using content analysis and thematic methods to identify key opportunities and challenges associated with ICT adoption in higher education.

5. ICT ADOPTION IN HIGHER EDUCATION

The adoption of Information and Communication Technology (ICT) in higher education in India has witnessed significant growth in recent years. According to the All India Survey on Higher Education (AISHE), India currently has more than 1,100 universities and over 43,000 colleges, many of which have gradually integrated digital technologies into their teaching and administrative processes. Reports from the Ministry of Education indicate that approximately 70 percent of higher education institutions have adopted some form of ICT-enabled teaching, particularly after the COVID-19 pandemic, which accelerated the shift toward online learning.

Government initiatives have played a crucial role in promoting ICT adoption. Platforms such as SWAYAM have enabled over one crore learners to enroll in online courses, thereby expanding access to quality education. Similarly, initiatives like DIKSHA, the National Digital Library, e-Pathshala, and Virtual Labs have contributed to the digital transformation of education by providing accessible learning resources and virtual experimentation facilities. These developments reflect a strong policy push under the National Education Policy 2020, which emphasizes the integration of technology in education to improve quality, accessibility, and equity.

Despite these advancements, the level of ICT adoption varies significantly across institutions and regions. While urban institutions tend to have better access to digital infrastructure, rural and

underdeveloped areas still face limitations, highlighting the uneven nature of technological integration in higher education.

Table 1: ICT Infrastructure & Adoption in India

Indicator	Data (Approx.)	Source
Total Universities	1,100+	AISHE Report
Total Colleges	43,000+	AISHE Report
Institutions using ICT tools	~70%	Ministry of Education
Students enrolled in online courses	1+ crore	SWAYAM
Digital platforms launched	5+ major platforms	Govt. of India

Table 2: Major Government ICT Initiatives

Initiative	Description	Purpose
SWAYAM	Online courses platform	Access to free education
DIKSHA	Digital learning portal	Teacher & student support
National Digital Library	E-resources platform	Academic access
e-Pathshala	Digital textbooks	School & higher education
Virtual Labs	Online lab experiments	Practical learning

6. OPPORTUNITIES OF ICT IN EDUCATION

The integration of ICT in higher education has created numerous opportunities that enhance the overall teaching and learning experience. One of the most significant advantages is improved accessibility, as digital platforms enable students to access educational resources at any time and from any location. This has been particularly beneficial for learners in remote areas, aligning with the vision of inclusive education emphasized in the National Education Policy 2020.

Another important opportunity is the flexibility offered by digital learning. ICT tools allow students to learn at their own pace, revisit recorded lectures, and engage with course materials according to their individual learning needs. Government-supported platforms such as SWAYAM have played a key role in facilitating self-paced learning and expanding educational reach.

ICT also enhances the quality of learning through interactive and multimedia-based teaching methods. The use of videos, simulations, and virtual laboratories makes complex concepts easier to understand and increases student engagement. Furthermore, ICT contributes to the development of essential digital and technical skills, which are increasingly important in the modern workforce. Reports from UNESCO and the World Bank emphasize that ICT-based education supports skill development, critical thinking, and lifelong learning.

In addition, ICT reduces the cost of education by minimizing the need for physical infrastructure and printed materials. Digital resources, online libraries, and e-content platforms provide cost-effective alternatives, making education more affordable and scalable.

Overall, ICT presents a transformative opportunity for higher education by improving accessibility, flexibility, engagement, and skill development. However, the extent to which these benefits are realized depends on effective implementation and the availability of supporting infrastructure.

7. FINDINGS OF THE STUDY

The analysis of secondary data indicates that the adoption of Information and Communication Technology (ICT) in higher education has expanded significantly in recent years, driven by policy initiatives and technological advancements. Government reports and institutional data suggest that a substantial proportion of higher education institutions in India have incorporated digital tools into their teaching and administrative processes. Platforms such as SWAYAM, the National Digital Library, and other digital initiatives have contributed to increased access to educational resources, thereby promoting inclusive learning opportunities.

The study finds that digital learning has enhanced flexibility in the teaching-learning process. Students are able to access course materials at their convenience, engage with multimedia content, and participate in online learning environments that support self-paced education. This shift has also encouraged the development of critical thinking, problem-solving abilities, and digital competencies, which are essential in the contemporary knowledge-based economy. Faculty members, in turn, have increasingly adopted ICT-enabled pedagogical practices, including virtual classrooms, online assessments, and interactive learning tools.

However, despite these positive developments, the findings reveal several persistent challenges that hinder the effective implementation of ICT in higher education. One of the most significant issues identified is the digital divide, which continues to create disparities in access to technology between urban and rural regions. Institutions in remote areas often lack adequate infrastructure, including reliable internet connectivity and access to digital devices, thereby limiting the reach and effectiveness of digital learning initiatives.

In addition, the study highlights the lack of sufficient training and technical support for faculty members as a major barrier to ICT adoption. Many educators face difficulties in adapting to digital teaching methods, which affects the quality of instruction and student engagement. Furthermore, resistance to change and a continued preference for traditional teaching approaches have slowed the pace of technological integration in some institutions.

Another important finding is that while ICT has the potential to reduce the cost of education and improve efficiency, its benefits are not uniformly distributed. The effectiveness of digital learning largely depends on the availability of supportive infrastructure, institutional readiness, and digital literacy among users. Overall, the study suggests that although ICT adoption has progressed considerably, its full potential remains underutilized due to structural and operational challenges.

8. CONCLUSION

The present study provides a comprehensive analysis of digital learning and ICT adoption in higher education, highlighting both its transformative potential and the challenges associated with its implementation. The findings demonstrate that ICT has emerged as a powerful tool for enhancing accessibility, flexibility, and quality in the teaching-learning process. Government initiatives and policy frameworks, particularly the National Education Policy 2020, have played a crucial role in promoting the integration of digital technologies in education. At the same time, the study underscores that the effective utilization of ICT is contingent upon several critical factors, including infrastructure availability, digital literacy, and institutional preparedness. Persistent issues such as the digital divide, inadequate technical support, and limited training opportunities for faculty

members continue to pose significant challenges. These barriers not only affect the quality of digital education but also raise concerns regarding equity and inclusivity.

The study concludes that while ICT has the capacity to transform higher education, its successful implementation requires a balanced and strategic approach. Policymakers and educational institutions must focus on strengthening digital infrastructure, providing continuous training for educators, and ensuring equitable access to technological resources. Addressing these challenges is essential for maximizing the benefits of digital learning and achieving the broader objectives of quality and inclusive education.

In conclusion, ICT represents both an opportunity and a challenge for higher education. Its future impact will depend on how effectively institutions adapt to technological changes and overcome existing limitations. Further research may focus on empirical analysis and region-specific studies to provide deeper insights into ICT adoption and its long-term implications.

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CAN AI INCREASE INDIA'S GDP? TOWARD VIKSIT BHARAT @2047: AN ECONOMIC ANALYSIS

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ABSTRACT

India's aspiration to attain developed nation status under Viksit Bharat @2047 requires sustained high growth, productivity enhancement and structural transformation. In this context, Artificial Intelligence (AI) has emerged as a major technological force capable of influencing output, employment, innovation and governance. The present paper evaluates whether AI can significantly increase India's Gross Domestic Product (GDP) over the next two decades. The study is based on secondary data collected from reliable sources such as the World Bank, International Monetary Fund, Reserve Bank of India, Ministry of Statistics and Programme Implementation, NITI Aayog and reputed industry reports.

The analysis suggests that India possesses favourable preconditions for AI-led growth, including a large digital population, strong software capabilities, expanding digital payments infrastructure and a young labour force. AI can raise GDP through productivity gains, cost reduction, efficient resource allocation, improved logistics, better agricultural yields, financial deepening and creation of new digital industries. Sectoral analysis indicates high growth potential in agriculture, manufacturing, finance, healthcare, logistics and public administration. However, skill shortages, unequal digital access, cybersecurity risks, low research intensity and labour displacement concerns may reduce gains if left unaddressed. The paper concludes that AI can become an important growth accelerator for India, but economic benefits will depend on timely policy intervention, institutional readiness and inclusive capacity building. If strategically deployed, AI can contribute substantially to India's transition toward a developed economy by 2047.

KEYWORDS: ARTIFICIAL INTELLIGENCE; GDP GROWTH; INDIA ECONOMY; PRODUCTIVITY; VIKSIT BHARAT 2047

1. INTRODUCTION

India is presently among the fastest-growing major economies and is expected to remain a key driver of global growth in the coming decade (IMF, 2025). Yet, achieving developed nation status by 2047 requires a sustained increase in productivity, industrial competitiveness, human capital and innovation capacity. Traditional factors of growth such as labour and capital accumulation alone may not be sufficient. Technology-led productivity growth has therefore become central to India's long-term development strategy. Artificial Intelligence refers to systems capable of performing tasks such as learning, prediction, language processing, automation and data-based decision-making. Across the world, AI is transforming business models, production systems and public administration. It is increasingly viewed not merely as a technological tool but as a new factor influencing economic growth.

India has unique advantages in this transition. It possesses a large working-age population, a globally recognised IT services sector, expanding digital public infrastructure, rapid smartphone penetration and strong entrepreneurial activity. At the same time, India faces structural challenges such as informal employment, productivity gaps and unequal access to technology. Against this background, the present paper examines whether AI can significantly increase India's GDP and help realise the national objective of Viksit Bharat @2047. The study combines economic analysis with policy perspectives using secondary data from authentic sources.

2. LITERATURE REVIEW

Economic theory recognises technology as a major determinant of long-run growth. Solow (1956) argued that increases in productivity arising from technological progress explain a large share of economic expansion beyond labour and capital accumulation. Later endogenous growth models emphasised innovation, knowledge and research investments as internal drivers of growth.

Recent literature has placed AI within this tradition. PwC (2017) estimated that AI could add substantial value to the global economy by 2030 through productivity gains and increased consumption effects. The report identified China and North America as major beneficiaries, while emerging economies could gain through faster diffusion.

McKinsey Global Institute (2023) observed that generative AI and automation technologies may create a new productivity frontier by reducing time spent on routine cognitive tasks, improving decision systems and accelerating innovation. However, gains depend on organisational adoption and workforce readiness.

OECD (2024) found that AI can improve firm-level productivity, but aggregate gains may take time because adoption costs, regulation and skill mismatches delay transmission to the wider economy. The study also noted the risk of widening inequality if benefits remain concentrated in advanced firms.

For India, NITI Aayog (2018) proposed the #AIforAll strategy, identifying healthcare, agriculture, education, smart mobility and urban governance as priority sectors. The report argued that AI should be aligned with inclusive development rather than only commercial use.

World Bank (2025) studies on digital transformation indicate that countries with strong digital infrastructure and human capital are better positioned to convert technological adoption into GDP growth. India's digital payments ecosystem and growing internet base are considered positive indicators.

The literature therefore suggests three broad conclusions: first, AI can raise productivity and output; second, benefits are conditional on skills and institutions; third, developing economies like India can gain significantly if adoption is broad-based and policy supported.

3. METHODOLOGY

The present study is descriptive, analytical and policy-oriented in nature. It relies exclusively on secondary data obtained from official, credible and publicly available sources. Major sources

include the International Monetary Fund (IMF), World Bank, Reserve Bank of India (RBI), Ministry of Statistics and Programme Implementation (MoSPI), NITI Aayog, India Brand Equity Foundation (IBEF), OECD and reputed industry reports such as PwC and McKinsey Global Institute.

The study uses recent macroeconomic indicators such as GDP size, growth rates, digitalisation trends, sectoral structure and employment patterns to examine India's readiness for AI-led growth. Sector-wise analysis is conducted for agriculture, manufacturing, services, finance, logistics and governance. Data tables and graphs are used to interpret broad trends rather than establish narrow econometric causality.

THE ANALYTICAL FRAMEWORK IS BASED ON THE RELATIONSHIP:

AI Adoption → Productivity Improvement → Lower Cost / Higher Efficiency → Output Expansion → GDP Growth

In addition, labour market effects, innovation potential and policy readiness are considered. Since AI is a rapidly evolving technology, precise long-term forecasts vary across institutions. Therefore, the paper focuses on realistic directional trends supported by multiple sources. The limitation of the study is that it does not use primary survey data or firm-level econometric models. However, secondary macroeconomic evidence is sufficient for evaluating national-level growth prospects.

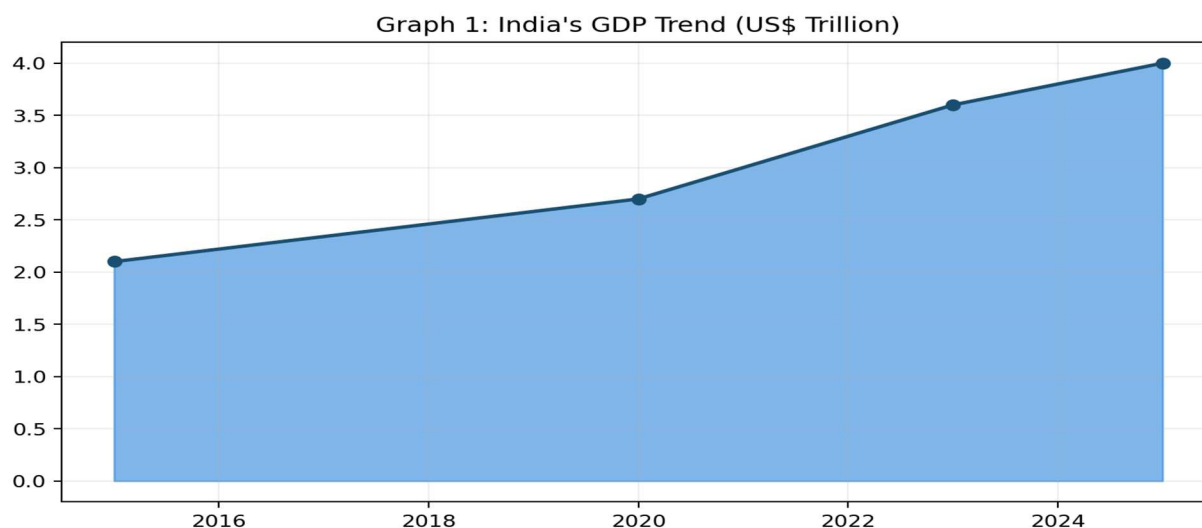
4. INDIA'S ECONOMIC POSITION

India enters the AI era from a position of growing economic strength. According to IMF estimates, India's nominal GDP crossed US\$4 trillion in 2025, making it one of the world's largest economies (IMF, 2025). Real growth has remained comparatively robust despite global slowdown pressures.

Table 1: Selected Economic Indicators of India

Indicator	Latest Estimate
Nominal GDP	US\$4 trillion+
Real GDP Growth	6%+
Population	1.4 billion+
Internet Users	800 million+
UPI Transactions	Highest globally

Source: IMF (2025), RBI (2025), World Bank (2025)



India also has a strong digital foundation. The expansion of Aadhaar, Unified Payments Interface (UPI), mobile connectivity and e-governance platforms has created a data-rich environment favourable for AI deployment. RBI (2025) notes that digital payments have expanded rapidly, reducing transaction costs and formalising segments of the economy. The country's demographic profile is another advantage. A large working-age population can support production growth if adequately skilled. India's established IT and software services sector further strengthens readiness for AI adoption through engineering talent, outsourcing experience and entrepreneurial ecosystems.

However, India's economic structure also reveals challenges. Agriculture still employs a significant workforce with relatively low productivity. Informal employment remains large and manufacturing productivity varies widely across firms. Regional inequality in digital access persists. Thus, India's current position may be described as a high-potential economy with strong scale advantages but uneven productivity. AI can help bridge these gaps if diffusion reaches both modern and traditional sectors.

5. AI SECTOR-WISE GDP IMPACT

AI can influence India's GDP most effectively when adopted across major productive sectors rather than confined to technology companies. Sectoral diffusion determines the aggregate growth outcome.

5.1 Agriculture

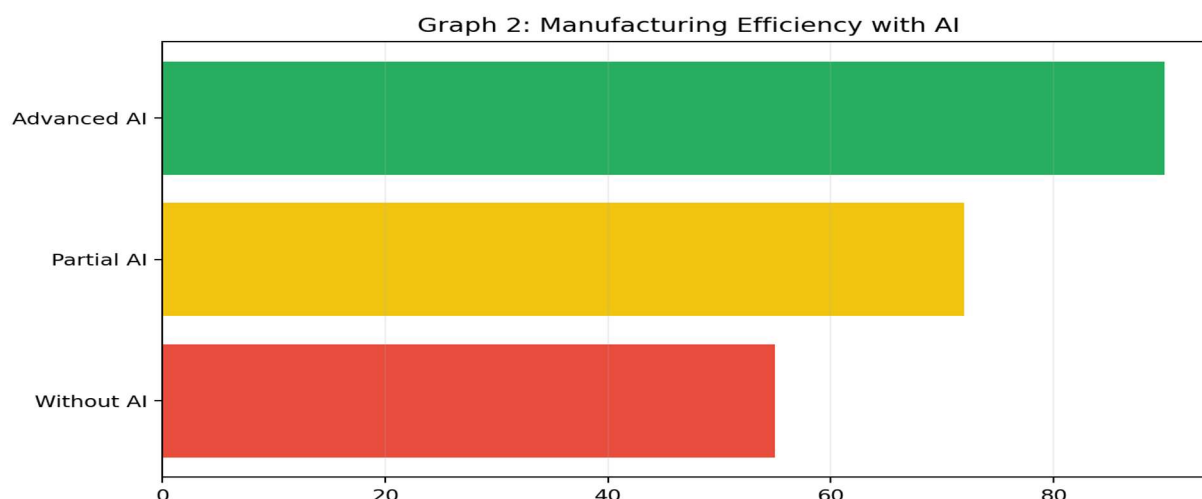
Agriculture supports a large share of India's labour force but contributes a lower share of GDP, reflecting productivity constraints. AI can improve farm economics through precision agriculture, weather forecasting, soil analytics, irrigation scheduling and pest detection. For example, satellite and sensor-based systems can guide fertiliser use and crop timing, reducing input waste. AI-supported market intelligence may also improve price realisation for farmers. Higher yields combined with lower costs increase farm incomes and rural demand, producing multiplier effects in the wider economy (FAO, 2023).

Table 2: AI in Agriculture

Application	Economic Benefit
Crop monitoring	Higher yield
Weather analytics	Lower risk
Input optimisation	Cost reduction
Market forecasting	Better prices

5.2 Manufacturing

Manufacturing is central to India's ambition to become a global production hub. AI-enabled manufacturing includes robotics, predictive maintenance, machine vision, demand forecasting and supply-chain optimisation. Large factories can reduce downtime through predictive maintenance systems that identify machine failures before breakdowns occur. Quality inspection through computer vision lowers rejection rates. Inventory optimisation reduces working capital costs. For India, even moderate productivity gains in manufacturing can significantly raise GDP because of the sector's strong backward and forward linkages. More competitive factories can also expand exports and reduce import dependence (IBEF, 2025).



5.3 Financial Services

India's financial sector has already undergone digital transformation. AI can deepen this progress through credit scoring, fraud detection, customer analytics, insurance pricing and regulatory compliance systems. Small borrowers often face information barriers. AI models using transaction histories and alternative data can expand credit access to MSMEs and households. Faster and more accurate lending decisions stimulate investment and consumption. Fraud detection systems reduce financial losses, while automation lowers service costs. These improvements raise financial efficiency and capital allocation quality—important determinants of GDP growth (RBI, 2025).

5.4 Logistics and Trade

High logistics costs have historically reduced India's competitiveness. AI can optimise routes, warehouse placement, fuel use, fleet management and demand forecasting. Better logistics lowers delivery time and inventory holding costs. Exporters benefit from more reliable supply chains. E-commerce growth also depends heavily on intelligent logistics systems. As trade efficiency improves, GDP gains emerge through larger market integration and lower business costs.

5.5 Healthcare

A healthier population is a more productive workforce. AI applications in healthcare include early diagnosis, imaging support, telemedicine triage, hospital scheduling and disease surveillance. India faces uneven access to specialists, especially in rural areas. AI-assisted screening tools can improve early detection of diseases while lowering pressure on tertiary facilities. Reduced illness burden raises labour productivity and household welfare.

5.6 Education and Skills

Human capital formation is essential for long-term GDP growth. AI-enabled learning platforms can personalise instruction, identify learning gaps and support multilingual education. India's scale makes traditional quality delivery difficult. Adaptive systems may help improve learning outcomes at lower marginal cost. Better education eventually raises employability, innovation and earnings.

5.7 Public Administration

Government efficiency directly influences economic performance. AI can improve tax compliance, traffic systems, welfare targeting, land records management and grievance redressal. Leakages in public schemes represent lost economic resources. More accurate targeting increases the productivity of public expenditure. Faster approvals and digital governance also improve ease of doing business.

Table 3: Governance Gains from AI

Area	Possible Economic Outcome
Tax analytics	Higher revenue
Subsidy targeting	Lower leakage
Urban traffic management	Time savings
Land record digitisation	Faster investment

5.8 Services and IT Exports

India's service sector contributes the largest share of GDP. AI can strengthen IT exports, business process management, design services, consulting and analytics. Rather than replacing India's IT advantage, AI can upgrade it. Firms offering AI integration, cloud management, data engineering and model governance may access new global demand (NASSCOM, 2024).

5.9 Aggregate GDP Effect

If AI adoption raises productivity even modestly across sectors, the cumulative GDP effect can be substantial. For example:

Agriculture productivity gain raises rural incomes

Manufacturing efficiency boosts exports

Finance improves investment allocation

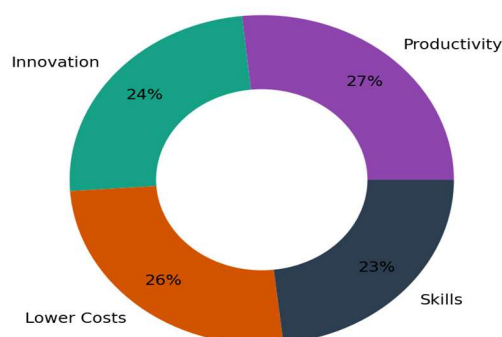
Logistics reduces economy-wide costs

Governance saves public resources

Education improves future labour quality

Thus, AI's largest value lies not in one industry but in economy-wide productivity enhancement.

Graph 3: Channels of GDP Impact



6. CHALLENGES

Despite strong potential, AI-led GDP growth is not guaranteed.

First, India faces a skill gap. Many workers lack digital literacy, advanced analytics training or technical capabilities needed in AI-enabled workplaces. Without large-scale reskilling, adoption may remain concentrated in a few sectors.

Second, the digital divide persists across regions, income groups and genders. If access to devices, internet and quality education remains unequal, AI may widen rather than reduce inequality.

Third, MSMEs often face cost barriers. Many small firms cannot easily invest in cloud systems, data infrastructure or specialised talent. Since MSMEs contribute significantly to employment, slow adoption here can limit national gains.

Fourth, data privacy and cybersecurity concerns may reduce trust in AI systems. Financial fraud, misuse of personal data and algorithmic bias can create economic and social costs.

Fifth, India's research intensity remains modest relative to advanced innovation economies. Limited R&D spending may slow indigenous model development and high-end technological leadership (UNESCO, 2023).

Sixth, labour displacement may occur in repetitive clerical or routine processing jobs. Transition costs can be socially significant if reskilling systems are weak.

Table 4: Constraints Summary

Challenge	Risk
Skill Gap	Low productivity gains
Digital Divide	Unequal benefits
High Cost	Slow diffusion
Privacy Risks	Low trust
Low R&D	Import dependence

Therefore, complementary reforms are essential for translating AI potential into GDP outcomes.

7. POLICY SUGGESTIONS

A nationwide mission should be introduced to integrate coding, analytics and digital reasoning from school education to higher education so that future workers are prepared for an AI-driven economy.

A dedicated reskilling fund should be established to support workers shifting from routine occupations to higher-value and technology-oriented jobs.

Special technology support should be provided to MSMEs through subsidised AI tools, cloud credits and professional advisory services to improve their competitiveness.

Rural digital infrastructure should be expanded through affordable broadband connectivity, access to digital devices and continuous training programmes.

Public and private expenditure on research and development should be increased by encouraging university-industry partnerships and innovation grants.

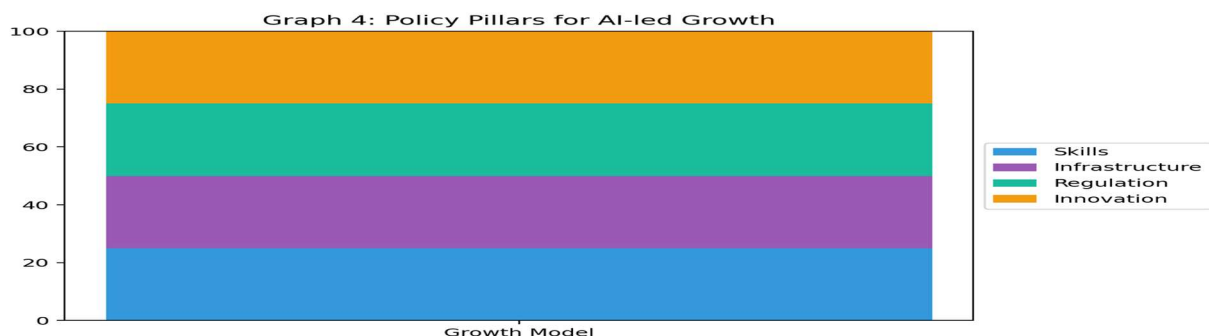
A responsible regulatory framework should be developed to ensure privacy protection, accountability and transparency in the use of AI systems.

Early deployment of AI should be prioritised in sectors such as agriculture, logistics, healthcare and public finance where social and economic returns are likely to be high.

An open public data ecosystem consisting of non-sensitive datasets should be promoted to encourage innovation, research and start-up growth.

Women and youth should receive targeted digital skilling opportunities so that labour-force participation and inclusive growth can improve.

Domestic technological capacity should be strengthened through investment in semiconductors, cloud systems and advanced computing infrastructure.



These measures ensure that AI functions as a productivity tool for the entire economy rather than only a benefit for large firms or metropolitan regions.

8. FINDINGS

The study generates six major findings. First, India possesses strong structural advantages for AI-led growth, including scale, digital public infrastructure and software capability. Second, AI can increase GDP primarily through productivity gains rather than simple job replacement. Third, agriculture, manufacturing, finance, logistics and governance present the highest near-term opportunities. Fourth, the aggregate impact of AI depends on broad diffusion across traditional sectors, not merely success of a few technology companies. Fifth, labour market disruption is manageable if reskilling and education systems respond in time. Sixth, policy quality will determine whether gains are inclusive or concentrated.

The evidence suggests that AI should be understood as a general-purpose economic technology similar to earlier waves of electrification or computing. Its benefits compound when adopted widely. For India, even modest sectoral productivity improvements can produce significant national output gains because of the economy's scale. However, failure to address digital inequality, skill shortages and innovation gaps may reduce benefits. Therefore, AI is neither an automatic solution nor a distant possibility—it is a strategic growth instrument requiring active policy direction.

9. CONCLUSION

India's journey toward Viksit Bharat @2047 requires a development model based on productivity, competitiveness, innovation and inclusion. Artificial Intelligence can play a significant role in this transition. The present study shows that AI has the capacity to increase India's GDP through multiple channels: higher agricultural productivity, smarter manufacturing, efficient finance, lower logistics costs, stronger governance and improved human capital. India is relatively well-positioned to benefit because it combines demographic scale, entrepreneurial dynamism, digital payments leadership and an established technology services base. These strengths create favourable conditions for rapid AI diffusion compared with many developing economies.

At the same time, AI is not a substitute for sound economic fundamentals. Without education reform, infrastructure expansion, labour reskilling, research investment and responsible regulation, gains may remain partial and unequal. The challenge is therefore institutional, not merely technological. From an economic perspective, AI should be treated as a multiplier of existing capabilities. Where governance is efficient, skills are strong and markets are competitive, AI can accelerate growth substantially. Where these conditions are weak, outcomes may disappoint. The central conclusion of the paper is that AI can significantly increase India's GDP, but only through strategic and inclusive adoption. If supported by timely policy and broad-based capacity building, AI can become one of the major engines driving India toward developed nation status by 2047.

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PSEUDOMONAS SPP.: A SCIENTIFIC OVERVIEW OF THEIR FUNCTIONAL ROLES IN SUSTAINABLE AGRICULTURE AND PHYTOPATHOGEN MANAGEMENT

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ABSTRACT:

Farming plays a significant role in improving the economy of a country. But the productivity of the crops is drastically reduced due to biotic factors such as pests, diseases, and nematodes because their infestation causes enormous suffering to the farmers. Depletion of soil fertility and environmental pollution has resulted from imbalances in fertilizer use, especially nitrogen and phosphorous, as well as the indiscriminate use of pesticides. A sustainable and eco-friendly solution to this problem is solved by PGPR (Plant growth-promoting rhizobacteria). Plant growth promotion and biocontrol of plant pathogens have been extensively explored in members of the genus *Pseudomonas* over the past two decades. *Pseudomonas* spp. beneficial effects range from nutrient solubilization to plant growth stimulation, biological control of insect pests and plant pathogens, and degradation of some organic and inorganic contaminants to heavy metal and pesticide bioremediation. *Pseudomonas* strains will play a critical role in sustaining crop output and soil health in the future decades, especially as global concerns about pollution and the production of pesticide-free organic foods develop.

KEYWORDS: PGPR, PSEUDOMONAS SPP., BIOCONTROL, SOIL FERTILITY, BIOREMEDIATION.

INTRODUCTION

Currently, the whole world is suffering from two severe concerns: the rising population and global warming. It is expected that the population of the world will reach ~9 billion in 2050 (Godfray et al. 2010), which creates extra pressure on food production, space, and the environment in improving living standards. On the other hand, the limited availability of land and depleting natural resources adversely affect the potential for increasing agricultural productivity (Ray et al. 2013). Therefore, to fulfill the requirements of food production, farmers continuously use huge amounts of fertilizers and pesticides in the field. Achieving the need for a growing population with limited resources without adversely affecting the environment is a major challenge for both farmers and researchers (Raaijmakers et al. 2009; Agaras et al. 2015). The use of agricultural by-products as biofertilizers, Phyto stimulators, and biocontrol agents together with appropriate crop management practices is an attractive choice in sustainable agricultural practices because of its eco-friendly nature or possibility to reduce the agrochemical applications (Adesemoye et al. 2009; Carvalho 2006). Recently, it is seen that during the production and storage of food and food materials, pest causes heavy loss of food grains which result in cost incensement. The challenges of disease management are so high that old strategies are not sufficient and should be improved. Plant disease management should strive to ensure food security and social stability by increasing crop productivity, reducing food contamination by microbial toxins, and guaranteeing the supply of diverse and reasonable A.

Kumar et al. 197 priced foods (Bahadur et al. 2014; Maurya et al. 2014; Jat et al. 2015; Kumar et al. 2015a; Ahmad et al. 2016; Meena et al. 2013a, 2016a; Parewa et al. 2014; Kumar et al. 2016b). In this context, an environment-friendly approach uses plant growth-promoting bacteria (PGPB) as one of the most effective and environmentally safe choices for the enhancement of plant growth and yield and/or for disease management (Compant et al. 2005; Kumar et al. 2015a, b).

RHIZOSPHERE AND THEIR INTERACTION WITH MICROBES

Plant growth in agricultural soils is influenced by many biotic and abiotic factors. Bacteria are the most abundant group of microorganisms coexisting with fungi, protozoa, and algae in the rhizosphere. Since bacteria are the most abundant microorganisms in the rhizosphere, they probably influence the physiology and competitiveness in root colonization in plants to a greater extent (Glick 2012). These effective colonizing microorganisms are classified according to the interactions with plants; these may be positive, negative, or neutral (Martinez-Viveros et al. 2010). Rhizobacterial species inhabit plant roots, and ex positive effects range from direct influence mechanisms to indirect effects during plant growth and development. Recently several PGPR isolates have used been as plant and soil inoculants for growth and disease management. These isolates belong to all the major families; some of the important species are *Pseudomonas*, *Azospirillum*, *Azotobacter*, *Klebsiella*, *Enterobacter*, *Alcaligenes*, *Arthrobacter*, *Burkholderia*, *Bacillus*, and *Serratia* which are broadly used plant-growth-promoting biocontrol agents (Joseph et al. 2007; Kumar et al. 2016b).

PSEUDOMONAS AS A PGP AGENT IN PLANT GROWTH

Nowadays the *Pseudomonas* species get high attention from the researcher in sustainable agriculture because of their contribution to growth promotion and induced systematic resistance (ISR) in plants through the different modes of action like suppression of plant diseases, improved nutrient acquisitions, and phytohormone production. *Pseudomonas* is an aerobic, gram-negative, Gamma proteobacteria, belonging to the family Pseudomonadaceae containing ~191 diversified species. Pseudomonads, due to metabolic versatility and genetic plasticity, are ubiquitous in the n soil ecosystem. They are common inhabitants of the rhizosphere of various agricultural crop plants wherein they play a major role in plant growth promotion and biocontrol agents that are made better suited for the growth, yields, and disease management of the plants (Lugtenberg and Kamilova 2009; Pathma et al. 2011; Jain and Pandey 2016; Kumar et al. 2016b). In the rhizospheric regions of plants, secreted of root exudates contain a large number of carbohydrates, lipids, and amino acids which act as chemoattractants for the microbes. The chemoattractant plays a significant role in microbial interaction.

It was concluded from the previous study that microbes showed strong chemoattractant toward particular carbohydrates or amino acids. In the case of tomato plants, *P. fluorescens* showed strong chemoattractants toward some amino acids like Cys, Gly, Ile, Lys, Met, Phe, Pro, and Ser which lead to effective root colonization (Oku et al. 2012) (Fig 1).

MECHANISM OF PSEUDOMONAS ACTION IN PLANT GROWTH PROMOTION

Plant growth-promoting bacteria (PGPB) enhance growth by making easily soluble phosphorus, nitrogen, and Fe (iron) from the insoluble non-diffusible form present in the soil. But currently, plenty of nutrients and minerals are present in the soil. To overcome the problems of insufficient

amount of nutrients, farmers are largely dependent upon the application of chemical fertilizers for the requirement of nitrogen and phosphorus in the soil. Continuous utilization of fertilizers adversely affects the texture and productivity of soil and also causes soil and water pollution which not only affects the environment or climate but also affects the health of human beings (Prakash and Verma 2016; Meena et al. 2015a, 2016b; Priyadharsini and Muthukumar 2016; Kumar et al. 2016a, 2017; Jaiswal et al. 2016; Jha and Subramanian 2016).

The mode of action of *Pseudomonas* is also common like other plant growth-promoting bacteria (PGPB). This involves complex mechanisms for growth and development. Recently many researchers use *Pseudomonas* sp. as plant or soil inoculants to enhance the growth and yields and for the modulation of secondary metabolite production. Kumar et al. (2016b) inoculates *Pseudomonas fluorescens* the yield and curcumin content of turmeric. Grobelak et al. (2015) utilized PGPR in case the of rape and fescue grass for the enhancement of the stem and root length. Hammami et al. (2013) used *Pseudomonas* strain Psf5, to control damping off disease in tomato seedlings caused by *Sclerotinia sclerotium* and also found significant increases in the plant stand as well as root dry weight of tomato. Goswami et al. (2013) also reported growth enhancement in chickpea and green gram after inoculation with the *Pseudomonas* sp. In another study, Manikandan et al. (2010) utilized liquid inoculants of *P. fluorescens* Pf1 to enhance the yield of tomato fruit, Fig. 7.1 An overview of *Pseudomonas* in plant growth and disease management A. Kumar et al. 199 and many more researchers utilized various strains of *Pseudomonas* sp. to enhance the growth and yields of various plant species as given in Table. The principal mechanism of growth promotion includes the Production of growth-stimulating hormones and solubilization and mobilization of phosphate, siderophores, ammonia, and HCN production (Whipps 2001; Idris et al. 2007; Richardson et al. 2009; Kumar et al. 2015a, b, 2016a, b).

PHOSPHATE SOLUBILIZATION

Phosphorus is one of the most essential and limiting macronutrients for plant growth. In nature, phosphorus is present in the form of rocks, but due to insoluble forms of phosphate, plants cannot be utilized. To reduce P deficiency and enhance crop production, frequent application of phosphate fertilizers is needed. The continuous application of phosphate fertilizers in the field may cause severe environmental problems and ALS increased the cost of crop production. Thus, solubilization and mineralization of phosphorus by phosphate-solubilizing bacteria are important traits of GPB (Richardson 2001). The solubilization of inorganic phosphorus occurs by the action of low molecular weight organic acids such as gluconic and citric acid, both of which are synthesized by various soil bacteria (Rodriguez et al. 2004; Kumar et al. 2016b; Raghavendra et al. 2016; Zahedi 2016; Meena et al. 2015b, f, 2016c, d; Rawat et al. 2016; Yasin et al. 2016; Saha et al. 2016a; Yadav and Sidhu 2016; Dotaniya et al. 2016).

SIDEROPHORE PRODUCTION

Iron is the most common element on earth and is required for the growth and synthesis of plants. In natural form, iron is present in ferric ion or Fe^{+3} , which is sparingly soluble; that's why this form is not utilized by both plants and microorganisms (Ma 2005). Both microorganisms and plants require a high level of iron and obtaining a sufficient amount of iron is more problematic. Bacteria synthesize siderophore molecules that have a high affinity for Fe^{+3} and act as chelating agents. It binds the Fe^{+3} molecules and made the insoluble to soluble and facilitates iron uptake by plants

and microorganisms (Hider and Kong 2010). Presently there are more than 500 known siderophores of which chemical structures of 270 have been determined (Meena et al. 2017). Siderophore-mediated competition for iron is one of the mechanisms responsible for the antagonistic activity of *Pseudomonas* sp. The secreted iron-chelating compound binds the Fe^{+3} taken up by microbial cells through specific membrane recognition (receptors), a membrane protein (Srivastava and Shalini 2008).

Table: The role of *Pseudomonas* in disease management

Bacteria	Plant	Impact of inoculation on plant	References
<i>Pseudomonas fluorescens</i>	Turmeric	Growth and curcumin content	Kumar et al. (2016b)
<i>Pseudomonas aeruginosa</i>	Tomato	Fruit yield	Dashti et al. (2012)
<i>Pseudomonas putida</i>	Tomato	Plant growth, yield	Shen et al. (2012)
<i>Pseudomonas putida</i> , <i>Pseudomonas fluorescens</i>	Rice	Grain iron	Sharma et al. (2013)
<i>Pseudomonas</i> sp., <i>Burkholderia caryophyllene</i>	Wheat	Growth and yield of wheat	Shaharoona et al. (2007)
<i>Pseudomonas</i> sp.	Maize	Compatible solutes, antioxidant	Sandhya et al. (2010)
PGPR	Soybean	Productivity	Salama et al. (2011)
<i>Pseudomonas aeruginosa</i>	Sesame	Growth and yield	Kumar et al. (2009a, b)
<i>Pseudomonas corrugata</i>	Maize	Grain yield	Kumar et al. (2007)
<i>Pseudomonas</i>	Wheat	Growth	Shaharoona et al. (2007); Zahir et al. (2009)
<i>Pseudomonas fluorescens</i>	Wheat	Seed yield and shoot dry mass.	Behn (2008)
<i>Pseudomonas fluorescens</i>	Mustard	Growth and yield attributes	Aeron et al. (2011)
<i>Pseudomonas putida</i>	Cherry	trees Fruit set, plant vegetative growth	Karakurt et al. (2011)
<i>Pseudomonas</i> sp.	Maize	Plant height, dry weight	Jarak et al. (2012)

Pseudomonas fluorescens	Catharanthus roseus	biomass yield and ajmalicine production	Jaleel et al. (2007)
PGPR	Cucumber	Root growth	Bae et al. (2007)
P. putida, P. fluorescens.	Spinach, Pepper	Plant heights	Hou and Oluranti (2013)
Pseudomonas spp.	Onion	Onion bud	Hartmann et al. (2009)
Pseudomonas	Tomato	Root growth	Belmont et al. (2007)
Pseudomonas fluorescens	Opium poppy	Morphine, thebaine, codeine	Bonilla et al. (2014)
P. fluorescens, Azospirillum brasilense	Marigold	Shoot fresh weight, root dry weight, leaf number, node number	Cappellari et al. (2013)
Pseudomonas putida, Pseudomonas fluorescens	Black henbane (Hyoscyamus niger)	Alkaloid yield and content	Ghorbanpour et al. (2013)
Pseudomonas putida	Maize	Grain yield	Dania and Moaveni (2011)
Pseudomonas fluorescens	Blackberries	Fruit quality	Garcia-Seco et al. (2013)

MODULATING PHYTOHORMONE LEVELS

Phytohormones play an important role in the growth and development of plants (Davies 2004). The plants grown under environmental stress often attempt to maintain the levels of their endogenous phytohormones to decrease the negative impacts of the environmental stressors (Salamone et al. 2005). IAA, gibberellins, and cytokinin are the most common plant hormones, required for the growth and development of plants, and their concentrations affect the morphogenesis of plants. PGPR secretes or is synthesized a significant amount of plant hormones and modulates the growth and synthesis of secondary metabolites (Kumar et al. 2015a, b; 2016b).

INDOLE ACETIC ACID

Indole-3-acetic acid (IAA) is the most common and studied auxin, which plays an important role in cell division, differentiation, and germination of seed and tubers controls vegetative growth and initiates lateral and adventitious root formation. Florescence affects photosynthesis, pigment formation, and biosynthesis of various metabolites in stress conditions (Spaepen and Vanderleyden 2011; Glick 2014). The response of IAA varies from species to species in the plant. Some of the plant species are sensitive to the IAA; it varies with the genotypes of the plants. In plant roots, endogenous IAA may be suboptimal or optimal for growth (Glick 2012).

ROLE OF PSEUDOMONAS IN DISEASE MANAGEMENT

Recently it is estimated that a huge amount of food commodities/crop loses annually due to diseases that are caused by fungus, nematodes, bacteria, etc. Plant diseases are a major factor

influencing food production and human societal development for thousands of years (Palmgren et al. 2015; Dun-chun et al. 2016). This efficient PGPB as biocontrol agents have certain advantages over conventional chemical control methods because PGPBs are nontoxic naturally occurring microorganisms, and their application is sustainable. Another advantage of PGPB is the diverse range of modes of action including antibiotic production, cell wall-degrading enzymes, biosurfactants, and volatiles' and also induces systematic resistance in plants (Perez-Montano et al. 2014). The term biocontrol is used for disease management that occurs during the plant growth stages and also during the storage of food. Studies on biocontrol of pathogens by Rhizobacteria usually focused on pathogenic microorganisms like weeds and insects (Flores-Fargas and O'Hara 2006; Siddiqui et al. 2005). Generally, cereals are mostly affected by soil-borne diseases concerning crops. The effective controls of diseases by using PGPR have been reported by many workers in different cereals and crops (Whipps 2001; Lucy et al. 005; Berg and Smalla 2009). Many of the bacterial strains have been identified and used as inoculants, which act as biocontrol agents in cereals. *Pseudomonas* is one of the most widely used groups of bacteria, which act as biocontrol agents in different plant species as described in Table 7.2. *Pseudomonas* as biocontrol research can be traced to totalization studies conducted at several laboratories with *P. fluorescens*, *P. putida*, *P. aeruginosa*, *P. syringae*, etc. that produce different antibiotics such as phenazine-1- carboxylic acid (PCA), 2,4-diacetylphloroglucinol (DAPG), pyrrolnitrin (PPRN), pyoluteorin (Plt), and neomycin A (Ligon et al. 2000; Raaijmakers and Weller 2001).

The genetic analysis of biocontrol resistance *Pseudomonas* indicated a positive correlation between disease separation and antibiotic production as in the disease of wheat caused by fungus *Gaeumannomyces graminis* var. *tritici* by antibiotic 2,4-diacetylphloroglucinol (2,4-DAPG), which suppress soilborne diseases and act as a biocontrol agent. *Pseudomonas syringae* strain 01 CE is a genetically modified strain that protects several crop plants from cold frost. The biocontrol potential of *Pseudomonas* an important agent to combat root and soilborne pathogens has been reported in many crops including chickpea, tomato, and wheat (Grover et al. 2009; Dashti et al. 2012; Perez-Montano et al. 2014). The earliest mechanism of biocontrol is the suppression of pathogens by secreting compound-like siderophores that efficiently sequester iron and deprive the pathogen of this element (Raaijmakers et al. 2002). The bacterial isolates inhibit the growth of pathogens through different mechanisms like by secreting antibiotics, toxins, and surface-active compounds (biosurfactants), by competition of minerals, and by secreting cell wall-degrading enzymes like chitinase and β -1, 3-glucanase (Haas and Defago 2005; Kumar et al. 2015a, b) and also through the production of metabolites which trigger the induction of systemic acquired resistance (Van Loon et al.1998).

Table; The role of *Pseudomonas* in disease management

Bacterial strain	Plants	Disease/Pathogen	References
<i>P. fluorescens</i>	Rice	Leaf folder insect and sheath blight disease	Kariba et al. (2010)
<i>P. fluorescens</i>	Rice	Rice blast disease	Lucas et al. (2009)
<i>Pseudomonas aeruginosa</i>	Sesame	<i>Heterodera cajani</i>	Kumar et al. (2009b)
<i>P. fluorescens</i>	Pigeon pea	Wilt disease	Kumar et al. (2010)
<i>Pseudomonas</i> sp.	Tomato	Blossom-end rot	Lee et al. (2010)

P. fluorescens	Cucumber	Cucumber root rot	Maleki et al. (2010)
P. fluorescens	Tomato	Bemisia tabaci	Shavit et al. (2013)
P. fluorescens	Pigeon pea	Heterodera Rajani	Meena et al., (2010)
Pseudomonas sp.	Tea	Blister blight disease	Saravanakumar et al. (2007)
P. fluorescens	Rice	Sheath rot disease (Sarocladium oryzae)	Saravanakumar et al. (2009)
P. fluorescens	Rice	Leaf folder pest	Saravanakumar et al. (2008)
P. fluorescens	Sugarcane	Sugarcane red rot	Senthil et al. (2011)
P. fluorescens	Tobacco	Tobacco mosaic virus	Shen et al. (2014)
P. fluorescens	Ground nut	Leafminer insect and collar rot pathogen	Senthilraja et al. (2013)
P. fluorescens	Tomato	Ralstonia solanacearum	Raza et al. (2016)
Pseudomonas strains	Cucurbit	Powdery mildew	Garcia-Gutierrez et al. (2012)
P. fluorescens	Mulberry	plant Root rot disease	Ganeshamoorthi et al. (2008)
Pseudomonas aeruginosa	Tomato	Cucumber mosaic virus CMV	Dashti et al. (2012)
Pseudomonas fluorescens	Mung bean	Root rot	Noreen et al. (2015)
Pseudomonas	Cucumber	Damping-off	Zohara et al. (2016)
Pseudomonas chlororaphis	Wheat	Antimicrobial	Jain and Pandey (2016)
P. fluorescens	Barley	Fusarium graminearum	Henkes et al. (2011)
P. fluorescens	Lupine	Fusarium solani	Howdy et al. (2011)
P. fluorescens	Chickpea	Fusarium oxysporum	Kandoliya & Vakharia (2013)
Pseudomonas rhodesiae	Pepper	Xanthomonas axonopodis	Kang et al. (2007)

MECHANISM OF BIOCONTROL BY PSEUDOMONAS STRAINS PRODUCTION OR SYNTHESIS OF ANTIBIOTICS

During past decades, numerous antibiotics have been isolated from various biocontrol strains representing different bacterial genera. Most of the antibiotics produced by bacterial biocontrol agents have a broad-spectrum activity. Antibiotics are organic, low molecular weight compounds that are deleterious to the growth or metabolic activities of other microorganisms (Fravel 1988; Raaijmakers et al. 2002). They act against various groups of microorganisms *Pseudomonas* sp. synthesizes pyrrolnitrin, DAPG like antibiotics acts against pathogenic fungi bacteria, helminths, etc. (Thomashow and Weller 1995; Raaijmakers et al. 2002). The production of antibiotics is modulated by both exogenous and endogenous factors; exogenous factors include both the biotic and abiotic factors (Shanahan et al. 1992). The addition of fertilizers, carbon sources and minerals

influence antibiotic production (Duffy and Defago 1999). The addition of glucose significantly enhanced the production of DAPG in *Pseudomonas* strains, whereas supplementation of phosphate fertilizer repressed the DPAG production of *Pseudomonas fluorescens* (Duffy and Defago 1999). It is reported in the previous study that bacterization of wheat seeds with *P. fluorescens* strains 2–79 resulted in significant suppression (~ 60%) of diseases in field trials (Weller 2007). *P. fluorescens* strain 2–79 and *P. chlororaphis* 30–84 produce anthranilic acid and strains 30–84 produce two other phenazines 2-hydroxyphenazine-1-carboxylic acid and 2-hydroxyphenazine as well as HCN, respectively, which act as a biocontrol agent (Pierson and Thomashow 1992). *P. fluorescens* strain CHA0 has isolated from the rhizosphere of tobacco 7 Role of *Pseudomonas* sp. in Sustainable Agriculture and Disease suppressive to black root rot of tobacco caused by *Thielaviopsis basicola* (Stutz et al. 1986). Strains CHA0 produce DAPG, Plt, Prn, HCN, pyochelin, pseudo action, and other bioactive metabolites (Voisard et al. 1994).

PRODUCTION OF CELL WALL-DEGRADING ENZYMES

One of the mechanisms used by biocontrol agents to control soilborne pathogens involves the production of cell wall-degrading enzymes (Kobayashi et al. 2002). Cell wall-degrading enzymes such as β -1, 3-glucanase, chitinase, cellulase, and protease secreted by biocontrol strains of PGPR exert a direct inhibitory effect on the hyphal growth of fungal pathogens (Bahadur et al. 2016a; Masood and Bano 2016; Meena et al. 2016e; Teotia et al. 2016). Chitinase and β -1, 3-glucanase degrade chitin, an insoluble linear polymer of α -1,4-N-acetylglucosamine (Labuschagne et al. 2010). *P. aeruginosa* and *P. fluorescens* have been found to have chitinolytic activities (Nelson and Sorenson 1999). Cell wall-degrading enzymes of rhizobacteria affect the structural integrity of the walls of the target pathogen (Budi et al. 2000). Someya et al. (2000) reported the chitinolytic and antifungal activities of a potent biocontrol strain of *S. marcescens* B2 against the soilborne pathogens *R. solani* and *F. oxysporum* (Saha et al. 2016b; Verma et al. 2014, 2015a, b; Meena et al. 2013b, 2014a; Sharma et al. 2016; Das and Pradhan 2016; Dominguez-Nunez et al. 2016).

PSEUDOMONAS IN INDUCED SYSTEMATIC RESISTANCE (ISR)

Pseudomonas strains protect the plants against pathogens through the induction of systematic resistance. Plants have the ability to acquire an enhanced level of resistance to pathogens after exposure to biotic stimuli provided by many different PGPR (Singh et al. 2015, 2016; Meena et al. 2013c, 2015d, e). This involves systematic resistance (induced systematic resistance (ISR) and systemic acquired resistance (SAR), which are activated by certain molecules secreted by microorganisms referred to as elicitors. Elicitors are generally cell wall polysaccharides, salicylic acid, cyclic lipopeptides, siderophores, antibiotics, and the signal molecule N-acyl homoserine lactones (AHLs) (Van loon 2007; Berg and Smalla 2009; Perez-Montano et al. 2014).

REGULATION OF PSEUDOMONAS FUNCTIONS BY SIGNALING MOLECULES

Many plants growth-promoting rhizobacteria (PGPR) exchange cell-to-cell communication signals between each other and regulate their gene expression in response to changes in population density with other rhizosphere-inhabiting bacteria and A. Kumar et al. 205 fungi in a process called quorum sensing (QS) which is mediated through small diffusible signal molecules, such as N-acyl homoserine lactones (AHLs) (PerezMontaño et al. 2014). In fluorescent pseudomonads, colonization, and biosynthesis of antimicrobial metabolite phenazines, QS regulation is AHL-based (De Maeyer et al. 2011).

INTERACTION OF PSEUDOMONAS WITH OTHER MICROBE IN RHIZOSPHERE

The rhizosphere is the most prominent habitat for a diverse group of microbes. These microbes interacted with each other and have a significant effect on the host plants. *Pseudomonas* is the most effective root colonizer present in both rhizospheres as well as within the tissue of plants. In the rhizosphere, microbes can have both beneficial and harmful effects on the plants. Plant species get benefits like phytohormone production, availability of nutrients, and abiotic tolerance through the mutualistic interaction with the microorganism in the rhizosphere. These benefits can be provided by different groups of microorganisms. Many studies examined the effect of co-inoculation with different groups of microbes in the soil or plants (Senthilraja et al. 2010; Hol et al. 2013). The co-inoculation of microbial species in the plant or soil may be *Pseudomonas* + fungi, *Pseudomonas* + other bacteria like *Bacillus* and *Azotobacter*, or *Pseudomonas* + different species of *Pseudomonas* (Domenech et al. 2006; Jaderlund et al. 2008). These multiple agents enhanced the possibility of better response in growth or biocontrol action in the plants due to the chance of better survivability of either of the strains in the applied environmental condition. It is also revealed from the previous study that co-inoculation of different microbial species is more effective than single inoculation for biocontrol (Whipps 2001; Hol et al. 2013). Akila et al. (2011) reported combined application of *P. fluorescens* and *Bacillus* sp. more effectively controls the *Fusarium* disease. Co-inoculation of *P. fluorescens* and *Azospirillum* stimulated the root growth in spring wheat (Combes-Meynet et al. 2011). The most common inoculation of fungi with *Pseudomonas* is the mycorrhizal fungi, used to improve plant growth and nutrition. Senthilraja et al. (2011) reported that combined use of *P. fluorescens* with *Beauveria bassiana* is more effective than a single application. In the case of interaction of *Pseudomonas* with other PGPR, *Bacillus* is the most common species. Garcia-Gutierrez et al. (2012) reported that the single or combined application of *P. fluorescens* with *Bacillus* is equally effective against bacterial and fungal pathogens. It is concluded from the previous study that combined introductions of *Pseudomonas* and other PGPR have been more beneficial in growth promotion and in biological control (Shrivastava et al. 2016; Velazquez et al. 2016; Sindhu et al. 2016; Meena et al. 2014b, 2015c; Bahadur et al. 2016b).

CONCLUDING REMARKS

In the current scenario, plant growth-promoting bacteria (PGPR) is one of the most suitable choices for plant growth promotion and disease management over the use of chemical fertilizers and pesticides. The rhizosphere is a large reservoir of bacteria, in which the *Pseudomonas* genus is most commonly found. The exudates of plant roots largely interact with the *Pseudomonas* species and help in root-colonizing activity. The beneficial effect of *Pseudomonas* includes plant growth promotion and biological control in the host plants. Besides this *Pseudomonas* strains have been broadly utilized in detoxifying certain organic and inorganic water pollutants (Wasi et al. 2011) and also in the bioremediation of heavy metals and pesticides (Lamire et al. 2010; Singh et al. 2011). The broad-spectrum rhizobacterial and endophytic strains of *Pseudomonas* can provide an effective, economical, and practical way of growth promotion, and plant protection, and also manage the environment from soil, air, and water pollution. Sustainable agriculture is the need of the world in recent times because of the adverse effect of chemicals used in agriculture. From the current study, it is recommended that *Pseudomonas* is one of the best choices as plant and soil inoculants and has been implemented for growth promotion and disease management.

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DIGITAL PUBLIC INFRASTRUCTURE (DPI) AND NEP 2020: A CRITICAL REVIEW OF COMMERCE EDUCATION IN BRIDGING THE FINANCIAL INCLUSION GAP

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ABSTRACT:

The research paper is a study conducted on understanding the relationship between Digital Public Infrastructure (DPI) and NEP 2020 in the context of financial inclusion. The research paper aims to study the relation between the execution of NEP 2020 and Digital Public Infrastructure (DPI), which would help in bridging the gap of financial inclusion. Here, the field of commerce is taken as particular. The objective of this study is fulfilled by using the secondary mode of data obtained through various government websites and other trusted sources by applying Karl Pearson's correlation coefficient and using graphs and schedules to have a clear and concise picture of the findings. The results achieved from this showed a very strong and supportive answer when talking about the relation between the implementation of NEP 2020, Financial Inclusion and development of DPI (Digital Public Infrastructure). Though there are many initiatives mentioned in the NEP 2020 for providing vocational education and interdisciplinary education but, there is no specific commerce-based model described in the whole policy. Therefore, the paper concludes by suggesting some real-time pragmatic practices that should be used by the government in order to enhance and integrate NEP 2020 more towards the stream of commerce and management. This is suggested through developing a simulation-based model or sandbox to gain hands-on experience for real-life professional problems and solutions.

KEYWORDS: NEP 2020, COMMERCE EDUCATION, FINANCIAL INCLUSION, DIGITAL PUBLIC INFRASTRUCTURE (DPI)

INTRODUCTION:

The dynamics of the world are changing rapidly across various domains and fields, and countries round the world are in the race of arriving at its earliest in fulfilling those goals. In this volatile global village, education too has become a part of this race, not of much significance but still playing a crucial part in the growth and development of the countries. Keeping the same in mind, the government launched the National Education Policy (NEP) in the year 2020 for the accomplishment of its economic as well as academic responsibilities. It aims for the holistic development of students along with faculties so that the faculties can reach the compatible level of teaching and not only develop the theoretical knowledge but also the qualities like communication, leadership and many more and get the students to come across the interdisciplinary approach of education along with providing knowledge aligned with the SDG goals. (Nayak & Nayak, 2025)

Before understanding and commenting about any concept, practice or approach, it is necessary to go through the fundamentals of it in the first place. Hence, the definitions and meaning of the fundamental and key points are given as below:

National Education Policy (NEP) 2020: ((SCERT), n.d.)

As defined by the State Council of Educational Research and Training (SCERT), “**The National Education Policy** is a comprehensive framework to guide the development of education in the country.”

Digital Public Infrastructure (DPI): ((ITU), n.d.)

Digital Public Infrastructure (DPI) refers to the foundational digital systems and technologies that support the delivery of public and private services to individuals and organizations. These systems are generally designed to be open, inclusive, and accessible, aiming to facilitate economic growth, social development, and enhance governance mechanisms.

Financial Inclusion: (Tay, Tai, & Tan, 2022)

Financial inclusion is known as a process of encouraging the accessibility and utility of formal financial services among public users and companies.

REVIEW OF LITERATURE:

(Bharvad & Bharvad, 2024)The authors of this study have discussed the NEP 2020's practical ramifications in light of the notable shifts in the field of commerce. In contrast to the conventional rote learning strategy, a dynamic approach has been presented that can assist students in acquiring the general practical abilities needed in any business in addition to domain-specific knowledge. The main conclusions of this study are about using an interdisciplinary approach to learning instead of the field-specific approach as stated in NEP 2020. However, the ability of faculty to create such a curriculum, provide the necessary resources and infrastructure, and grow faculty to keep up with the altered and advanced syllabus is limited. The paper also suggests adding industrial trainings, internships, etc. To promote hands-on training for the students.

(Rama, 2025)In order to bridge the gap between theoretical knowledge and grade-focused attitude to skill and implied knowledge, which can create an environment of job creators rather than job seekers, the research paper focuses on the impact of NEP 2020 in relation to the commerce and management field. This article addresses some of the main ideas and topics that are important for implementing the NEP 2020 in management and commerce curricula. FYUGP (Four-Year Undergraduate Programme), ABC (Academic Bank of Credit), inculcation of practical industrial training through internships and apprenticeships, workshops, expert sessions, hands-on training programmes, and many other noteworthy aspects have all been highlighted in an overview of NEP 2020. According to the text, in order to combine the necessary and learned abilities, the policy should emphasise experiential and objective-based learning. Since the article is theoretical, it also highlights some potential opportunities and difficulties that may arise when putting this policy into practice.

(Chaurasia & Tyagi, 2025)The authors of this paper discuss how NEP 2020 will be implemented in the field of commerce through methods such as transdisciplinary education. education given directly to students with the aid of practical experiences that can be obtained through internships and offering students an industry-centric curriculum that is intended to impart technical skills like critical thinking and problem-solving in addition to job opportunities. The study presents the primary data gathered from secondary sources using questionnaires and in-person interviews with individuals with extensive expertise in the business world. Tables and charts were used to display the data that had been gathered. Therefore, a summary of NEP, 2020's integration into the field of

trade has been covered in this paper, including some important points like the traditional commerce education and the one that was implemented after NEP, 2020, approaches and activities that are industry-oriented and provide employable mass, challenges in implementing the same, and limitations in gathering the data through primary data.

(Kulal, N., Dinesh, Bhat, & Girish, October 21, 2024) This essay sought to consider the viewpoints of various stakeholders in the NEP 2020's implementation, including educators, students, and the general public. Through questionnaires and interviews, an explanatory sequential mixed-method technique is used to comment on the potential and drawbacks of NEP, 2020. With 92 teachers, 256 students, and 12 topics spread throughout 40 colleges in the state of Karnataka, a sample size of 380 was considered. This practice led to the conclusion that there is room for improvement in the NEP, 2020, which would support SDG goal 4 of education and allow students to have multiple entry and exit systems going forward, thereby improving the Gross Enrolment Ratio (GER) from the students' point of view. Regarding educators and subject matter specialists, the NEP, 2020, can encourage the policy's execution, which would reinforce important aspects like the student-teacher ratio, infrastructure development, workload delegation, and many more. Overall, stakeholders have a favourable opinion of NEP 2020's implementation.

(Chopra, Sidana, & Arora, 2025) The study of the research paper is based on the development of DPI (Digital Public Infrastructure) in lieu of promoting financial inclusion. The authors have discussed the role of DPI in not only enhancing the level of financial inclusion in India but also its alignment with SDG (Sustainability Development Goal) 10, which is on eradicating inequality from all forms and fulfilling the vision of India in covering the major population under financial inclusion by Viksit Bharat @ 2047. In the implementation of the same, India has adopted a digital stack of 3 layers, which is identity, payments and data layers. On further study it was found that the financial inclusion done through Digital Public Infrastructure showed a positive relationship between these two variables. The study is based on the quantitative approach focused on econometric modelling to cover the effect of DPI on financial inclusion from 2004 to 2021. The research methodology was further divided into various components like two-stage PCA (Principal Component Analysis), ARDL (Autoregressive Distributed Lag) modelling, systematic testing process and model framework. From this, it was concluded that the distribution of the data was normal.

(Pandey & Thaker, 2025) The paper is a study conducted on the significant contribution made by the DPI (Digital Public Infrastructure) in digital financial inclusion. The data were analysed and collected through secondary sources of data like various government reports and case studies. Based on that, the study extends over the contributions made by Fintech companies in increasing financial inclusion with the help of DPI. The instances of e-KYC through PAN cards and Aadhaar cards have been quoted in this, showing the extent of digitalisation done till date and its future in enhancing the same with the use of advanced technology to promote more seamless and secured transactions, as the risk of fraud and digital theft has increased with the increase in the volume of transactions taking place on digital platforms offered by the Fintech companies like Zerodha and Paytm. The paper also portrays how the Government of India's India Stack, which includes Aadhaar, UPI (Unified Payment Interface), GST and Digi Locker in its version 1.0 and Account Aggregators, Open Network for Digital Commerce, Open Credit Enablement Network (OCEN), CBDC, National

Health, Agri and Logistics Stacks in its version 2.0, has taken a positive turn in the fulfilment of the objectives set by the government.

(Goel, 2020) The paper uncovers the impact of the Trinity initiative, i.e. Jan Dhan-Aadhar-Mobile banking, on financial inclusion, for which the primary data of 150 households are collected through a questionnaire in the Delhi region. The sample was further collected equally from low-class and high-class households, with 75 samples from each class. The study included factors like educational level, income class, age group and occupation. From this information, it was concluded that even after constant efforts put in by the government of India, factors such as the low level of education and trust level of people in government schemes stand as barriers to achieving the set objectives of the government.

(Devi, 2025) The paper comments on integrating the concept of financial literacy with that of NEP, 2020. It showcases the current status of India when compared with the global scenario. Hence, a 4-stage model has been prepared and presented by the researcher in the paper. Apart from this, the challenges that one may face while implementing the same have also been discussed over. Also, the recommendations in the form of Public-Private Partnerships (PPPs), faculty development and training programmes and digital integration are presented.

OBJECTIVES:

To understand the relation between DPI (Digital Public Infrastructure) and NEP 2020.

To find the extent of co-relation between DPI and NEP 2020

To provide relevant conclusions and suggestions for NEP 2020 in the context of DPI

RESEARCH METHODOLOGY:

The data collected for this research is from a secondary source, which includes the data and reports issued by various government bodies of national and international levels. A quantitative and descriptive approach of research methodology is adopted using statistical parameters like correlation using tools like Excel. The data are collected over a period of a decade so as to make a comparison between the data post and pre-NEP 2020 implementation. Official sources of websites like RBI (Reserve Bank of India), NPCI (National Payment Corporation of India), UIDISE+, UIDAI, etc. have been used to obtain the data.

As the data collected is found to be present in different scales, like percentages, absolute and index numbers, direct comparison does not become feasible. Therefore, the data is standardized through the index transformation technique. All of the data have been converted into a common scale which ranges from 0 to 100 index with the help of Min-Max Normalization. The formula for which is as follows:

$$X_{normalized} = \frac{X - X_{min}}{X_{max} - X_{min}} \times 100$$

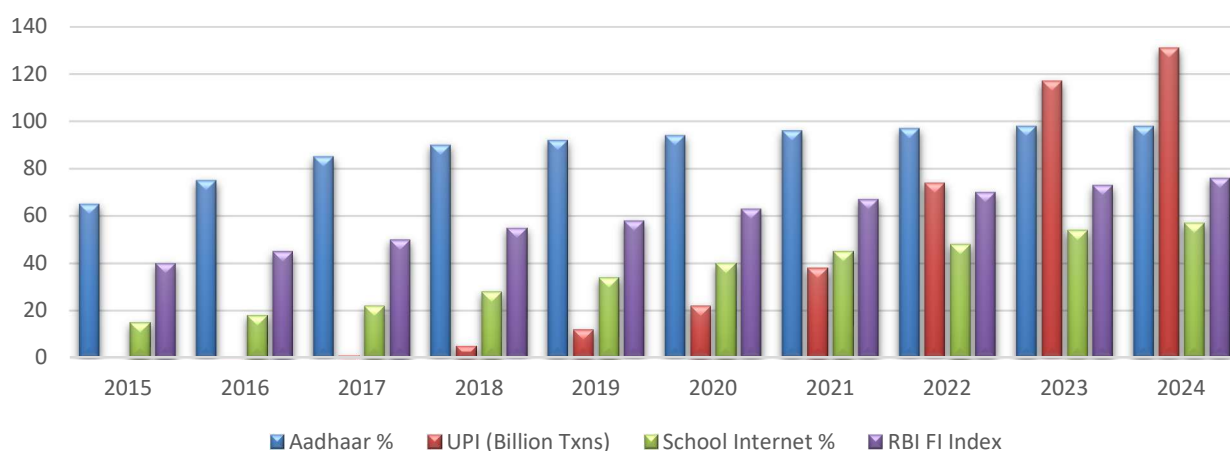
Here, X = value of data, X_{max} = Maximum value and X_{min} = Minimum value.

To study the quantitative data, Karl Pearson's correlation coefficient has been used for finding the correlation between the variables.

Analysis:

Year	Aadhaar %	Normalized value	UPI (Billion Txns)	Normalized value	School Internet %	Normalized value	RBI FI Index	Normalized value
2015	65	0	0	0	15	0	40	0
2016	75	30.3	0.1	0.08	18	7.14	45	13.89
2017	85	60.61	1	0.76	22	16.67	50	27.78
2018	90	75.76	5	3.82	28	30.95	55	41.67
2019	92	81.82	12	9.16	34	45.24	58	50
2020	94	87.88	22	16.79	40	59.52	63	63.89
2021	96	93.94	38	29.01	45	71.43	67	75
2022	97	96.97	74	56.49	48	78.57	70	83.33
2023	98	100	117	89.31	54	92.86	73	91.67
2024	98	100	131	100	57	100	76	100

Trends of Variables over a decade



The above is a summarized form of the data obtained through various government official sites that clearly shows that there is a constant positive growth in all the variables taken into account. The

rate of increase in Aadhaar penetration may not be significant, but an immense hike can be observed in other parameters like UPI transactions, School Internet and Financial Inclusion Index.

When the correlation was applied to these variables, the following data were obtained:

Relationship	Correlation (r)	Strength
Aadhaar ↔ FI	0.93	Very Strong
UPI ↔ FI	0.87	Strong
UPI ↔ Education	0.90	Very Strong
Aadhaar ↔ Education	0.88	Strong
Education ↔ FI	0.99	Very Strong

From the above information, it is crystal clear that there is a strong relation between all the variables under study. This states that the NEP 2020 has a direct and strong positive effect on the financial inclusion drive the government intends to achieve.

CONCLUSIONS AND SUGGESTIONS:

From the obtained data, it can be concluded that though the government is working on the development and enhancement of NEP 2020, there still lags a gap between the practicality and knowledge imparted in the commerce field. Hence, a suggestion of developing a practical model specifically for the field of commerce and management is presented over here. The government can inculcate the simulation-based applications and sandbox environment, enabling students to get hands-on experience without concerning themselves about the security and safety issues, such as those of the threat of fraud or digital theft.

The concepts and technological advancements in the form of digital currency (Digital Rupee Wallets, CBDC), the practice of AI in the fields of auditing and accounting and other interdisciplinary knowledge, like developing graphs and charts for data analysis through AI-based software like Julius AI and Tableau instead of technically and economically premium tools like SPSS, are suggested to be a part of students' curriculum. This will lead to bridging the gap between "what is taught" and "what is needed" in the real-world setting.

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A COMPARATIVE STUDY OF EMPLOYEE ENGAGEMENT IN WORK-FROM-HOME VS OFFICE- BASED WORK IN ANAND DISTRICT

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ABSTRACT

Traditional workplace structures have been drastically altered by the trend toward remote work. Employee engagement levels in work from home and office-based work environments are examined and compared in this study. The study assesses elements including productivity, communication, work-life balance, and job satisfaction using survey-based data and secondary research. According to the finding, office-based work fosters more organizational engagement and collaboration whereas WFH enables flexibility and better work-life balance. According to the study's finding, the strategy for increasing employee engagement might be a hybrid model. This study aims to assess the mediating effect of work-to-family positive spillover and work-life balance, as well as to develop and validate a theoretical model that explains job satisfaction in remote work impacted by family-supportive supervisory behaviors. Most of us are pushed to be perform more, faster, and with less resources in today's hectic workplace. The pressure to succeed seems to be greater than it has ever been. We are expected to be excellent parents and lead fulfilling personal lives in which we raise flawless children, enjoy our hobbies, contribute, and take excellent care of our bodies, souls, and brains while working two or three jobs. This study presents a comparative analysis of employee engagement in work-from-home and office-based work setting within Anand District. The primary objective is to examine how different work environments influence employee engagement levels, productivity, communication, and overall job satisfaction.

KEY WORDS: EMPLOYEES' ENGAGEMENT, WORK-LIFE BALANCE, JOB SATISFACTION, EMPLOYEES' PRODUCTIVITY

INTRODUCTION

Work from home

Key elements of Work from Home

Advantages include the ability to balance work and family life, no commute time, the possibility of increased productivity due to less office distractions, and cost savings on meals and travel.

Cons: dependency on home internet and technology, potential for social isolation, communication bottlenecks, and a blurring of work-life boundaries that results in overworking.

Perfect for: jobs requiring intense concentration, workers requiring adaptability and highly task-oriented tasks.

Office based work

Key Aspects of Office-Based Work

Benefits include enhanced teamwork, impromptu brainstorming, quicker networking, simpler management supervision, and clear "switching off" from work.

Cons: less flexibility, time and money spent commuting, and possible interruptions from coworkers.

Perfect for: Roles demanding strict confidentiality, cooperative initiatives, team development, and new hires in need of training.

Work-Life balance

Work-life balance means the balance between work and life. The amount of time you spend working vs spending time with friends, family and pursuing your interests is known as work-life balance. However, the phrase has recently come under scrutiny since it implies that our personal and professional lives are two distinct, competing domains that are always compete for our attention. We may unintentionally encourage negative attitudes about our personal or professional lives, such as feeling bad when we neglect one duty in favour of another.

As a result, some have started promoting the “work-life integration” or “the synergistic melding of our personal and professional commitments.”

According to this viewpoint, employment is just one of many facets of our life that must be considered into account in addition to other crucial issues like our homes, families, communities and personal wellbeing. Proponents contend each is essential to our survival and feeds the others.

Importance of work-life balance

Maintaining a healthy work-life balance can enhance your mental, emotional, and physical well-being. Long hours have been linked to major health problems such “poor sleep, depression, heavy drinking, diabetes, impaired cognition, and heart disease,” according to studies unfortunately, as these problems develop, they can also have an impact on our work-life balance, which can worsen the conditions itself and create a vicious cycle.

Long work hours may be linked to higher production by businesses and employees; however, many researchers disagree. For instance, a Stanford University and IZA study discovered that as employees reached a certain number of hours, their productivity started to decline as likelihood of errors and accidents rose.

LITERATURE REVIEW

1).(Shah et al., 2025)

The goal of the study is to examine the association between work-life balance and job satisfaction among middle-level female employees in Ahmedabad, India’s service industry. Design/ Methodology/Approach: A structured questionnaire was used to gather data using purposive sampling. The research divides workers into high- and low-level work-life balance categories using hierarchical cluster analysis.

Finding: The current study’s results are consistent with the job demands- resources paradigm.

The findings show a favourable correlation between higher Job satisfaction and higher work-life balance levels. Family care was the most important element affecting WLB, followed by individual expectations.

Research implications: HR professionals can use the practical insights this study offers to create gender- inclusive policies that improve employee happiness and retention in the service industry.

2). (Binaebi Gloria Bello et al., 2024)

The importance of work-life balance in contemporary organizational management has drawn the attention of human resources specialists, who are crucial in establishing workplace regulations. This essay offers a through analysis of the idea and how it affects modern businesses, with a focus on HR’s role in promoting a healthy work-life balance.

Rapid technological breakthroughs, globalization, and shifting societal expectations define the modern office environment, which affects how individuals view their personal and professional life. The success of an organization as a whole, job happiness, and employee well-being all depend on achieving work-life balance. Because work-life balance has a significant impact on corporate culture, productivity, and talent retention, the HR department plays a key role in developing

policies and programs that support it. This analysis examines several tactics used by HR professionals to improve work-life balance, such as telecommuting choices, flexible work schedules, and wellness initiatives. It explores the difficulties organizations encounter when putting these ideas into practice, including opposition from conventional workplace structure and the requirement to adjust to the varied demands of employees.

The study also highlights the benefits of effective work-life balance programs, including enhanced employees' engagement, less burnout, and enhanced company reputation. Additionally, taking into account the COVID-19 pandemic's effects on remote work patterns, shifting demographics, and integration of technology, the study explores the changing role of HR in navigating the dynamics terrain of work-life balance. It highlights the necessity for HR professionals to take a proactive stance, using data analytics and ongoing feedback system to customize policies to meet the various demands of workers. This HR-focused review concludes by highlighting the importance of work-life balance in contemporary organizations and professional domains, ultimately leading to improved employee well-being and organizational success.

3). (Brough & Paula, 2020)

The various definitions of work-life balance are reviewed in this chapter, including those that emphasize the equity of time spent in the work and non-work domains, satisfaction with performance/ time spent in each domain, and each role's importance to a person. Most people agree that a preferred definition should emphasize work-life rather than work-family in order to incorporate demands obligations that are not related to family, such education or travel commitments. The common causes and effects of work-life balance that arise from both the job and non-work domains are also covered in this chapter. Work demands and resources, family demands and resources, and personality antecedents, including data linking psychological capital to work-life balance, are among them. This chapter concludes by discussing the future directions for study on work-life balance, with an emphasis on individuals' levels of resilience and mindfulness as well as technological developments like Fitbits. The chapter's concluding highlights the growing body of research that connects an organization's work life balance culture to employee appointments and retention.

4). (Warren, 2021)

Given that technology has the capacity to either smooth or disrupt workplace gender equality, the paper questions "where are we" in the study of work-life balance within industrial relations and "where to next" if we to uncover levers for positive change.

How men and women from various social classes care for and work together. In order to identify shortcoming in the mainstream work-life balance agenda's overwhelming emphasis on the time constraints cited by middle-class workers who are financially comfortable and its disregard for financial issues, it first shines a classed lens on it. The study then examines the implications of the rise in gig labour for work-life balance through an improved conceptualization. Gig labour is marketed as providing freedom and independence, allowing caregivers to work while providing care, yet it is carried out without the safety precautions that are more typical in formal employment. Work-life balance may be impacted by financial difficulty, work intensity, and unpredictability in both work and income. In order to promote workplace gender equality for all "where to next" is creating a more inclusive strategy that acknowledges gender, class, and other forms of diversity.

5). (Veena Latha, 2019)

Most of us are pushed to perform more, faster, and with less resources in today's hectic workplace. The pressure to succeed seems to be greater than it has ever been. We are expected to be excellent

parents and lead fulfilling personal lives in which we are raise flawless children, enjoy our hobbies, contribute in the community, and take excellent care of our bodies, souls, and brains while working two or three jobs. The pursuit of balance is an admirable objective, but most people find it unachievable. Rather, it has turned into just another “to-do” in an ever-growing, guilt-inducing list. Sometimes we can take more time off, while other times we have to put in more work than usual. Some times we can devote more time to our interests and passions; other times, other priorities come first. Sometimes we take great care of ourselves, and other times we fall short; sometimes we give our family a lot of attention, and other times we don’t have as much time or energy to dedicate to them. The goal of balance is to lead a well-rounded existence and to consistently revitalize your creative energies in order to reach your full potential. When we have adequate time to pursue our passionate personal and professional interest, we are able to achieve life balance.

However, you may experience stress, a decline in productivity, and strained interpersonal connections if you believe that one aspect of your life is consuming too much of your energy. The risks of work-life imbalance, the advantages of a healthy work-life balance, and the tactics that may be used to preserve a perfect work-life balance are all highlighted in this paper.

6). (S. & S.N., 2023)

The purpose of this study is to identify research gaps in order to suggest future research opportunities and goals, as well as to improve an understanding of work-life balance (WLB) and its link with other types of work-related behaviour. Design, methodology, and approach: the current study aims to provide a through overview of the research conducted by the pioneers in the field of WLB and its associated issues. This systematic review contains 99 research studies in total. The research articles have been categorized according to the sector, methodology, geographic distribution, and year of publication. There is discussion of the numerous ideas and elements that have contributed significantly, the factors that affect WLB, its significance, and its Result: the study highlights the gaps in the literature and the potential for further study in the field of WLB.

The current study identified research gaps in the systematic review and classifications according to the industry under study, year of publication, research methodology, and demographics.

RESEARCH METHODOLOGY

Research problem

A Comparative Study of Employee Engagement in Work-from-Home vs Office-Based Work in Anand District

Scope of the study

This study focuses on analysing and comparing the level of employee engagement individuals working under work from home and work from office arrangements within Anand District of Gujarat.

Objectives of study

To measure the level of employee engagement in work from home settings and office-based settings

To evaluate how both work modes affect worker productivity

To make suggestions for enhancing participation

Nature of data

Primary data: employees’ direct responses to standardized surveys

Secondary data: information gathered about employee involvement and remote work journals, research papers, websites, and reports

Sampling Design

Population: Employees working in organizations in Anand District

Sample Size: The study included a total of 109 participants.

Sampling Technique: The sampling technique used for the present study is Convenient Sampling.

HYPOTHESIS

H0: There is no significant difference in employee engagement between employee working from home and those working in office-based.

H1: There is significant difference in employee engagement between employee working from home and those working in office-based.

H0: There is no significant correlation between employee engagement and productivity.

H2: There is significant correlation between employee engagement and productivity.

H0: There is no significant association between feel about work-life balance and employee working from home and those working in office-based.

H3: There is significant association between feel about work-life balance and employee working from home and those working in office-based.

DATA ANALYSIS AND INTERPRETATION

H0: There is no significant difference in employee engagement between employee working from home and those working in office-based.

H1: There is significant difference in employee engagement between employee working from home and those working in office-based.

T-Test

Group Statistics					
	Are you working from home or in an office?	N	Mean	Std. Deviation	Std. Error
Employee Engagement Scale	in an office	75	3.0347	.47120	.05441
	work from home	34	3.3353	.37730	.06471

Independent Samples Test									
		Levene's Test for Equality of Variances		t-test for Equality of Means					
		F	Sig.	T	Df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference
									Lower
									Upper
employee Engagement Scale	Equal variances assumed	1.445	.232	-3.272	107	.001	-.30063	.09187	-.48275
									.11851

	Equal variances not assumed			-3.556	78.633	.001	-.30063	.08454	-.46891	-.13234
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There is a statistically significant difference in employee engagement between those who work from home and those who work from in an office, according to the results of the independent sample t-test ($p < 0.05$).

Compared to office-based workers ($M = 3.03$), employees who worked from home reported higher levels of engagement ($M = 3.34$). Consequently, the null hypothesis is disproved.

H0: There is no significant correlation between employee engagement and productivity.

H2: There is significant correlation between employee engagement and productivity.

Correlations

Descriptive Statistics			
	Mean	Std. Deviation	N
Employee Engagement Scale	3.1284	.46390	109
Productivity Scale4	2.7156	.37495	109

Correlations			
		Engagement Scale	Productivity_Scale4
Employee Engagement Scale	Pearson Correlation	1	.555**
	Sig. (2-tailed)		.000
	N	109	109
Productivity Scale4	Pearson Correlation	.555**	1
	Sig. (2-tailed)	.000	
	N	109	109
**. Correlation is significant at the 0.01 level (2-tailed).			

The association between productivity and employee engagement was investigated using a Pearson correlation analysis.

The findings showed that employee engagement and productivity had a somewhat favourable link ($r = 0.555$, $p < 0.01$).

This suggests that production tends to arise in tandem with employee engagement. The link is statistically significant because the p-value is than 0.05.

As a result, the null hypothesis is disproved, and it can be said that productivity and employee engagement are significantly correlated.

H0: There is no significant association between feel about work-life balance and employee working from home and those working in office-based.

H3: There is significant association between feel about work-life balance and employee working from home and those working in office-based.

Chi-square

Are you working from home or in an office? * 1Do you generally feel you are able to balance your work-life balance? Crosstabulation
Count

	1Do you generally feel you are able to balance your work-life balance?		Total
	No	Yes	
Are you working from in an office	27	48	75
home or in an office? work from home	23	11	34
Total	50	59	109

Chi-Square Tests			
	Value	Df	Asymptotic Significance (2-sided)
Pearson Chi-Square	9.437 ^a	1	.002
Linear-by-Linear Association	9.350	1	.002
N of Valid Cases	109		
a. 0 cells (0.0%) have expected count less than 5. The minimum expected count is 15.60.			
b. Computed only for a 2x2 table			

The relationship between employees' perceptions of work-life balance and their form of work (working from home versus in an office) was investigated using a chi-square test of independence. The two variables were found to be statistically significantly correlated ($\chi^2(1) = 9.437$, $p = 0.002$). this suggests that an employee's work style has a big impact on their capacity to manage a work and personal obligations.

As a result, the alternative hypothesis is accepted and the null hypothesis is rejected.

LIMITATIONS OF STUDY

1. The study is confined to area of Anand District only
2. Due to time and resource limitations a limited sample size was used
3. Data collected through Google form may be subject to respondent's bias or inaccurate responses.

SCOPE FOR FURTHER RESEARCH:

Future studies can be extended beyond Anand District to other districts of Gujarat

The current study considers multiple sectors collectively like IT, Banking, Education, Manufacturing only so future research can focus on specific industries.

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A PRODUCTIVE MCR SYNTHESIS OF SUBSTITUTED IMIDAZOLE VIA CONDENSATION METHOD BY VARIOUS CATALYSTS & SOLVENTS

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ABSTRACT:

One pot multi component synthesis of 5-ethoxy-4-methyl (Substituted phenyl)-4-5-dihydro-1-H-imidazole is prepared by the ethyl acetoacetate type ketone, substituted aldehydes and ammonium acetate in Acid (Acetic acid used as catalyst) via condensation method because in such cases acetic acid is used as catalyst in reaction. The product is gluey therefore the experiment was to lessen the stickiness using approximately same molar ratio. In this experiment acetic acid is used as catalyst. In the course of the reaction the mass is automatically liquefied with the heat increasing at a constant rate under controlled systems. In this method the temperature rises steadily up to 80°C at continuous stirring for 2 to 3 hours. The diluted sulphuric acid is used as catalyst in case the product is not sticky but the yield is very negligible. In the reaction Ethanol and Acetone are used as solvents. Ethanol gave good yield when used as a solvent. All the synthesized moiety are proved by some analytical data as well as spectral data for confirmation of structure.

KEY WORDS: ETHYL ACETO ACETATE, AMMONIUMACETATE, ALDEHYDE, ACETIC ACID, SULPHURIC ACID

INTRODUCTION:

One pot multi component synthesis of 5-ethoxy-4-methyl (Substituted phenyl)-4-5-dihydro-1-H-imidazole is prepared by the ethyl acetoacetate type ketone, Substituted aldehydes and ammonium acetate in Acid (Acetic acid used as catalyst) via condensation method because in such cases acetic acid is used as catalyst in reaction. The product is gluey therefore the experiment was to lessen the stickiness using approximately same molar ratio. In this experiment acetic acid used as catalyst. In the course of the reaction the mass is automatically liquefied with the heat increasing at a constant rate under controlled systems. In this method the temperature rises steadily up to 80°C at continuous stirring for 2 to 3 hours. The diluted sulphuric acid is used as a catalyst in case the product is not sticky but the yield is very negligible. In the aforementioned reaction Ethanol and Acetone are used as solvents. Ethanol gave good yield when used as a solvent. Imidazole derivatives are widely applicable in biological activity. They possess anti-microbial, anti fungal properties. They play a very important role in the field of antihypertensive drugs as a central structural lead molecule. In most of the situations the Acetic acid is used as solvent but they can also act catalyst in this classes of reactions. But if we try different acid in lower concentrations (25% H₂SO₄) in water those acids also tend to react as catalysts. The reactions are in comparison of Strong acid activity and weak acid activity as well as solvent & catalyst. The ethanol and acetone was used as solvent for the reaction rate study because the Imidazole derivatives have many uses for the inorganic metal complex synthesis as well as catalysis and organo metallic compounds.

A one-pot, multicomponent synthesis of 5-ethoxy-4-methyl-(substituted phenyl)-4,5-dihydro-1H-imidazole was developed using ethyl acetoacetate, substituted aldehydes, and ammonium acetate. This study focuses on the comparative efficiency of acid catalysts and solvent systems in optimizing

yield and product consistency. While glacial acetic acid serves as an effective catalyst and medium, the resulting product often exhibits a gluey, high-viscosity texture. Experimental modifications were conducted to mitigate this stickiness by maintaining precise molar ratios and controlled thermal parameters.

The reaction proceeds via a condensation mechanism. Under a controlled system with continuous stirring, the reaction mass undergoes automatic liquefaction as the temperature is steadily increased to 80°C over a duration of 2 to 3 hours. The study further compared the catalytic efficiency of weak versus strong acids like Acetic Acid. Acetic Acid acted as both catalyst and solvent, providing significant yields but resulting in a sticky physical state. Diluted Sulphuric Acid, when employed as a catalyst in an aqueous medium, it reduced the stickiness of the final product; however, the resulting yield was negligible compared to the organic acid route. A comparative analysis between Ethanol and Acetone was performed. Ethanol was identified as the superior solvent, significantly enhancing the reaction rate and final yield.

SIGNIFICANCE AND APPLICATIONS

Imidazole derivatives are of paramount importance in medicinal chemistry due to their broad spectrum of biological activities, including antimicrobial and antifungal properties. Imidazole ring serves as a critical structural pharmacophore in the development of antihypertensive drugs. Beyond pharmacology, these derivatives are essential ligands in inorganic metal complex synthesis, organometallic chemistry, and homogenous catalysis. The synthesized 5-ethoxy-4-methyl-(substituted phenyl)-4,5-dihydro-1H-imidazole serves as a versatile polydentate ligand in coordination chemistry. The primary coordination centers are the nitrogen atoms within the dihydro-imidazole (imidazoline) ring. Specifically, the sp^2 hybridized imine nitrogen (N-3) possesses a high-density lone pair, making it a potent nucleophilic site for coordination with transition metal ions. In a typical coordination environment, these imidazole derivatives act as neutral N-donor ligands. When reacted with transition metals such as Cu^{+2} , Zn^{+2} , or Ni^{+2} , the imidazole ring facilitates the formation of stable chelate structures. For instance, in $Cu(II)$ complexes, the metal center often adopts a square-planar or distorted octahedral geometry, coordinated by the imidazole nitrogen's and auxiliary anions or solvent molecules. The electron-donating nature of the methyl group at the C-4 position further enhances the basicity of the ring nitrogen's, thereby increasing the stability constant of the resulting metal-ligand complexes. Steric and Electronic Influence of the 5-Ethoxy Group.

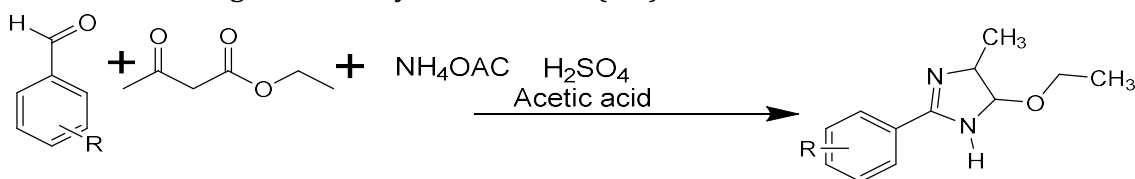
The presence of the 5-ethoxy ($-OCH_2CH_3$) group is a critical structural feature that distinguishes this molecule from simpler imidazole derivatives. This substituent exerts a dual influence on the coordination behavior. The ethoxy group is an electron-donating group (EDG) via the mesomeric (+M) effect. This increases the electron density within the heterocyclic ring system, making the nitrogen lone pairs more available for dative bonding with metal d-orbitals. This results in stronger Metal-Ligand (M-L) bonds compared to unsubstituted analogs. The bulky nature of the ethoxy group provides significant steric hindrance near the coordination site. This "steric bulk" can be strategically used to prevent the formation of polynuclear clusters, instead favouring the synthesis of discrete mononuclear complexes. Furthermore, the ethoxy group can influence the "bite angle" of the ligand, potentially leading to strained coordination geometries that are highly active in homogeneous catalysis. Simple coordination, these imidazole-metal complexes show great promise

in the field of Organometallic Chemistry. The dihydro-imidazole framework is a precursor to N-Heterocyclic Carbenes (NHCs). By deprotonating the C-2 position, these molecules can form exceptionally strong carbon-metal bonds, which are the backbone of modern catalysts used in cross-coupling reactions and olefin metathesis.

The synthesis of 5-ethoxy-4-methyl derivatives opens new avenues for bio-inorganic research. Given the antimicrobial nature of the imidazole core, its coordination with bioactive metals like Zinc or Silver could lead to synergistic effects, enhancing the therapeutic index of the drugs. Future studies will focus on the X-ray crystallographic characterization of these complexes to precisely determine the bond lengths and angles, providing deeper insight into the relationship between the 5-ethoxy substitution and the overall molecular stability. This one-pot synthesis, therefore, provides not just a chemical product, but a foundational building block for advanced materials science and medicinal inorganic chemistry.

Experimental method&materials: All the solvent and chemicals are purchased were industrial grade. It was further purified by crystalline method. The melting points were determined by melting point apparatus made by omega. TLC- plates made by Merck company. The spot is determined by the UV/iodine chamber. the IR spectrum by The SHIMAZU & NMR by the Bruker NMR instrument in the DMSO-*d*₆ as a solvent and NMR frequency is 400MHz. the mass spectra are determined by the Jeol SX-102 mass spectrometer. all structures are determined by the analytical data and spectrum data.

Experimental section: Ethyl acetoacetate and substituted aromatic aldehyde are mixed by stirring for 20 min till it dissolves completely. the aldehyde in the ethyl acetoacetate then add ammonium acetate and then stirred for 20 min till the solution is hazy then addition of different catalyst like acetic acid, sulphuric acid & hydrochloric acid of different concentration is done at various intervals of temperature. Then vacuum filter it and recrystallize from acetone and check the TLC and reactions monitoring hexane ethyl acetate ratio (7:3).



R= Substituted Aldehydes

Ethyl aceto acetate

ANALYSIS:

(1) 5-ethoxy-4-methyl-2-phenyl-4,5-dihydro-1H-imidazole

¹H NMR: δ = 1.35 (t, -CH₃), δ = 3.87 (m, O-CH₃), δ = 3.47 (m, -CH₃), δ = 4.3 (d, N-CH), δ = 8.58 (s, NH), δ = 7.52 (m, CH₂-CH₂), δ = 7.82 (d, CH=CH). ¹³C NMR: δ = 12.9, δ = 15.8, δ = 62.8, δ = 64.12, δ = 84.10, δ = 128.10, δ = 131.19, δ = 133.24, δ = 166.47. IR: alkyl C-H (2937 cm⁻¹), aromatic C-C (3300 cm⁻¹), N-H (3475 cm⁻¹), O-CH₂ (3200 cm⁻¹), aromatic ring,

Mass spectroscopy: (m/z): M+205, 128, and 88

(2) 5-ethoxy-4-methoxy-2-(3-nitrophenyl)-4,5-dihydro-1H-imidazole

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^1H NMR: δ =1.39(t, -CH₃), δ =1.20(t, -C-CH₃), δ =3.42(s, -CH), δ =3.92(d, O-CH₂), δ =4.32(d, N-CH₂), δ =8.29(s, N-H), δ =7.67(t, Aromatic ring) ^{13}C NMR: δ =13.15, δ =15.98, δ =63.47, δ =84.75, δ =122.31, δ =127.85, δ =131.45, δ =134.57, δ =148.75, δ =164.67. IR: 3380 cm⁻¹ (N-H, str), 2990 cm⁻¹ (C-H, str), 1664 cm⁻¹ (C=N, str).
Mass spectroscopy: (m/z): M+250, 128, 89

(3)5-ethoxy-4-methyl-2-(2-nitrophenyl)-4,5-dihydro-1H-imidazole

^1H NMR: δ =1.24(t, -CH₃), δ =1.37(t, -C-CH₃), δ =3.64(s, -CH), δ =3.82(d, O-CH₂), δ =8.17(d, N-CH₂), δ =7.34(s, NH), δ =7.85(t, Aromatic ring) ^{13}C NMR: δ =15.21, δ =16.85, δ =63.54, δ =64.75, δ =77.20, δ =84.80, δ =125.54, δ =128.90, δ =133.40, δ =154.75. IR: 3212 cm⁻¹ (N-H, str), 3110 cm⁻¹ (C-H, str), 1696 cm⁻¹ (C=N, str), 3026 cm⁻¹ (C-H, str).
Mass spectroscopy: (m/z): M+250, 128, 88

(4)2-(2-chlorophenyl)5-ethoxy-4-methyl-4,5-dihydro-1H-imidazole

^1H NMR: δ =1.20(t, -CH₃), δ =1.29(t, -C-CH₃), δ =3.57(s, -CH), δ =3.97(m, O-CH₂), δ =8.36(d, N-CH₂), δ =7.51(t, Aromatic ring) ^{13}C NMR: δ =13.87, δ =14.78, δ =63.54, δ =62.8, δ =85.28, δ =127.42, δ =130.78, δ =133.75, δ =168.15. IR: 3390 cm⁻¹ (N-H, str), 3100 cm⁻¹ (C-H, str), 1630 cm⁻¹ (C=N, str).
Mass spectroscopy: (m/z): M+239, 128, 88

(5)2-(2,4-dichlorophenyl)-5-ethoxy-4-methyl-4,5-dihydro-1H-imidazole

^1H NMR: δ =1.15(t, -CH₃), δ =1.32(t, -C-CH₃), δ =3.42(s, -CH), δ =3.89(m, -CH₂), δ =8.42(d, N-CH₂), δ =6.75, δ =7.49(t, Ar-H), δ =7.58(d). ^{13}C NMR: δ =12.90, δ =15.20, δ =63.84, δ =84.22, δ =125.39, δ =128.12, δ =131.14, δ =138.57, δ =165.12. IR: 3375 cm⁻¹ (N-H, str), 3107 cm⁻¹ (C-H, str), 1645 cm⁻¹ (C=N, str).
Mass spectroscopy: (m/z): M+274, 128, 88

(6)5-ethoxy-2(3-methoxyphenyl)-4-methyl-4,5-dihydro-1H-imidazole

^1H NMR: δ =1.24(t, -CH₃), δ =1.37(t, -C-CH₃), δ =3.41(s, -CH), δ =3.95(m, -CH₂), δ =7.78(d, N-CH₂), δ =6.45, δ =7.24(t, Aromatic ring), δ =7.58(d). ^{13}C NMR: δ =13.28, δ =17.32, δ =55.80, δ =63.45, δ =84.25, δ =113.24, δ =120.47, δ =129.71, δ =133.44, δ =158.87, δ =166.75. IR: 1665 cm⁻¹ (C-C, str), 3110 cm⁻¹ (C-H, str), 1550 cm⁻¹ (C=N, str), 1615 cm⁻¹ (C-N, str).
Mass spectroscopy: (m/z): M+235, 128, and 88

(7)5-ethoxy-2(4-methoxyphenyl)-4-methyl-4,5-dihydro-1H-imidazole

^1H NMR: δ =1.17(t, -CH₃), δ =1.26(t, -C-CH₃), δ =3.42(s, -CH), δ =3.84(m, -CH₂), δ =8.27(d, N-CH₂), δ =6.25, δ =7.24(d, aromatic ring), δ =7.48(d). ^{13}C NMR: δ =12.48, δ =15.32, δ =53.47, δ =62.47, δ =84.78, δ =114.25, δ =127.04, δ =135.87, δ =133.44, δ =162.70, δ =165.16. IR: 1665 cm⁻¹ (C-C, str), 3110 cm⁻¹ (C-H, str), 1550 cm⁻¹ (C=N, str), 1615 cm⁻¹ (C-N, str).
Mass spectroscopy: (m/z): M+235, 128, and 88

(8)5-ethoxy-2(4-fluorophenyl)-4-methyl-4,5-dihydro-1H-imidazole

^1H NMR: δ =1.21(t, -CH₃), δ =1.37(t, -C-CH₃), δ =3.4(s, -CH), δ =3.89(m, O-CH₂), δ =8.14(d, N-CH₂), δ =6.42, δ =7.49(d, Aromatic ring), δ =7.61(d). ^{13}C NMR: δ =12.78, δ =15.21, δ =62.17, δ =64.21, δ =84.21, δ =118.46, δ =130.12, δ =167.24. IR: 3091 cm⁻¹ (N-H, str), 2960 cm⁻¹ (C-H, str), 1651 cm⁻¹ (C=N, str).
Mass spectroscopy: (m/z): M+223, 128, and 88.

(9)3-(5-methoxy-4-methyl-4,5-dihydro-1H-imidazole-2-yl) phenol

^1H NMR: δ =1.21(t, -CH₃), δ =1.37(t, -C-CH₃), δ =3.4(s, -CH), δ =3.89(m, O-CH₂), δ =8.14(d, N-CH₂), δ =6.42, δ =7.49(d, Aromatic ring), δ =7.61(d). ^{13}C NMR: δ =12.78, δ =15.21, δ =62.17, δ =64.21, δ =84.21, δ =118.46, δ =130.12, δ =167.24. IR: 3091 cm⁻¹ (N-H, str), 2960 cm⁻¹ (C-H, str), 1651 cm⁻¹ (C=N, str).

Mass spectroscopy : (m/z): M+223, 128, and 88.

(10)4-(5-methoxy-4-methyl-4, 5-dihydro-1H-imidazole-2-yl-) phenol

¹HNMR: δ =1.27(t, -CH₃), δ =3.31(s, -CH₃), δ =3.79(m, -CH₂), δ =8.31(d, N-CH₂), δ =6.24, δ =7.34(d, Aromatic ring), δ =7.53(s), δ =7.61(m), δ =9.47(s, -OH), ¹³CNMR: δ =12.10, δ =55.74, δ =63.24, δ =86.29, δ =114.74, δ =118.75, δ =123.47, δ =133.14, δ =134.39, δ =158.34, δ =166.25. IR: 3296cm⁻¹(N-H, str), 2947cm⁻¹(C-H, str), 1642cm⁻¹(C=N, str).

Mass spectroscopy : (m/z): M+221, 128, and 88

RESULT:

The above work is done for the of 5-ethoxy-4-methayl (Substituted phenyl)-4-5-dihydro-1-H-imidazole through the single step and Cyclization of ethyl acetoacetate with the substituted aromatic aldehydes and contribution ammonium acetate for the contribution of nitrogen in the structure of Imidazole ring.

The formation of Imidazole ring is confirmed by the 3349cm⁻¹(N-H-str), δ =8.25(s.1H,N-H), and mass spectroscopy data (M+1). They are the most similar fragmentation in Imidazole ring mass spectroscopy analysis, the different solvent like acetone and ethanol are used as a solvent in the synthesis. Acetic acid, sulphuric acid (25%) used as catalyst in reaction. This case acetic acid is used as catalyst as well as solvent, the reaction mass is sticky post heating and product separation is very complex. Specifically, in this type acid catalyst reaction, the solvent or acid catalyst are added in the reaction result in excess amount of the yield. The product formed is very sticky therefore the equivalent molar ratio of acid catalysts is used in reaction to mentioned. When Ethanol and acetone is used as solvent in the reactions and acetic acid as catalyst, they offer substantial yield as compared to when the sulphuric acid as catalyst and acetone as solvent.

Serial no	Sub. aldehyde R=Substitution	Melting Point	Catalyst: Acetic acid (pure)		Catalyst: H ₂ SO ₄ (25%)	
			Yield (EtOH as Solvent)	Yield (Acetone as Solvent)	Yield (EtOH as Solvent)	Yield (Acetone as Solvent)
1	Benzaldehyde	106C	78	87	24	39
2	3-Nitrobenzaldehyde	127C	69	85	27	34
3	2-nitrobenzaldehyde	145C	73	86	11	38
4	2-Chlorobenzaldehyde	178C	62	80	18	24
5	2,4-Dichlorobenzaldehyde	204C	78	84	24	36
6	3-Methoxybenzaldehyde	172C	68	87	31	39
7	4-Methoxybenzaldehyde	189C	74	85	26	33
8	4-Fluorobenzaldehyde	178C	64	85	14	22
9	3-Hydroxybenzaldehyde	204C	75	81	27	39
10	4-Hydroxybenzaldehyde	149C	63	89	34	41

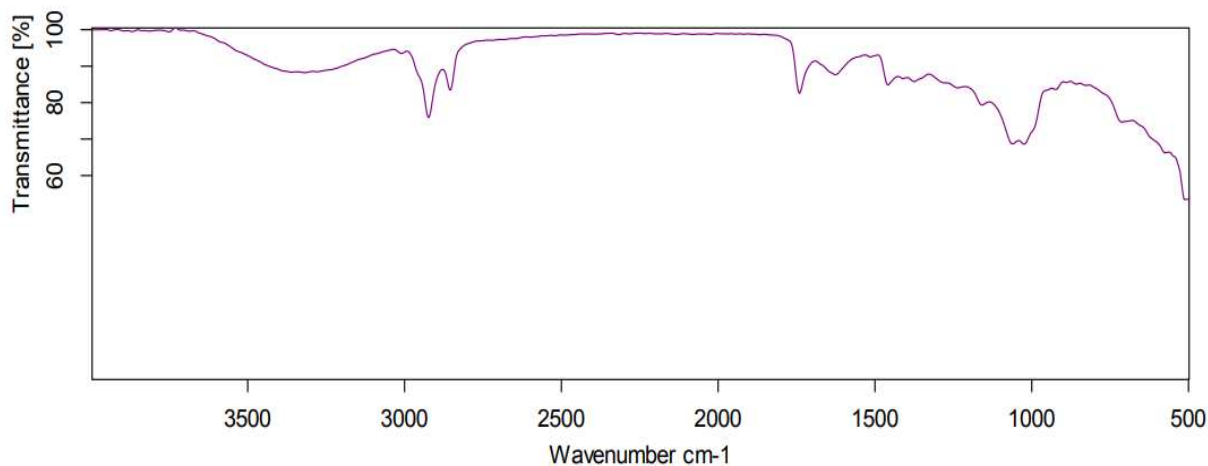
CONCLUSION:

Acetic acid is worked as a active catalyst in this type reactions and ethanol is good solvent in these reactions. The quantity is high then equimolar the reaction mass is sticky therefore the acetic acid and the strong acid like sulphuric acid when diluted are not also not useful for this type reactions.

Supportive data

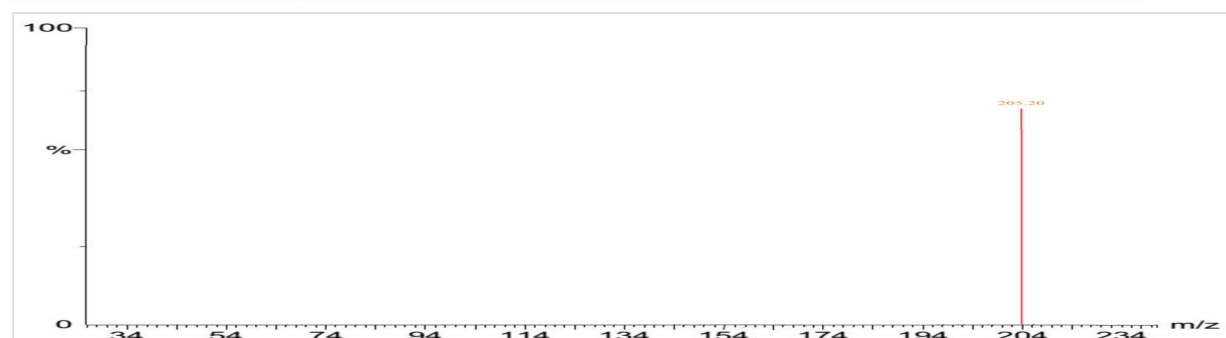
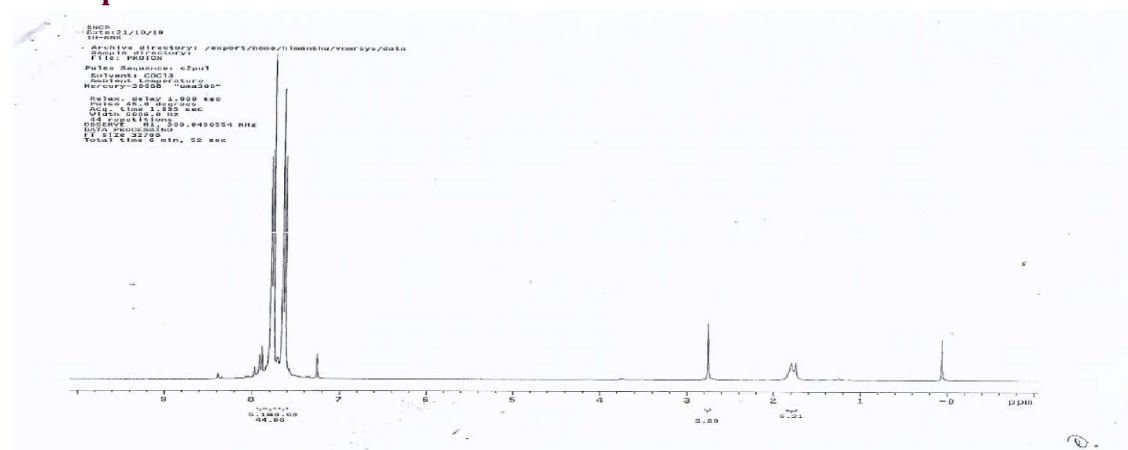
5-ethoxy-4-methayl-2-phenyl-4,5-dihydro-1H-imidazole

IR



¹HNMR

Mass spectra



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AN ANALYTICAL STUDY OF THE RIGHT TO DIE WITH DIGNITY UNDER ARTICLE 21 OF THE CONSTITUTION OF INDIA

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ABSTRACT

The constitutional jurisprudence surrounding the Right to Die with Dignity under Article 21 has undergone a profound transformation in India. Traditionally confined within the theoretical boundaries of the “Right to Life,” the concept has evolved into a practical and enforceable right through judicial activism. The landmark judgment of *Harish Rana v. Union of India* (2026) marks a historic turning point by operationalizing the framework laid down in *Common Cause v. Union of India* (2018, modified in 2023). This paper critically analyzes the evolution, judicial interpretation, and contemporary application of the right to die with dignity, highlighting the pressing need for legislative intervention. It further examines comparative global frameworks and emphasizes the importance of balancing human dignity, autonomy, and safeguards against misuse.

KEYWORDS: ARTICLE 21, RIGHT TO LIFE, RIGHT TO DIE WITH DIGNITY, PASSIVE EUTHANASIA, LIVING WILL, ADVANCE MEDICAL DIRECTIVES, JUDICIAL ACTIVISM, MEDICAL ETHICS, CONSTITUTIONAL LAW, END-OF-LIFE CARE

INTRODUCTION

On **March 11, 2026**, the Supreme Court of India in *Harish Rana v. Union of India* allowed the withdrawal of Clinically Assisted Nutrition and Hydration (CANH) from a patient in a Permanent Vegetative State (PVS) since 2013. This decision represents the first full-scale implementation of the end-of-life framework articulated in *Common Cause* (2018) and subsequently simplified in 2023.

The judgment bridges the gap between constitutional theory and medical reality. Article 21, which guarantees the Right to Life and Personal Liberty, has been judicially expanded to include the right to live with dignity. The logical extension of this principle is that dignity must also extend to the process of dying.

The Indian judiciary has thus played a transformative role in redefining the contours of life and death, emphasizing that prolonging biological existence without dignity may violate constitutional morality.

LITERATURE REVIEW

The right to die with dignity in India has predominantly evolved through judicial pronouncements rather than legislative enactments. Scholars have consistently argued that reliance on judicial guidelines creates inconsistency and limits accessibility. The Law Commission of India, through its **196th Report (2006)** and **241st Report (2012)**, strongly recommended legal recognition of passive euthanasia and living wills. However, legislative inertia has persisted.

The Harish Rana case demonstrates how judicial frameworks can be operationalized effectively. Yet, it also exposes systemic limitations—only those with access to courts can realize this right. This raises concerns regarding equality and accessibility under Article 14. Thus, there is a compelling need to transition from a judge-made regime to a comprehensive statutory framework.

RESEARCH OBJECTIVES

To trace the evolution of Article 21 from a mere “right to life” to a “right to die with dignity.”
To analyze judicial developments culminating in *Harish Rana v. Union of India* (2026).
To examine the legal and ethical dimensions of passive euthanasia in India.
To compare India’s approach with international legal frameworks.
To identify gaps and suggest legislative reforms.

RESEARCH HYPOTHESES

The right to die with dignity is a natural extension of the right to life under Article 21.
Judicial activism has played a decisive role in recognizing passive euthanasia in India.
The absence of statutory backing creates inconsistencies and accessibility issues.
Comparative international models provide viable frameworks for India.
Legislative intervention is essential to ensure uniformity and prevent misuse.

RESEARCH QUESTIONS

Does Article 21 constitutionally justify the right to die with dignity?
How has the Supreme Court shaped euthanasia jurisprudence?
What are the ethical implications of withdrawing life support?
Is judicial regulation sufficient without legislative backing?
What lessons can India learn from global practices?

ANALYSIS

1. Evolution of ‘Right to Die’ Jurisprudence in India

(i) Gian Kaur v. State of Punjab (1996)

The Supreme Court held that Article 21 does not include the right to die but acknowledged that the right to live with dignity includes a dignified death in the natural course.

(ii) Aruna Shanbaug v. Union of India (2011)

The Court permitted passive euthanasia under strict judicial supervision, marking the first step toward recognizing end-of-life autonomy.

(iii) Common Cause v. Union of India (2018)

A Constitution Bench:

Recognized **Advance Medical Directives (Living Wills)**

Legalized passive euthanasia

Established procedural safeguards

(iv) 2023 Modification

Simplified procedures for executing living wills, making them more accessible.

(v) Harish Rana v. Union of India (2026)

The landmark judgment of *Harish Rana v. Union of India* (2026) represents a watershed moment in the evolution of the Right to Die with Dignity under Article 21 of the Constitution of India. While

earlier decisions such as *Common Cause v. Union of India* (2018) laid down the normative and procedural framework for passive euthanasia and Advance Medical Directives (AMDs), their practical application remained largely untested. This case marks the **first comprehensive judicial implementation** of that framework in a real-life medical context.

The Supreme Court, in this case, permitted the withdrawal of **Clinically Assisted Nutrition and Hydration (CANH)** from a patient who had remained in a **Permanent Vegetative State (PVS)** for over a decade. By doing so, the Court moved beyond abstract recognition and translated constitutional principles into actionable relief, thereby bridging the gap between legal theory and medical practice.

A significant contribution of the judgment lies in its **clarification of procedural ambiguities** that persisted after the *Common Cause* ruling. The Court streamlined the process relating to:

Constitution and functioning of medical boards

Role of hospital authorities in decision-making

Execution and verification of Advance Medical Directives

Judicial oversight mechanisms to ensure transparency and accountability

Importantly, the Court emphasized that the continuation of artificial life-sustaining treatment in cases of irreversible medical conditions may, in certain circumstances, amount to a violation of the patient's **right to live with dignity**, thereby reinforcing the idea that dignity extends to the end-of-life phase.

The judgment also significantly **strengthens the principle of patient autonomy**, recognizing the individual's right to make informed decisions regarding medical treatment, including the refusal or withdrawal of life support. It aligns Indian constitutional jurisprudence with global human rights standards that prioritize personal liberty, bodily integrity, and dignity.

However, the Court also acknowledged the potential risks of misuse and underscored the necessity of strict procedural safeguards. It reiterated that in the absence of a comprehensive statutory framework, judicial guidelines must be followed meticulously.

In essence, *Harish Rana v. Union of India* (2026) transforms the Right to Die with Dignity from a **theoretical constitutional entitlement into a practically enforceable right**, while simultaneously highlighting the urgent need for legislative intervention to institutionalize and regulate end-of-life care in India.

2. CONSTITUTIONAL DIMENSIONS

Article 21 has evolved from a narrow interpretation to a broad, dynamic right encompassing dignity, autonomy, and privacy (*Maneka Gandhi, Puttaswamy*). The right to die with dignity aligns with:

Human dignity

Bodily autonomy

Right to privacy

3. ETHICAL AND MEDICAL CONSIDERATIONS

Conflict between **sanctity of life** and **quality of life**

Role of medical professionals in decision-making

Importance of informed consent and family participation

Need for ethical medical boards

4. COMPARATIVE INTERNATIONAL PERSPECTIVE

Netherlands & Belgium: Legalized active euthanasia with strict safeguards

Canada (MAID): Expanding eligibility criteria

Switzerland: Liberal approach to assisted suicide

Spain & Australia: Regulated voluntary euthanasia

Colombia: Progressive framework including non-terminal cases

India's approach remains cautious, permitting only passive euthanasia.

CONCLUSION

The recognition of the right to die with dignity marks a significant milestone in Indian constitutional jurisprudence. The Supreme Court has successfully harmonized medical ethics with constitutional values of dignity and autonomy.

However, reliance on judicial guidelines alone is insufficient. The absence of a statutory framework creates ambiguity, inequality, and potential misuse. A comprehensive legislation is essential to institutionalize this right and ensure uniform application across the country.

FINDINGS

Article 21 has evolved into a dynamic right including dignified death.

Judiciary has been the primary driver of euthanasia jurisprudence.

Lack of legislation creates procedural inconsistencies.

Awareness of living wills remains low.

Medical infrastructure for end-of-life care is inadequate.

Judicial process is not easily accessible to all citizens.

Ethical dilemmas persist in medical practice.

Comparative models show feasibility of regulation.

Safeguards are essential to prevent abuse.

Legislative delay undermines constitutional guarantees.

SUGGESTIONS

Enact a comprehensive **End-of-Life Care Law**.

Provide legal recognition and simplified procedures for **Living Wills**.

Establish **independent medical boards** in hospitals.

Create awareness programs on patient rights.

Ensure accessibility for economically weaker sections.

Introduce strict safeguards against coercion and misuse.

Train healthcare professionals in ethical decision-making.

Digitize and register advance directives.

Provide judicial oversight mechanisms.

Align Indian law with global best practices while preserving constitutional values.

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**RETHINKING JUSTICE DELIVERY FOR GLOBAL
TRANSFORMATION: A COMPARATIVE STUDY OF POLICE,
FORENSIC, AND JUDICIAL ACCOUNTABILITY FOR SPEEDY
TRIAL WITH SPECIAL REFERENCE TO GUJARAT, INDIA**

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ABSTRACT

The right to a speedy trial, recognized under Article 21 through *Hussainara Khatoon v. State of Bihar* and reinforced in *A.R. Antulay v. R.S. Nayak*, remains one of the most frequently violated constitutional guarantees in India's criminal justice system. Existing explanations of delay focus mainly on judicial backlog and insufficient judges, while ignoring deeper systemic causes such as investigative inefficiencies, forensic delays, weak charge evaluation, witness management issues, and poor coordination among police, forensic laboratories, prosecution, and courts. This paper reconceptualizes delay as a system-wide accountability deficit across the entire criminal justice chain rather than a court-centric problem.

Using doctrinal, comparative, and multidisciplinary methods, the study integrates constitutional law with management science, digital governance, and forensic administration. It focuses on the State of Gujarat as a practical model and draws comparative insights from common-law jurisdictions. The research evaluates whether India's transition from the IPC, CrPC, and Evidence Act to the *Bharatiya Nyaya Sanhita*, *Bharatiya Nagarik Suraksha Sanhita*, and *Bharatiya Sakshya Adhinyam* improves trial efficiency through forensic integration, electronic evidence, and procedural reforms. It concludes that statutory change alone is insufficient without enforceable timelines, digital case tracking, forensic performance standards, and coordinated institutional accountability. The paper proposes a Gujarat-based Integrated Accountability Model linking police, forensic science, prosecution, and judiciary through technology-enabled monitoring to ensure a time-bound and efficient criminal justice system.

KEYWORDS: SPEEDY TRIAL, CRIMINAL JURISPRUDENCE, POLICE ACCOUNTABILITY, FORENSIC GOVERNANCE, JUDICIAL CASE MANAGEMENT, GUJARAT MODEL

INTRODUCTION

Timeliness in criminal justice is a constitutional mandate under Article 21, as affirmed in *Hussainara Khatoon* and structured in *A.R. Antulay*. A criminal trial functions as a continuous chain from FIR to final adjudication, where delay at any stage undermines fairness, public confidence, and the rights of both accused and victims.

However, India's approach remains largely court-centric, focusing on judicial backlog while ignoring systemic causes such as investigative inefficiency, forensic delays, weak charge-sheets, poor witness management, adjournments, and inter-agency disconnect between police, forensic bodies, prosecution, and courts.

This paper argues that speedy trial requires **integrated and shared accountability across the entire criminal justice system**, consistent with *Kartar Singh* and *P. Ramachandra Rao*. While the

new criminal codes (BNS, BNSS, BSA) introduce procedural modernization, their effectiveness depends on enforceable timelines, digital integration, and institutional coordination.

Using Gujarat as a case study, the paper proposes an Integrated Accountability Model that treats delay as a systemic failure across the entire criminal justice lifecycle, rather than a purely judicial issue.

2. RESEARCH QUESTIONS

Why is the Article 21 right to speedy trial weakly enforced, and what institutional and administrative gaps cause delay?

At which FIR-to-judgment stages do delays occur, and how do investigation, forensic, prosecution, witness, and judicial processes contribute?

How does poor coordination among police, forensic agencies, prosecution, and courts affect trial efficiency and fairness?

Can fixed timelines, forensic standards, digital systems, and adjournment control reduce delay without affecting due process?

What best practices from common law systems can improve coordination and case management?

How do new criminal laws improve time-bound and technology-driven justice compared to earlier laws?

How can Gujarat act as a pilot model for an integrated criminal justice accountability system?

3. OBJECTIVES OF THE STUDY

- To examine Article 21 and judicial development of speedy trial as part of fair procedure.
- To map delay points from FIR to judgment and corresponding institutional responsibility.
- To assess forensic delays, including backlog, reporting time, and evidentiary gaps.
- To compare international case management and accountability models for best practices.
- To evaluate the role of technology in improving coordination across criminal justice institutions.
- To propose a scalable Gujarat-based integrated criminal justice reform model.

4. METHODOLOGY

Doctrinal analysis of constitutional jurisprudence and criminal procedure, focusing on judicial interpretation of Article 21 and statutory provisions governing investigation and trial.

Process mapping of the investigation–forensic–prosecution–court workflow to identify structural delay points and responsibility gaps.

Comparative study of selected common-law systems to extract adaptable practices in case management, forensic governance, and prosecution coordination.

Multidisciplinary inputs from information technology and management science to propose dashboard monitoring, workflow analytics, and performance metrics for institutions.

5. CONSTITUTIONAL FOUNDATIONS OF SPEEDY TRIAL

Article 21 has expanded “procedure established by law” to mean a process that is just, fair, reasonable, and timely, thereby making the right to a speedy trial an integral part of fair procedure grounded in dignity, liberty, and the rule of law. This obligation extends beyond the judiciary to all stakeholders in the criminal justice system, including police, forensic agencies, and prosecutors, establishing speedy trial as a shared constitutional responsibility.

This principle has been consistently affirmed by the Supreme Court. In *Maneka Gandhi v. Union of India* (1978), the Court introduced fairness and reasonableness into Article 21, forming the basis for timely justice. *Hussainara Khatoon v. State of Bihar* (1980) recognized speedy trial as a fundamental right and addressed the plight of undertrials. In *A.R. Antulay v. R.S. Nayak* (1992), the Court laid down factors for assessing delay and emphasized institutional accountability. *P. Ramachandra Rao v. State of Karnataka* (2002) reaffirmed the right while rejecting rigid timelines. Collectively, these rulings establish speedy trial as a constitutional mandate requiring system-wide accountability across the criminal justice process.

6. THE DELAY CONTINUUM IN CRIMINAL TRIAL

Delay in criminal trials is a cumulative outcome of interconnected stages in the criminal justice system, reflecting systemic diffusion of responsibility across investigation, forensic science, prosecution, and judiciary.

Investigation Stage: Delays arise from weak evidence collection, poor crime scene handling, delayed witness examination, and late charge-sheets due to absence of timelines and monitoring.

Forensic Stage: Backlogs, shortage of experts, delayed reports, and chain-of-custody issues significantly affect charge framing and trial readiness.

Prosecution Stage: Poor coordination with investigators, weak pre-trial preparation, and ineffective witness management lead to adjournments and fragmented proceedings.

Judicial Stage: Adjournment practices, weak case-flow management, and lack of strict time standards prolong trials, often inheriting earlier systemic delays.

Overall, speedy trial jurisprudence treats delay as a systemic, multi-institutional issue requiring coordinated accountability across the entire criminal justice chain.

7. COMPARATIVE PERSPECTIVE

The comparative benchmark highlights selected common law jurisdictions' approaches to improving criminal justice efficiency, aimed at identifying adaptable reforms for Gujarat.

Investigation timelines: India lacks fixed timelines, while the UK and Australia use structured supervision, the US applies speedy trial standards post-charge, and Canada enforces judicial control over delays. Reform focus: statutory milestones with periodic review.

Forensic reporting: India faces delays and backlog, whereas other jurisdictions use accredited labs, audits, and digital tracking. Reform focus: forensic turnaround time (TAT) norms with performance monitoring.

Police-prosecution coordination: India follows a sequential model, while others ensure early involvement through joint reviews and structured case conferences. Reform focus: early-stage coordination mechanisms.

Case tracking: India has fragmented systems, while others use integrated digital case management. Reform focus: unified FIR-to-judgment dashboard.

Adjournment control: India sees frequent adjournments, while others apply strict judicial scheduling. Reform focus: adjournment accountability systems.

Witness management: India faces summons delays, while others use structured support and tracking systems. Reform focus: digital summons and real-time monitoring.

8. SPECIAL REFERENCE TO THE STATE OF GUJARAT

Gujarat has a strong foundation for speedy trial reforms, including e-Courts, CCTNS policing, a developed forensic system, structured prosecution, and judicial digital initiatives.

However, delays persist due to poor inter-agency coordination, absence of forensic timelines, delayed prosecutorial involvement, lack of unified FIR-to-judgment tracking, and weak monitoring of summons, witnesses, and adjournments.

With its existing infrastructure, Gujarat is well positioned to implement integrated reforms such as real-time case dashboards, forensic turnaround standards, joint police–prosecution coordination, and adjournment accountability systems for time-bound justice delivery.

9. THE GUJARAT INTEGRATED ACCOUNTABILITY MODEL

The Gujarat Integrated Accountability Model is a technology-driven framework to ensure the right to speedy trial through measurable accountability across the criminal justice chain.

It proposes statutory investigation timelines under BNSS with supervisory and prosecutorial review to ensure time-bound investigation, including evidence collection, witness examination, and case diary management. It also introduces forensic turnaround standards linked with performance metrics under the Directorate of Forensic Science to avoid delays in charge-sheeting and trial progression.

The model integrates all agencies through a unified FIR-to-judgment dashboard linking CCTNS, forensic systems, prosecution data, and e-Courts for real-time monitoring. It further establishes district-level joint review cells, adjournment accountability registers, and digital witness and summons tracking systems.

Overall, it creates an integrated accountability system to improve coordination, reduce delays, and ensure time-bound criminal justice delivery.

10. ROLE OF TECHNOLOGY AND MANAGEMENT SCIENCE

Technology and management science form the operational backbone of speedy trial by enabling coordinated, data-driven criminal justice administration.

A unified dashboard integrating CCTNS, forensic labs, prosecution systems, and e-Courts enables real-time tracking of cases from FIR to judgment, including timelines, forensic delays, adjournments, and witness status, shifting oversight from reactive to proactive intervention.

Workflow analytics help identify systemic bottlenecks such as forensic backlog, summons delays, and repeated adjournments, enabling better resource allocation. Overall, this transforms fragmented administration into efficient, technology-driven justice delivery with reduced trial timelines.

11. IMPACT OF TRANSITION FROM OLD CRIMINAL LAWS TO NEW CRIMINAL CODES ON SPEEDY TRIAL

India's shift from the IPC, CrPC, and Evidence Act to the Bharatiya Nyaya Sanhita, Bharatiya Nagarik Suraksha Sanhita, and Bharatiya Sakshya Adhiniyam significantly impacts investigation efficiency, forensic reliance, and judicial case management—key elements of a speedy trial.

The earlier framework suffered from lack of structured timelines, frequent adjournments, delayed charge-sheets, and weak pre-trial control. The new laws introduce time-bound investigation, digital communication, and structured case progression.

They also strengthen integration of forensic and electronic evidence, ensuring earlier scientific involvement, while improving case management through digital summons, electronic documentation, and streamlined scheduling. Additionally, they promote early and continuous coordination between police, prosecution, and courts through integrated case flow mechanisms.

For Gujarat, with its advanced digitization and forensic infrastructure, these reforms provide a strong foundation to implement time-bound, technology-driven criminal justice processes and enhance the right to speedy trial.

12. FINDINGS

Delay is multi-institutional, arising from cumulative inefficiencies across police, forensic, prosecution, and judiciary.

The system is largely sequential and uncoordinated, causing delays at every stage transition.

Forensic delays significantly hinder charge-sheeting, framing of charges, and trial readiness.

Lack of timelines and KPIs leads to weak institutional accountability.

Data fragmentation prevents real-time monitoring and coordination.

Delays harm fairness, evidence quality, victim satisfaction, and public trust.

Integrated digital monitoring can reduce delays without major legislative change.

Institutional discipline and coordination are more critical than statutory reform alone for speedy trial.

13. SUGGESTIONS

Statutory Time Standards: Enforce fixed timelines for FIR, investigation, forensic reporting, charge-sheet, and trial to reduce delay and ensure predictability.

Forensic TAT Norms: Set category-wise deadlines for forensic reports (DNA, cyber, ballistic, etc.) with performance-based evaluation.

Digital FIR-to-Judgment Platform: Create an integrated dashboard linking police, forensic, prosecution, and e-Courts for real-time case tracking.

Police-Prosecution Coordination: Ensure early joint review of cases to improve evidence quality and reduce defective charge-sheets.

Case Flow & Adjournment Control: Introduce strict case management with recorded reasons for adjournments and monitoring of repeated delays.

Witness Management System: Use digital summons, centralized tracking, and support systems to ensure timely witness attendance.

Performance Accountability: Define KPIs for police, forensic units, prosecution, and judiciary linked to delay reduction.

Forensic Capacity Building: Strengthen manpower and infrastructure to reduce backlog and improve scientific output timelines.

Inter-Agency Training: Conduct regular joint training for better coordination among all criminal justice stakeholders.

Gujarat Model Strategy: Pilot integrated reforms in Gujarat and scale nationally based on outcomes for speedy trial under Article 21.

14. CONCLUSION

The right to speedy trial under Article 21, as affirmed in Hussainara Khatoon and A.R. Antulay, cannot be achieved through court-centric reforms alone, as delay stems from systemic fragmentation across investigation, forensic science, prosecution, and judiciary. It requires integrated accountability across the FIR-to-judgment chain, supported by timelines, performance standards, and digital monitoring.

Gujarat, with strong digitization, policing, and forensic infrastructure, is well placed for reform. Through statutory timelines, forensic TAT standards, digital dashboards, inter-agency coordination, adjournment control, and technology-driven case management, it can develop a scalable Integrated Accountability Model ensuring time-bound justice delivery.

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ARTIFICIAL INTELLIGENCE AND FINANCE

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ABSTRACT :

The use of Artificial Intelligence in finance is on the rise. Nowadays, Fintech companies are using advanced AI technology to provide more convenient, efficient, and affordable financial services to their customers. The growing adoption of AI can primarily be attributed to intense competition, innovation and a focus on customer satisfaction. Using technology, companies can provide several services to their customers. The current paper discusses a few AI tools used by financial companies, including the benefits of AI adoption.

INTRODUCTION :

The finance industry generates huge and constantly growing amount of data about customer behaviour and preferences. Daily transactions about buying, selling, investments, banking, market trends can be harnessed to train AI models to create predictive models. These applications can identify patterns and predict future trends in the market, enabling financial institutions to make more informed decisions about investments and other financial operations. Also, using AI, financial companies can analyse customer behaviour and preferences to offer tailored recommendations and personalised services to customers. By leveraging AI applications, financial institutions can optimise operations, reduce costs and provide better customer service. Even today, regulators are leveraging AI as a means of improving their regulatory capabilities.

The Different AI applications include :

SUPERVISED MACHINE LEARNING

Supervised learning involves developing a model by providing a set of input-output pairs to learn a mapping function from the input to the output. Such learning techniques include decision trees, neural networks and more. They help financial companies in financial prediction, portfolio management and credit evaluation.

UNSUPERVISED MACHINE LEARNING TECHNIQUES

The primary objective of unsupervised learning is to identify meaningful patterns or relationships within a set of input data. Important techniques include clustering, dimensionality reduction, These techniques help in fraud detection, customer segmentation and portfolio optimisation.

ROBOTICS PROCESS AUTOMATION

Robotics Process Automation (RPA) is increasingly used in financial services to automate repetitive human tasks. It aims to reduce operational costs and human errors, increase efficiency and enhance customer experience. RPA is used for performing common tasks such as account opening and closing, claims processing, fraud detection and prevention, compliance and reporting.

BENEFITS OF USE OF AI IN THE FINANCE SECTOR

1. Help in Decision-making process

One of the biggest benefits of using AI in the finance sector is improving decision-making related to credit assessment, lending and investment. AI models are very useful for more accurate, fast and informed decision-making process. They are very helpful to banks in taking lending decisions. These models can greatly help in the credit risk assessment of a loan applicant due to their reliance on diverse data, especially non-traditional data. These models also have high prediction accuracy as they can detect poor signals and non-linearities in explanatory variables.

AI models can collect data about consumer behaviour, through digitisation of customer contacts and sources like social networks. Further, AI-based robotic advisors are now being increasingly used to help customers make investment decision-making. Given the risk appetite of customers, AI-based models can recommend investment portfolio construction and re-construction. They can help recommend optimal investment strategies.

2. Automating Key Business Processes

With the advent of robotic advisers, financial institutions have started automating key business processes using RPA algorithms. Such robotic advisors support customer services in retail banking and in wealth management. They help automate financial planning services like tax planning guidance, opening a bank account, recommending insurance policies, giving investment advice, and many other essential financial services.

As customers require several types of financial services to be delivered with a wider range of goods and services, these automated processes help organisations deliver them quickly, thus enhancing user experience and creating an impression that AI interactions are at par with those of humans. Thus, customers obtain personalised services for little or no cost. Also, it helps institutions operate round the clock, delivering cutting-edge services, and improving client experiences.

3. Improvement in Algorithmic Trading

Nowadays, AI is being extensively being used in equity trading and trading in foreign exchange market. As algorithmic trading relies on real time data, it is more efficient than human traders. AI-models can identify unexpected market trends quickly, and thus can send better trading signals to human traders. Thus, AI models used for equity trading can be more efficient than human traders.

4.Improvement in Financial Forecasting

As financial institutions have to face a lot of credit risk, newly developed AI models help such institutions to counter them by better financial forecasting. Whether it is credit forecasting of an individual borrower or an SME, these models utilise diverse sets of traditional and non-traditional data compared to traditional techniques. By utilising a diverse data set, AI-based forecasting models produce better, richer insights within a limited amount of time, thus vastly reducing the time and cost of producing a forecast.

5. Improvement in Compliance & Fraud Detection

Further, AI-based models can help institutions achieve compliance faster, in real-time, and with limited resources. They help real-time monitoring of data, which is very useful for timely detection of suspicious activities and fraud. As these models are trained on huge sets of historic data, they can identify hidden fraud patterns by considering non-traditional financial data.

6. Reduction in Illegal Insider Trading

Insider trading in the stock market means trading based on non-public price sensitive information. Insider trading, which is illegal in India, is difficult to detect by regulators. But using AI models, regulators can detect potential insider trading around price-sensitive events. Through clustering,

discontinuities in an investor's trading activity can be identified and be acted upon. Thus, regulators can stay ahead of insider trading and other financial crimes and thus ensure that the financial sector remains transparent, fair, and free from illegal activities, ultimately maintaining the integrity of financial markets.

7. Reduction in Operational Costs

The adoption of AI can further lead to a reduction in operational costs. With the help of AI, loan default rates can be reduced. Further, robust credit score assessment, better customer targeting, earlier detection of fraud and improved speed in providing customer service can help reduce the cost of transactions. By minimising the involvement of humans, AI can be utilised to increase the speed and efficiency of the payment process.

CONCLUSION

Thus, there are several benefits of AI adoption, especially for finance companies. AI can also significantly help in digital financial inclusion of the unorganised sectors of the economy too. However, the adoption of AI is blended with many threats such as lack of transparency, job displacement of employees, data privacy issues, systematic risk. Still the advantages of AI within a regulated environment can help overcome these threats and help in transforming the financial landscape of the economy.



UNDERSTANDING DIGITAL PAYMENT ADOPTION IN INDIA: TRENDS, DETERMINANTS, AND ANALYTICAL INSIGHTS

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ABSTRACT

The rapid growth of digital payment systems has transformed India's financial ecosystem, making it a global leader in real-time transactions. This study analyzes the trends and determinants of digital payment adoption in India using secondary data from the Reserve Bank of India (RBI) and the National Payments Corporation of India (NPCI) for the period 2020–2025. The findings reveal exponential growth in digital transactions, driven primarily by the Unified Payments Interface (UPI), which accounts for nearly 85% of total transaction volume. UPI transactions increased from 18.88 billion in 2020 to over 228 billion in 2025, indicating widespread adoption. However, declining growth rates suggest a transition toward a mature and stable phase. Key determinants influencing adoption include ease of use, security and trust, technological infrastructure, government initiatives, financial literacy, and socio-economic factors. Convenience and trust emerge as the most significant drivers. Despite strong growth, challenges such as cybersecurity risks, digital divide, and limited financial awareness remain. The study concludes that digital payments are enhancing financial inclusion and economic efficiency, while offering data-driven insights for policymakers, businesses, and future research.

KEYWORDS: DIGITAL PAYMENTS, UNIFIED PAYMENTS INTERFACE (UPI), FINANCIAL TECHNOLOGY (FINTECH), DIGITAL PAYMENT ADOPTION, FINANCIAL INCLUSION, INDIA

1. INTRODUCTION

Digital transformation has fundamentally reshaped financial systems across the globe, and India has emerged as one of the fastest-growing ecosystems for digital payment adoption. A key driver of this transformation is the introduction of the Unified Payments Interface by the National Payments Corporation of India, which has enabled instant, interoperable, and user-friendly transactions across banks and platforms. Its simplicity, accessibility, and widespread integration into mobile applications have significantly enhanced financial inclusion and reduced dependency on traditional banking channels.

In addition, proactive government initiatives such as Digital India and the landmark Demonetisation in India have accelerated the shift toward a less-cash economy by promoting digital infrastructure, encouraging electronic transactions, and fostering behavioral change among consumers and businesses. These efforts have been complemented by rapid smartphone penetration, affordable internet access, and the expansion of fintech services, all of which have contributed to the growing adoption of digital payments across urban and rural areas.

Furthermore, the outbreak of the COVID-19 pandemic acted as a significant catalyst, as concerns over hygiene and physical contact led to a sharp increase in the use of contactless and mobile-based payment methods. Consumers increasingly preferred digital modes such as QR code payments,

mobile wallets, and UPI-based applications, thereby reinforcing long-term shifts in payment behavior.

Against this backdrop, the present study seeks to provide a comprehensive analysis of the evolving trends and key determinants influencing digital payment adoption in India. By examining patterns in transaction growth, technological accessibility, and policy interventions, the study offers meaningful insights into the factors driving this transformation and its implications for the future of a digitally empowered economy.

2. LITERATURE REVIEW

The digital payment ecosystem in India has witnessed remarkable growth over the past decade, driven by technological innovation, regulatory support, and increasing digital penetration. Digital payments include instruments such as the Unified Payments Interface (UPI), mobile wallets, NEFT, RTGS, and card-based transactions.

Among these, UPI has emerged as the most dominant platform due to its interoperability, real-time processing, and ease of use. According to D. K. Sahoo, B. C. M. Patnaik, and I. Satpathy (2024), UPI has revolutionized the digital payment landscape by enabling seamless interbank transactions through a unified platform. Their study highlights that the simplicity and accessibility of UPI have significantly enhanced financial inclusion and reduced dependency on cash-based transactions.

Similarly, R. Kumawat (2025) emphasizes that the Indian digital payment system has evolved into a robust and scalable ecosystem, with UPI supporting both peer-to-peer (P2P) and person-to-merchant (P2M) transactions. The study further notes that India has emerged as a global leader in real-time digital payments, driven by strong digital public infrastructure.

The adoption of digital payment systems has been widely studied using theoretical frameworks such as the Technology Acceptance Model (TAM) and Diffusion of Innovation (DOI). Various scholars have identified multiple determinants influencing user adoption.

M. Shahid (2022) found that perceived ease of use significantly influences users' intention to adopt UPI services. The study suggests that simplified interfaces and quick transaction processes enhance user experience and encourage continued usage. According to Sahoo, Patnaik, and Satpathy (2024), users are more likely to adopt digital payment systems when they perceive them as secure and reliable. Their research highlights that trust in banking systems and digital platforms plays a crucial role in reducing perceived risks.

Kumawat (2025) notes that regions with better digital infrastructure show higher adoption levels, whereas limited access remains a barrier in rural areas. Sahoo et al. (2024) emphasize that policy interventions, such as digitalization programs and financial inclusion strategies, have contributed to widespread acceptance of digital transactions in India.

Recent research by R. Malik et al. (2025) highlights the role of socio-economic factors such as income levels, education, and regional disparities in shaping digital payment adoption. Their study

indicates that urban areas exhibit higher adoption compared to rural regions due to better access to resources and infrastructure.

2.3 RESEARCH GAP

Despite extensive research on digital payment systems, certain gaps remain in the existing literature. A significant portion of prior studies, such as those conducted by Shahid (2022) and Sahoo et al. (2024), rely primarily on primary data collected through surveys, often limited in scope and geographical coverage.

Moreover, there is limited research focusing on recent large-scale trends (2024–2025) using updated datasets. Malik et al. (2025) point out that the rapid growth of UPI and digital payments in recent years requires more comprehensive and data-driven analysis to capture evolving user behavior and transaction patterns.

Additionally, existing studies often examine individual determinants in isolation rather than providing an integrated framework that combines trends, determinants, and policy impacts. Therefore, the present study aims to bridge this gap by offering a comprehensive and updated analysis of digital payment adoption in India, incorporating recent trends and broader economic implications.

3. OBJECTIVES OF THE STUDY

To examine the growth and recent trends in digital payment adoption in India.

To analyze the usage patterns of various digital payment modes, including the Unified Payments Interface, mobile wallets, NEFT, RTGS, and card-based transactions.

To identify and evaluate the key determinants influencing the adoption of digital payments, such as ease of use, security, technological infrastructure, financial literacy, and government initiatives.

To provide analytical insights into the growth trajectory and future prospects of digital payments in India.

4. RESEARCH METHODOLOGY

4.1 Research Design

The present study adopts a **descriptive and analytical research design** to examine the trends, patterns, and determinants of digital payment adoption in India. The descriptive approach is used to outline the growth and usage patterns of digital payment systems, while the analytical approach helps in identifying relationships and drawing meaningful insights from the data.

4.2 Nature and Sources of Data

The study is based on **secondary data**, collected from reliable and authentic sources. The data has been compiled from Reports of the Reserve Bank of India (RBI), Publications of the National Payments Corporation of India, Government portals and initiatives such as Digital India, Research journals, working papers, and industry reports, and Statistical databases and financial reports. The data primarily covers the period **2020–2025**.

4.4 Tools and Techniques of Analysis To achieve the study's objectives, descriptive statistics are used to analyze growth trends, transaction volume, and usage patterns; comparative analysis is applied to evaluate different payment modes such as UPI, cards, and wallets; and trend analysis is employed to examine year-wise growth in digital payments.

4.5 Scope of the Study

The study focuses on digital payment systems in India, particularly emphasizing the growth of the Unified Payments Interface and other electronic payment methods. It analyzes national-level trends and does not focus on any specific region or demographic group.

4.6 Limitations of the Study

The study is based entirely on secondary data, which may have inherent limitations in terms of accuracy and completeness.

The analysis depends on publicly available data and may not capture real-time fluctuations.

Behavioral aspects of users are interpreted indirectly due to the absence of primary survey data.

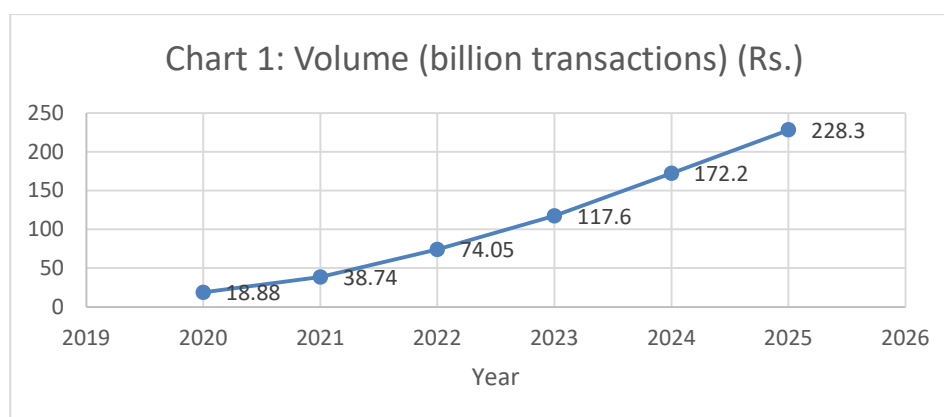
Rapid technological changes may affect the relevance of findings over time.

5. DATA ANALYSIS AND INTERPRETATION

5.1 Trend Analysis of UPI Transactions in India

Table 1: Growth of UPI Transactions in India (2020–2025)

Year	Volume (billion transactions in ₹)
2020	18.88
2021	38.74
2022	74.05
2023	117.6
2024	172.2
2025	228.3



(Source: NPCI, YourStory Research)

The data presented in Table 1 and the corresponding chart reveal a remarkable and consistent upward trend in UPI transaction volumes in India over the period 2020 to 2025. In 2020, UPI transactions stood at 18.88 billion, which increased more than twelvefold to 228.3 billion by 2025. This sharp rise indicates the rapid adoption of digital payment systems across the country. The growth is particularly significant between 2021 and 2023, where transaction volumes nearly tripled from 38.74 billion to 117.6 billion, reflecting increased consumer trust and widespread usage.

The trend line in the chart shows a steep and accelerating growth curve, suggesting not just linear growth but exponential expansion in digital payment adoption. The consistent year-on-year increase highlights the scalability and acceptance of UPI platforms among both urban and rural populations.

The growth can be attributed to increased smartphone and internet penetration, government initiatives promoting a cashless economy, the expansion of UPI-enabled apps such as Google Pay, PhonePe, and Paytm, as well as a behavioral shift toward contactless payments, particularly after COVID-19.

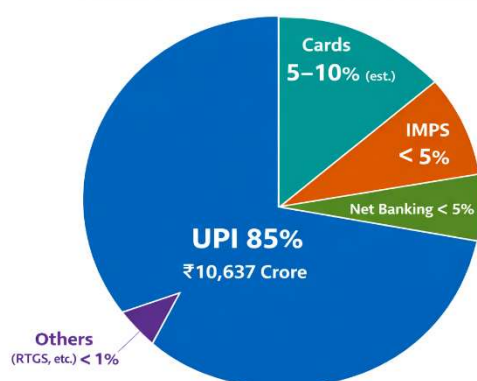
By 2024 and 2025, the volume surpasses 170 billion and 228 billion transactions, respectively, indicating that UPI has become a dominant mode of retail digital payments in India. Overall, the table and chart demonstrate that UPI is not only growing rapidly but also transforming the Indian payment ecosystem, making transactions more accessible, efficient, and inclusive.

5.2 Share of Digital Payment Modes in India

Table 2: Share of Payment Systems by Volume (2025)

System	Share (%)	Transactions (crore in ₹.)
UPI	85	10,637
Cards (Debit/Credit)	~5-10 (est.)	N/A
IMPS	<5	N/A
Net Banking	<5	N/A
Others (RTGS, etc.)	<1	N/A
(Source: Economic Times)		

Digital Payment System Share in India



The table 2 and corresponding chart clearly shows the dominance of UPI, which accounts for about 85% of digital transactions (₹10,637 crore), making it the most widely used payment system in India. Its growth is driven by convenience, low cost, and integration with apps like Google Pay, PhonePe, and Paytm. In comparison, card payments contribute only 5–10%, while IMPS, Net Banking, and others each hold less than 5%, indicating limited use for everyday transactions. Overall, the data highlights a shift toward UPI-led, mobile-based payments, making it the central driver of India's digital payment ecosystem.

5.3 Growth Rate Analysis of UPI

Table 3: Year-on-Year (YoY) Growth of UPI Transactions

Year	Volume (Billion)	Volume Growth (%)	Value (₹ Trillion)	Value Growth (%)
2021	38.74	105.2%	71.54	130.8%

2022	74.04	91.1%	125.94	76.0%
2023	117.67	58.9%	182.84	45.2%
2024	172.21	46.3%	246.80	35.0%
2025	228.50	32.7%	299.74	21.5%

(Sources: NPCI, RBI Annual Reports, and Industry Analysis)

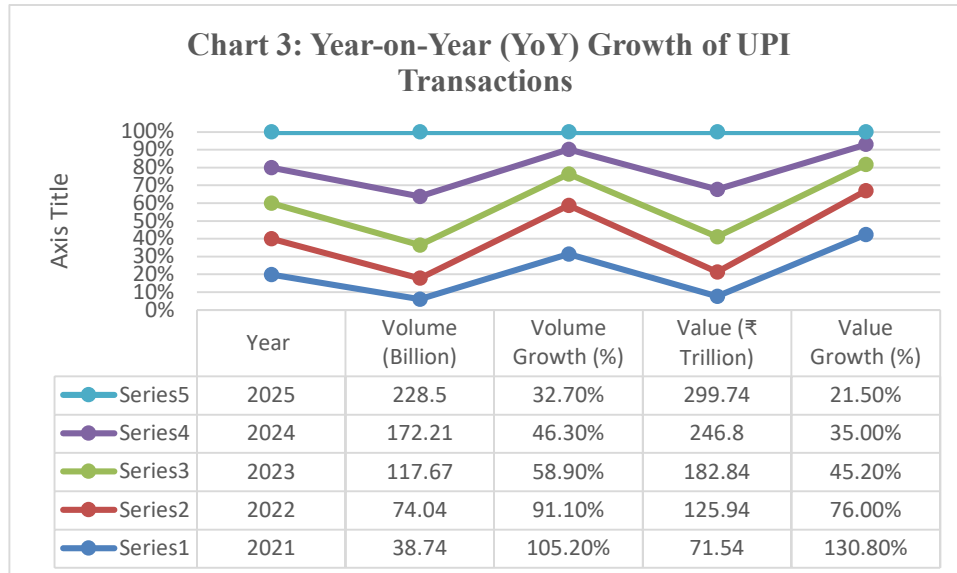


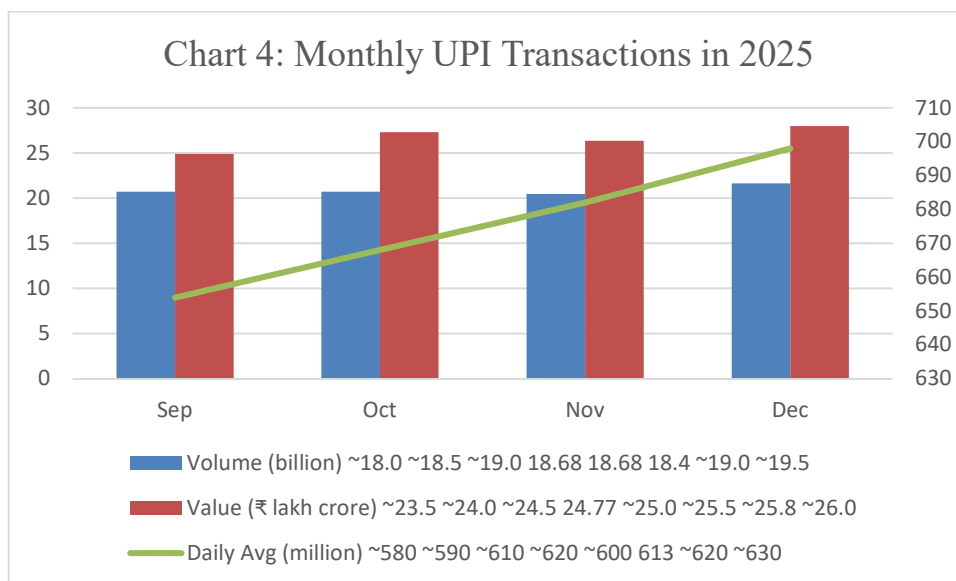
Table 3 and corresponding chart shows that while UPI transaction volume continues to rise steadily from 2021 to 2025, the year-on-year (YoY) growth rate is declining over time. Volume growth drops from 105.2% (2021) to 32.7% (2025), and value growth from 130.8% to 21.5%, indicating market maturation. Despite slower growth rates, the consistent increase in both volume and value reflects strong and sustained adoption of UPI. This suggests a transition from a high-growth phase to a stable expansion phase in India's digital payment ecosystem.

5.4 Monthly Transaction Evidence of the Year 2025

Table 4: Monthly UPI Transactions in 2025

Month	Volume (₹ billion)	Value (₹ lakh crore)	Daily Avg. (₹ million)
Jan	~18.0	~23.5	~580
Feb	~18.5	~24.0	~590
Mar	~19.0	~24.5	~610
Apr	18.68	24.77	~620
May	18.68	~25.0	~600
Jun	18.40	~25.5	613
Jul	~19.0	~25.8	~620
Aug	~19.5	~26.0	~630
Sep	20.70	24.90	654
Oct	20.70	27.28	668
Nov	20.47	26.32	682
Dec	21.63	27.97	698

(Source: YourStory Research)



The data shows a steady upward trend in UPI transactions throughout the year, with both volume and value gradually increasing. Transaction volume rises from about 18 billion in January to 21.63 billion in December, indicating growing user adoption.

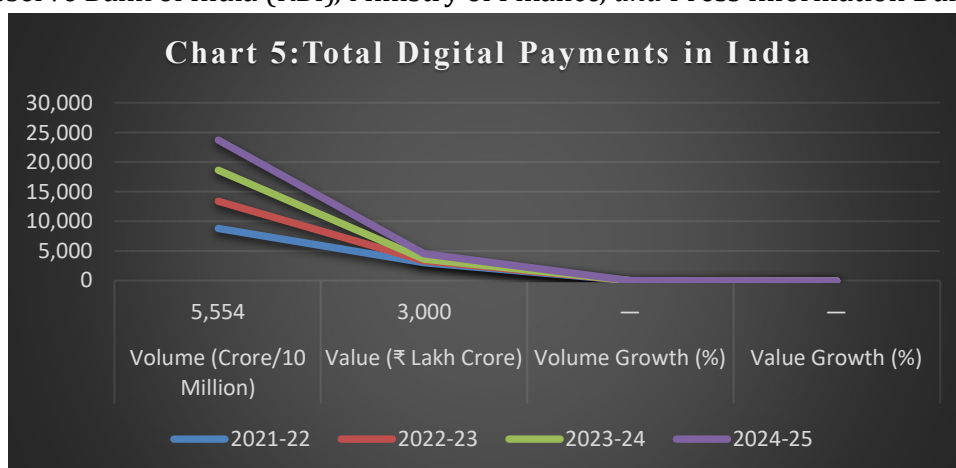
The transaction value also increases overall, reaching a peak of around ₹27.97 lakh crore in December, despite minor fluctuations (e.g., a dip in September). This suggests increasing high-value transactions alongside volume growth. The daily average transactions show a consistent rise from ~580 million to ~698 million, reflecting increasing frequency of usage. Overall, the trend indicates strong and continuous growth in UPI usage, with slight mid-year fluctuations but a clear year-end peak, highlighting expanding reliance on digital payments in India.

5.5 Overall Digital Payments Growth

Table 5: Total Digital Payments in India

Financial Year	Volume (Crore/10 Million)	Value (₹ Lakh Crore)	Volume Growth (%)	Value Growth (%)
2020-21	5,554	3,000	—	—
2021-22	8,839	3,021	59.1%	0.7%
2022-23	13,462	3,355	52.3%	11.1%
2023-24	18,737	3,659	39.2%	9.1%
2024-25	23,834	4,580	27.2%	25.2%

(Sources: Reserve Bank of India (RBI), Ministry of Finance, and Press Information Bureau.)



The table shows a consistent increase in UPI transaction volume and value from 2020–21 to 2024–25, indicating strong growth in digital payments. Transaction volume rises sharply from 5,554 crore to 23,834 crore, though the growth rate gradually declines from 59.1% to 27.2%, suggesting a shift from rapid expansion to a more mature growth phase.

In contrast, transaction value shows moderate but steady growth, with a notable surge in 2024–25 (25.2%), indicating an increase in higher-value transactions. Overall, the data reflects sustained adoption of UPI, with expanding usage and a transition toward higher transaction values and market stability.

5.6 Key Analytical Insights

UPI's Market Dominance: UPI accounts for ~85% of total digital transactions, clearly emerging as the backbone of India's payment ecosystem, far ahead of cards, IMPS, and net banking.

Exponential Long-Term Growth: UPI transaction volume increased from 18.88 billion (2020) to 228.3 billion (2025), showing massive adoption and scalability across the country.

Declining Growth Rates (Market Maturity): Year-on-year growth in both volume and value is decreasing, indicating a shift from a high-growth phase to a stabilization phase as the market matures.

Rising Transaction Value: Despite slower growth rates, total transaction value continues to increase, especially in recent years, suggesting greater trust and higher-value usage of UPI.

Monthly Consistency with Upward Trend: Monthly data for 2025 shows steady growth with minor fluctuations, and a clear peak toward year-end, reflecting seasonal and economic activity patterns.

Increasing Daily Usage: Daily average transactions rise from ~580 million to ~698 million, highlighting growing frequency and habitual use of UPI among consumers.

Shift to Mobile-First Payments: The dominance and growth of UPI indicate a strong transition toward mobile-based, real-time payment systems, reducing reliance on traditional methods.

Marginal Role of Other Systems: Cards (5–10%) and others (<5%) play a limited role, mainly for specific use cases, reinforcing UPI's universal applicability.

Financial Inclusion Impact: The widespread growth suggests improved accessibility of digital payments, contributing to financial inclusion and a less-cash economy.

Future Outlook: The trend indicates sustained growth with stabilization, where future expansion will likely come from higher transaction values, rural penetration, and innovation, rather than rapid user base expansion.

5.2 Determinants of Adoption

5.2 DETERMINANTS OF DIGITAL PAYMENT ADOPTION

The adoption of digital payment systems in India is influenced by a combination of technological, behavioral, and institutional factors. Based on data trends and existing literature, several key determinants have been identified that significantly impact the usage of digital payment platforms such as the Unified Payments Interface.

5.2.1 Ease of Use and Convenience

Ease of use is one of the most critical factors influencing digital payment adoption. Platforms like UPI offer a simple interface, quick transaction processing, and minimal procedural complexity, making them accessible to a wide range of users. The availability of features such as QR code payments, one-click transactions, and mobile integration has significantly enhanced user convenience. It means higher perceived ease of use leads to greater acceptance and continued usage of digital payment systems, particularly among first-time users.

5.2.2 Security and Trust

Security concerns play a vital role in shaping user behavior toward digital payments. Trust in the system is influenced by factors such as data protection, secure authentication (PIN, OTP), and regulatory oversight. Users are more likely to adopt digital payments when they perceive them as safe and reliable. It means that a strong security framework increases user confidence and reduces perceived risk, thereby promoting adoption.

5.2.3 Technological Infrastructure

The availability of reliable internet connectivity, smartphone penetration, and digital infrastructure significantly determines adoption levels. Urban areas with better access to technology show higher adoption rates compared to rural areas. It suggests that Technological accessibility acts as a foundational requirement; without it, adoption remains limited regardless of other factors.

5.2.4 Government Policies and Initiatives

Government initiatives such as Digital India and policy measures like Demonetisation in India have accelerated digital payment adoption by encouraging a shift toward a cashless economy. Regulatory support and awareness campaigns have further strengthened the ecosystem. Government intervention acts as a catalyst, promoting behavioral change and supporting infrastructure development.

5.2.5 Financial Literacy and Awareness

Financial literacy influences the ability of individuals to understand and use digital payment systems effectively. Awareness about digital platforms, transaction processes, and security measures enhances user confidence. Higher financial literacy leads to increased adoption, especially in semi-urban and rural areas.

5.2.6 Socio-economic Factors

Factors such as income level, education, occupation, and geographic location also affect adoption. Higher-income and urban populations tend to adopt digital payments more rapidly due to better access to technology and financial services. Socio-economic disparities create uneven adoption patterns across regions and population groups.

The analysis indicates that digital payment adoption in India is primarily driven by **user-centric factors such as convenience and trust**, supported by **technological infrastructure and policy initiatives**. While the ecosystem has matured significantly, challenges such as digital divide and financial literacy continue to influence adoption patterns.

6. FINDINGS

The study identifies several key findings based on the analysis of trends, transaction data, and determinants influencing digital payment adoption in India:

UPI has emerged as the dominant digital payment system, contributing nearly 85% of total transaction volume, thereby forming the backbone of India's digital payment ecosystem. Transaction volumes have grown exponentially from 18.88 billion in 2020 to 228.3 billion in 2025, indicating widespread adoption, although declining growth rates suggest a shift toward a mature and stable market phase. Transaction values continue to rise, reflecting increasing user trust and higher-value usage. Monthly and daily trends show consistent and habitual usage, confirming that digital payments have become an integral part of everyday financial behavior.

Among the key determinants, ease of use and convenience are the primary drivers of adoption, supported by features such as qr-based payments and seamless mobile integration. Security and trust further influence adoption by reducing perceived risks through strong authentication and regulatory mechanisms.

Technological infrastructure, including internet access and smartphone penetration, remains a fundamental enabler, while government initiatives have played a catalytic role in accelerating adoption and promoting a cashless economy. Additionally, financial literacy and awareness significantly enhance user participation, particularly in semi-urban and rural areas. However, socio-economic disparities continue to create uneven adoption patterns, with higher uptake among urban and higher-income groups. Despite rapid growth, challenges such as the digital divide, cybersecurity concerns, and limited awareness in rural areas persist. Overall, digital payment adoption in India is driven by a combination of convenience, trust, infrastructure, and policy support, positioning UPI as the central force in the country's evolving digital economy.

7. IMPLICATIONS OF THE STUDY

The findings of this study on digital payment adoption in India offer several important implications for policymakers, financial institutions, businesses, and researchers.

7.1 Policy Implications

The dominance of UPI highlights the success of digital public infrastructure. Policymakers should strengthen rural digital infrastructure, promote financial literacy, enhance cybersecurity, and support fintech innovation. These measures will accelerate the shift toward a less-cash economy and ensure inclusive growth.

7.2 Managerial Implications

Banks, fintech companies, and payment service providers should prioritize user-friendly and seamless interfaces, invest in robust security features to build trust, develop targeted solutions for rural and low-literacy users, and leverage data analytics to better understand customer behavior and preferences.

7.3 Economic Implications

The growth of digital payments significantly benefits the economy by reducing cash dependence and transaction costs, enhancing transparency, and bringing more users into the formal financial system. Overall, digital payments act as a catalyst for economic efficiency and financial inclusion.

7.4 Social Implications

Digital payments enhance access to financial services, enable quick and convenient transactions, and promote inclusion across socio-economic groups, thereby contributing to a more inclusive and equitable financial system.

7.5 Academic Implications

The study provides a foundation for future research on digital payments, encourages the application of models like Technology Acceptance Model (TAM) and Unified Theory of Acceptance and Use of Technology (UTAUT) in the Indian context, and highlights the need for more data-driven and longitudinal studies. Overall, it contributes to the literature by offering updated and analytical insights.

7.6 Future Research Implications

Future research can focus on comparative studies (e.g., urban vs. Rural or india vs. Other countries), incorporate primary data to analyze user behavior, and explore the role of emerging technologies such as central bank digital currency (cbdc) and artificial intelligence (ai) in digital payments.

8. Conclusion and suggestions

8.1 CONCLUSION

The present study examined the trends, determinants, and analytical insights of digital payment adoption in India. The findings clearly indicate that India has emerged as a global leader in digital payments, driven by rapid technological advancements, supportive policy initiatives, and increasing user acceptance.

The growth of the Unified Payments Interface has been particularly significant, transforming the digital payment ecosystem by enabling seamless, real-time, and low-cost transactions. The analysis reveals that digital payments have experienced exponential growth in both transaction volume and value, especially in the post-pandemic period.

The study further identifies that **ease of use, security and trust, and technological infrastructure** are the most influential determinants of digital payment adoption. Government initiatives and financial literacy also play a supportive role in encouraging digital transactions. While adoption levels are high in urban areas, disparities still exist in rural regions due to infrastructural and awareness-related challenges.

Overall, the study concludes that digital payments are not only reshaping financial transactions but also contributing significantly to financial inclusion, transparency, and economic efficiency. The ecosystem is gradually moving toward a mature stage, characterized by stable growth and widespread acceptance.

8.2 SUGGESTIONS

Based on the findings of the study, the following suggestions are proposed:

1. Strengthening Digital Infrastructure

There is a need to improve internet connectivity and smartphone accessibility, particularly in rural and remote areas, to ensure inclusive adoption of digital payment systems.

2. Enhancing Financial Literacy

Government agencies and financial institutions should conduct awareness programs to educate users about digital payment methods, benefits, and security practices.

3. Improving Security Measures

Continuous enhancement of cybersecurity frameworks is essential to build trust among users. Advanced fraud detection systems and user protection mechanisms should be prioritized.

4. Promoting User-Friendly Platforms

Payment service providers should focus on designing simple, intuitive, and multilingual interfaces to cater to diverse user groups.

5. Encouraging Innovation in Fintech

Regulatory bodies should support innovation in financial technology to improve efficiency, reduce costs, and expand the scope of digital payments.

6. Bridging the Urban–Rural Divide

Targeted strategies should be implemented to address regional disparities in adoption, ensuring equitable access to digital financial services.

7. Continuous Monitoring and Policy Support

Policymakers should regularly assess the performance of digital payment systems and introduce adaptive policies to sustain growth and address emerging challenges.

In conclusion, digital payment adoption in India represents a transformative shift toward a more inclusive, efficient, and technology-driven financial system. With continued policy support, technological advancement, and user awareness, digital payments are expected to play a pivotal role in shaping the future of the Indian economy.

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THE CASE FOR A "ROMEO AND JULIET" CLAUSE IN INDIA

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INTRODUCTION

The Protection of Children from Sexual Offences Act, 2012 (POCSO Act) was enacted with a clear and necessary purpose to protect children below the age of 18 from sexual abuse, exploitation and harassment¹. Over the years it has played a vital role in addressing serious offences and strengthening child protection laws in India.

However, alongside its success certain practical concerns have emerged. One such issue is the law's strict and uniform application in cases involving consensual relationships between adolescents. This has led to a growing debate on whether the law, in its current form, sometimes goes beyond its intended purpose.

THE PROBLEM OF BLANKET CRIMINALISATION

Under the POCSO Act, any sexual activity involving a minor is treated as an offence irrespective of consent². The law does not differentiate between exploitative conduct and voluntary relationships between teenagers. As a result, even consensual relationships between individuals close in age, such as 16 and 18 or 15 and 17, can lead to serious criminal charges.

This approach often turns what is essentially a mutual relationship into a criminal case. A key issue here is that the Act does not recognise the consent of a minor as a valid defence. Therefore, even where both parties willingly participate, the legal consequences remain severe.

¹ Protection of Children from Sexual Offences Act, 2012 (act no. 32 of 2012)

² Protection of Children from Sexual Offences Act, 2012 s.2(d)

The punishment framework under the POCSO Act further intensifies this problem. Offences such as penetrative sexual assault carry a minimum sentence of 10 years, which may extend to life imprisonment. In cases involving younger minors, the punishment can go up to 20 years. Even non-penetrative offences attract imprisonment ranging from 3 to 5 years.

Given these mandatory minimum sentences, courts are left with limited discretion once an offence is established. This can result in harsh outcomes where young individuals involved in consensual relationships face long-term legal and social consequences. Judicial interpretation has also reinforced the strict nature of the law, particularly in recognising that the consent of a minor is legally irrelevant³.

THE CONCEPT OF THE ROMEO AND JULIET CLAUSE

Some legal systems, like those in the United States and Canada, have a Romeo and Juliet clause that protects young people from being charged with crimes. This clause provides that people who are close in age and have consensual relationships cannot be held criminally responsible.

The underlying aim is to prevent the criminalisation of adolescent relationships that do not involve coercion or exploitation, while still maintaining strict penalties for genuine offences.

If adapted to the Indian context, such a clause could function as a limited exception under POCSO.

It may apply in situations where:

Both individuals are adolescents,

The age difference falls within a reasonable range, and

There is no element of coercion, manipulation or abuse.

This would allow the law to distinguish between consensual relationships and cases involving actual harm.

JUDICIAL PERSPECTIVE IN INDIA

The Supreme Court of India has acknowledged this issue in recent years. In *State of Uttar Pradesh v. Anurudh and Anr.*⁴ The Court observed that the POCSO Act, having set aside the

³ *Independent Thought v. Union of India*, (2017) 10 SCC 800

⁴ 2026 INSC 47 or 2026 SCC OnLine SC 40

procedural error, the Supreme Court acknowledged the well-intentioned purport of the High Court. The POCSO Act, designed to protect children, is teetering on the edge of inversion. The decision in *State of Uttar Pradesh v. Anurudh* (9 January 2026) marks an important clarification on the limits of judicial intervention at the bail stage in POCSO cases. The Supreme Court ruled that figuring out the victim's age is something for the trial to decide. This must follow the order outlined in the Juvenile Justice Act, where documentary evidence is most important and a medical examination should only be used as a last option. The Court stressed that when courts handle bail issues under Section 439 CrPC, they cannot hold a mini trial by looking at detailed evidence like age determination.

The Court found that the Allahabad High Court went beyond its authority by requiring mandatory medical tests and giving general directions that apply to all POCSO cases. While discussing wider issues, the Supreme Court recognised the increasing trend of POCSO being used in consensual teenage relationships. It suggested that lawmakers think about adding a Romeo and Juliet clause to avoid criminalising these relationships. This judgment strengthens procedural rules in bail cases and adds to the ongoing discussion about changing age-of-consent laws in India. The Court noted that many cases involve consensual relationships between adolescents. Treating all these cases as serious sexual offences without looking at the factual context may lead to unfair outcomes. It also pointed out the lasting impact these prosecutions can have on young people.

The Court suggested that the Union Government should think about adding a provision like the Romeo and Juliet clause. It stressed that criminal law should not interfere in consensual relationships with a small age difference and no signs of exploitation.

THE GLOBAL PRECEDENTS

USA: A majority of states have a close in age exemption covering a gap of 3 to 4 years to avoid sex offender registration.

France: The age of consent is 15 years. The Romeo and Juliet clause allows a 5 year age gap exemption.

Canada: A tiered consent framework applies. Persons aged 12 to 13 can consent to partners less than 2 years older, and those aged 14 to 15 can consent to partners less than 5 years older. **United Kingdom:** Discretion applies to mandatory reporting for consensual acts between peers.

THE WAY FORWARD

The debate around introducing a Romeo and Juliet clause is not about weakening child protection laws. Instead, it is about making the law more balanced and aligned with social realities.

A carefully designed provision with clear safeguards could ensure that genuine cases of abuse continue to be punished strictly, that consensual adolescent relationships are not unnecessarily criminalised, and that courts are given limited but meaningful discretion in appropriate cases.

Any such reform would need to be approached cautiously, keeping in mind the primary objective of child protection.

Policy discussions and expert reports have also highlighted the complexities surrounding age of consent and adolescent relationships in India⁵.

THE CASTE AND RELIGION QUESTION

A study by Enfold India shows that nearly 80 per cent of POCSO cases filed by parents involve adolescent relationships. Many of these cases are not about abuse but about young couples who belong to different castes or religions. This reveals an uncomfortable reality: when teenagers are in relationships within the same caste or religion, families often accept them and sometimes even turn them into marriages. But when these relationships cross social boundaries, the same families turn to the law.

In such situations, the age of consent under the POCSO Act is often used not to protect children but to control them. Instead of addressing real cases of sexual abuse, the law ends up being used against adolescents who are in consensual relationships. This shifts the purpose of the law away from protection and turns it into a tool for enforcing social norms, especially those related to caste and religion.

⁵ Law Commission of India, Report no.172 on Review of Rape Laws (2000)

The impact of this is vast. It reinforces existing social divisions and limits the freedom of young people to make personal choices. It also places consensual relationships under the same legal category as exploitative ones, which can be unfair and harmful.

One possible solution is to introduce a close in age exemption, often called a Romeo and Juliet clause. This would protect adolescents who are close in age and in consensual relationships from being criminalised. It would also reduce the chances of families misusing the POCSO Act simply because they disapprove of a relationship.

Such a change would help bring the law back to its original purpose of protecting children from real harm, while also respecting the realities of adolescent relationships in today's society.

CONCLUSION

The POCSO Act remains one of the most important legislations for the protection of children in India. At the same time, its application in cases of consensual adolescent relationships raises important questions about fairness and proportionality.

Implementing a specific Romeo and Juliet clause could help create a better balance between protection and practicality. This would keep the law strong against misuse while ensuring it does not unintentionally punish young people trying to navigate relationships.

In a legal system that seeks to deliver justice, such a reform would reflect both sensitivity and reason.

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આંતરરાષ્ટ્રીય અર્થશાસ્ત્ર-“આંતરરાષ્ટ્રીય વેપારના પરિપેક્ષમાં”

ડૉ.ભાનુભાઈ ડી.પરમાર

આચાર્ય શ્રી, પી.એમ.પટેલ ઈન્સ્ટીટ્યુટ ઓફ બીઝનેસ એડમિનિસ્ટ્રેશન, આણંદ.

પ્રસ્તાવના:

દેશના સર્જતાં આંતરરાષ્ટ્રીય ક્ષેત્રના આર્થિક પ્રશ્નોએ અર્થશાસ્ત્રીઓમાં રસ અને વિવાદ સર્જ્યો છે. પ્રો.એડમ સ્મિથ, ડેવિડ હ્યૂમ, રિકાર્ડોયુગ જેવા અર્થશાસ્ત્રીઓના અભ્યાસના વિષયોમાં આવા આર્થિક પ્રશ્નો મોખરે હતા. આ પરંપરાને બીજા અર્થશાસ્ત્રીઓએ પણ ચાલુ રાખી હતી. જેના કારણે આજનું અર્થશાસ્ત્ર એક સ્વતંત્ર શાખા તરીકે આંતરરાષ્ટ્રીય અર્થશાસ્ત્ર તરીકે અસ્તિત્વ ધરાવે છે.

આંતરરાષ્ટ્રીય અર્થશાસ્ત્રમાં ઘણા બધા અર્થશાસ્ત્રીઓનો ફાળો મહત્વનો છે. તેમણે અર્થશાસ્ત્રમાં સારો એવો વિકાસ થાય એ માટે તેમજ તેમ ઊભા થતાં પ્રશ્નોની ચર્ચાને તેમણે આંતરરાષ્ટ્રીય વેપારના કાર્યક્ષેત્રમાં સામેલ કરેલ છે. જેમ કે

આંતરરાષ્ટ્રીય વેપારનું કાર્યક્ષેત્ર

૧. આંતરરાષ્ટ્રીય નાણાકીય અર્થશાસ્ત્ર:

આંતરરાષ્ટ્રીય નાણાકીય અર્થશાસ્ત્રમાં ઘણા બધા મુદ્દાઓની ચર્ચા કરવામાં આવી છે જેમાં આંતરરાષ્ટ્રીય નાણાકીય વ્યવસ્થાનો ઇતિહાસ, રોકડતાની સમસ્યાઓ, આંતરરાષ્ટ્રીય નાણા ભંડોર, દેશની લેણદેણના સરવયામાં ઊભા થતાં પ્રશ્નો, ડોલરનું વિનિમય ધોરણ વગેરે બાબતોને સમજાવવામાં આવી છે.

૨. ભારતના આંતરરાષ્ટ્રીય વેપારના પ્રશ્નો:

આંતરરાષ્ટ્રીય અર્થશાસ્ત્રમાં ભારતના આંતરરાષ્ટ્રીય વ્યાપારના પ્રશ્નોને રજૂ કરવામાં આવ્યા છે જેમાં ભારતની નિકાસો અને નિકાસનીતિ, વિદેશી મૂડીના પ્રશ્નો, ભારતના વિદેશ વ્યાપારના વ્યાપક વલણો, આયાતો અને આયાતનીતિ વગેરેનો સમાવેશ થાય છે.

૩. શુદ્ધ સિદ્ધાંત:

આંતરરાષ્ટ્રીય અર્થશાસ્ત્રના શુદ્ધ સિદ્ધાંતોમાં વ્યાપારની તરાહને સમજાવતા સિદ્ધાંતો, વ્યાપારની વહેંચણી, તેના લાભો, ઉત્પાદન ક્ષેત્ર નો વિકાસ, આર્થિક વિકાસ અને વ્યાપાર, વ્યાપારનીતિ અને ઉત્પાદનના સાધનો ના આવક પર પડતી અસરોની ચર્ચા કરવામાં આવી છે.

૪. આંતરરાષ્ટ્રીય વેપાર અને અલ્પવિકસીત દેશો:

આંતરરાષ્ટ્રીય અર્થશાસ્ત્રમાં અલ્પવિકસિત દેશોનું સ્થાન, અલ્પવિકસિત દેશોના આર્થિક વિકાસ પરની અસરો, આંતરરાષ્ટ્રીય વેપાર ને લગતા પ્રશ્નો, અલ્પવિકસિત દેશોના પ્રશ્નો, વગેરેને સમજાવવામાં આવ્યા છે.

આમ આંતરરાષ્ટ્રીય અર્થશાસ્ત્રના કાર્યક્ષેત્રમાં આંતરરાષ્ટ્રીય અર્થતંત્રમાં વિવિધ ક્ષેત્રોને લગતા પ્રશ્નો કે વિકાસ ને સમજાવવામાં આવેલા છે.

આંતરરાષ્ટ્રીય વેપારનો અર્થ:

આંતરરાષ્ટ્રીય વ્યાપાર અને આર્થિક વિકાસ એકબીજાના પૂરક છે. આયાતો દ્વારા કોઈપણ દેશની જરૂરી યંત્રસામગ્રી, મુડીના સાધનો, કાર્યોમાલ યંત્રોના છૂટા ભાગો, ટેકનિકલ કૌશલ્ય અને જરૂરી વસ્તુઓ તથા સેવાઓ મેળવી શકે છે. આયાતો

દેશના આર્થિક વિકાસનો દર ઝડપી અને વેગીલો બનાવવા માટે આવશ્યક છે. એ જ રીતે નિકાસો દ્વારા વિદેશી હંડિયામણ પ્રાપ્ત કરીને અર્થતંત્રને સ્વાવલંબી બનાવી શકાય છે. આમ આયાત વેપાર અને નિકાસ વેપારને ઘડનારા પરિબળો આંતરિક આર્થિક પરિસ્થિતિના ઘડતરમાં મહત્વની ભૂમિકા નિભાવે છે.

આંતરરાષ્ટ્રીય વેપારને આર્થિક વિકાસ ના એક એન્જિન તરીકે ઓળખવામાં આવે છે. વિદેશ વેપાર નું કદ અને તેમજ તેનું બંધારણ તેમજ તેની વેપાર ની શરતો એ દેશના આર્થિક વિકાસના સ્વરૂપ અને વિકાસના સ્તરને નિર્ણાયક રીતે અસર કરે છે.

બે પક્ષો વચ્ચેનો વિનિમય એટલે વ્યાપાર કરનારા બંને પક્ષો જો એક જ દેશમાં રહેતા હોય તો આંતરિક વેપાર, પરંતુ જો બંને પક્ષો અલગ અલગ દેશના હોય તો તે આંતરરાષ્ટ્રીય વેપાર કહેવાય. બધો જ વેપાર પછી તે આંતરિક હોય કે આંતરરાષ્ટ્રીય શ્રમ વિભાજન અથવા ઉત્પાદન ક્ષેત્રે વિશિષ્ટીકરણનું પરિણામ છે.

આંતરરાષ્ટ્રીય વેપારના ઉદભવવા માટેના કારણો:

બે દેશો આંતરરાષ્ટ્રીય વેપારથી નીચેના કેટલાક કારણોસર જોડાવા તૈયાર થતા હોય છે જેમ કે-

કોઈ એક દેશ અન્ય દેશની સરખામણીમાં ઓછો કાર્યક્ષમ,

કોઈ એક દેશ અન્ય દેશની સરખામણીમાં નીચેના કેટલાક કારણોસર ઓછો કાર્યક્ષમ જોવા મળતો હોય છે જેમ કે જે ટેકનોલોજી નો અભાવ માનવ મૂડી માળખાગત સુવિધાઓ વગેરેને વિગતે જોઈએ કુદરતી સંસાધનોની અછત: જો દેશ પાસે જરૂરી કાચો માલ કે ઊર્જાના સ્ત્રોતો ન હોય. ટેકનોલોજીનો અભાવ: જૂની ઉત્પાદન પદ્ધતિઓ અને આધુનિક મશીનરીનો અભાવ કાર્યક્ષમતા ઘટાડે છે. માનવ મૂડી : કુશળ કામદારો અને યોગ્ય શિક્ષણ કે તાલીમની ઉણપ. માળખાગત સુવિધાઓ: ખરાબ રસ્તા, વીજળીની અસ્થિરતા અથવા નબળું પરિવહન તંત્ર ઉત્પાદન ખર્ચ વધારે છે.

દર્શાવેલ કારણોને કારણે એક દેશ અન્ય દેશની સરખામણીમાં ઓછો કાર્યક્ષમ સાબિત થાય છે અને તેથી તે કાર્યક્ષમ દેશ સાથે આંતરરાષ્ટ્રીય વેપારથી જોડાવા તૈયાર થાય છે

માનવ જરૂરિયાતો અમર્યાદિત.

"માનવ જરૂરિયાતો અમર્યાદિત છે, પરંતુ તેને સંતોષવાના સાધનો મર્યાદિત છે."

આ વિભાવનાને કારણે આંતરરાષ્ટ્રીય વેપારનું સર્જન થતું જોવા મળે છે જરૂરિયાતોનો અંત નથી: એક જરૂરિયાત પૂરી થતા જ બીજી નવી જરૂરિયાત ઊભી થાય છે. જેમ કે, સાયકલ આવ્યા પછી સ્કૂટર અને પછી કારની ઈચ્છા થાય છે. પુનરાવર્તિત જરૂરિયાતો: કેટલીક જરૂરિયાતો વારંવાર સંતોષવી પડે છે, જેમ કે ખોરાક અને પાણી. પસંદગીની સમસ્યા: સાધનો (નાણાં, સમય, કુદરતી સંપત્તિ) મર્યાદિત હોવાથી માણસે નક્કી કરવું પડે છે કે કઈ જરૂરિયાત અત્યારે સંતોષવી અને કઈ જતી કરવી. આને જ 'પસંદગીનું અર્થશાસ્ત્ર' કહેવાય છે. આ રીતે માનવીની જરૂરિયાતો અમર્યાદિત હોવાને કારણે તેને સંતોષવા માટે બે દેશો આંતરરાષ્ટ્રીય વેપારથી જોડાતા હોય છે

સાધનોની કાર્યકુશળતા અલગ અલગ

ઉત્પાદનના સાધનોની કાર્ય કુશળતા અલગ અલગ હોવાને લીધે પણ બે દેશો આંતરરાષ્ટ્રીય વ્યાપાર થી જોડાય છે જેમાં જોઈએ તો વિશિષ્ટીકરણ ગુણવત્તામાં તફાવત અને સાધનોની આવી જતા એ મહત્વના પરિબળો જોવા મળે છે જેને વિગતે સમજીએ અર્થશાસ્ત્રમાં સાધનોની કાર્યકુશળતા અલગ-અલગ હોવી એ એક મહત્વનું પાસું છે. દરેક સાધન (જમીન, મૂડી કે શ્રમ) દરેક કામ માટે એકસરખું યોગ્ય હોતું નથી. આના મુખ્ય કારણો નીચે મુજબ છે વિશિષ્ટીકરણ કોઈ એક વ્યક્તિ કે મશીન એક ચોક્કસ કામમાં નિષ્ણાત હોય છે, પણ બીજા કામમાં તેની કાર્યક્ષમતા ઓછી હોઈ શકે. દાખલા તરીકે, એક સારો સોફ્ટવેર

એન્જિનિયર ખેતીકામમાં તેટલો કાર્યક્ષમ ન પણ હોય. ગુણવત્તામાં તફાવત બધી જમીન એકસરખી ફળદ્રુપ હોતી નથી, કે બધા મશીનો એકસરખી ઝડપે કામ આપતા નથી. સાધનોની અવેજતા એક સાધનની જગ્યાએ બીજા સાધનનો ઉપયોગ હંમેશા શક્ય નથી હોતો. જો તમે મશીનની જગ્યાએ માણસ પાસે કામ કરાવો, તો તેની કાર્યક્ષમતા અને પરિણામ અલગ જ હશે.

સાધનોની અસમાન વહેંચણી.

આ રીતે સાધનોની અલગ અલગ કાર્યકુશળતા બે દેશો વચ્ચે આંતરરાષ્ટ્રીય ઉદ્ભવવા માટેનું મુખ્ય કારણ બને છે. સાધનોની અસમાન વહેંચણી એ વૈશ્વિક અર્થતંત્રની એક કડવી વાસ્તવિકતા છે. કુદરતી સંપત્તિ, મૂડી અને ટેકનોલોજી દુનિયાના દરેક ખૂણે એકસરખા પ્રમાણમાં ઉપલબ્ધ નથી. આ અસમાનતાના મુખ્ય કારણો અને અસરો નીચે મુજબ છે ભૌગોલિક કારણો અમુક દેશો પાસે પુષ્કળ ખનિજ તેલ છે (જેમ કે આરબ દેશો), જ્યારે અમુક પાસે ફળદ્રુપ જમીન કે નદીઓ છે. આ કુદરતી બક્ષિસ દરેક પાસે અલગ-અલગ છે. આર્થિક અસમાનતા વિકસિત દેશો પાસે 'મૂડી' અને 'ટેકનોલોજી' વધારે છે, જ્યારે વિકાસશીલ દેશો પાસે 'શ્રમ' (વધુ વસ્તી) વધારે છે. તકનો અભાવ શિક્ષણ અને સ્વાસ્થ્ય જેવી મૂળભૂત સુવિધાઓની વહેંચણી અસમાન હોવાથી માનવ-સાધનોની કાર્યક્ષમતામાં મોટો તફાવત જોવા મળે છે. જેને કારણે આંતરરાષ્ટ્રીય વેપાર ઉદ્ભવતો જોવા મળે છે.

ટેકનોલોજીકલ જ્ઞાનનો અભાવ.

ટેકનોલોજીકલ જ્ઞાનનો અભાવ એ બે દેશો માટે વેપાર ઉદ્ભવવા માટેનું સૌથી મહત્વનું કારણ છે કારણ કે ટેકનોલોજી નો અભાવ હોય તો તેની સીધી અસર ઉત્પાદકતા પર પડતી હોય છે તેને કારણે પણ બે દેશો આંતરરાષ્ટ્રીય વેપારથી જોડાતા હોય છે ટેકનોલોજીકલ જ્ઞાનનો અભાવ એ કોઈ પણ દેશ કે સાધન માટે સૌથી મોટો અવરોધ છે. જ્યારે કોઈ દેશ પાસે સાધનો (કાચો માલ કે શ્રમ) હોય પણ તેનો ઉપયોગ કરવાની આધુનિક પદ્ધતિ ન હોય, ત્યારે તેની ઉત્પાદકતા ખૂબ જ ઘટી જાય છે. આનાથી નીચે મુજબની સમસ્યાઓ સર્જાય છે બગાડ જ્ઞાનના અભાવે સાધનોનો પૂરેપૂરો ઉપયોગ થઈ શકતો નથી અને કિંમતી સંસાધનો વેડફાય છે. ઊંચો ઉત્પાદન ખર્ચ જૂની પદ્ધતિઓથી કામ કરવામાં સમય અને મહેનત વધારે લાગે છે, જેનાથી વસ્તુ મોંઘી બને છે. નબળી ગુણવત્તા વૈશ્વિક બજારમાં સ્પર્ધા કરવા માટે જે ગુણવત્તા જોઈએ, તે ટેકનોલોજી વગર મેળવવી મુશ્કેલ છે. આને કારણે બે દેશો વચ્ચે આંતરરાષ્ટ્રીય વ્યાપાર ઉદભવે છે.

સાધનોની અગતિશીલતા.

સાધનોની અગતિશીલતા એટલે ઉત્પાદનના સાધનો (જેમ કે શ્રમ કે મૂડી) એક સ્થળેથી બીજા સ્થળે અથવા એક વ્યવસાયમાંથી બીજા વ્યવસાયમાં સરળતાથી જઈ શકતા નથી. જે બે દેશો વચ્ચે આંતરરાષ્ટ્રીય વ્યાપારનું સર્જન કરે છે. શ્રમની અગતિશીલતા માણસો કુટુંબ, ભાષા, સંસ્કૃતિ કે રહેઠાણના મોહને કારણે પોતાનું વતન છોડીને બીજા દેશ કે શહેરમાં કામ કરવા તૈયાર નથી હોતા. વ્યવસાયિક અગતિશીલતા કોઈ એક કામમાં કુશળ વ્યક્તિ બીજા પ્રકારનું કામ શીખવા માટે તૈયાર નથી હોતી અથવા તેના માટે જરૂરી તાલીમનો અભાવ હોય છે. ભૌગોલિક અને કાયદાકીય અવરોધો બે દેશો વચ્ચે વિઝાના નિયમો, સરહદી પ્રતિબંધો કે પરિવહનની મુશ્કેલીઓ પણ સાધનોને અગતિશીલ બનાવે છે.

આંતરરાષ્ટ્રીય વેપારની મર્યાદાઓ.

આંતરરાષ્ટ્રીય વ્યાપાર ફાયદાકારક હોવા છતાં તેની કેટલીક ગંભીર મર્યાદાઓ અને ગેરફાયદા પણ છે:
પરંતંત્રતામાં વધારો: જ્યારે કોઈ દેશ જીવનજરૂરી વસ્તુઓ (જેમ કે અનાજ કે તેલ) માટે બીજા દેશ પર નિર્ભર રહે છે, ત્યારે યુદ્ધ કે કટોકટીના સમયે તેની હાલત કફોડી થઈ જાય છે. આ એક સૌથી મોટી મર્યાદા છે.

સ્થાનિક ઉદ્યોગોને નુકસાન: વિદેશી કંપનીઓ સસ્તી અને આધુનિક વસ્તુઓ બજારમાં લાવે ત્યારે દેશના નાના અને ગૃહ ઉદ્યોગો તેમની સામે ટકી શકતા નથી અને બંધ થઈ જાય છે. જેની અર્થતંત્ર પર ગંભીર અસરો સર્જાતી હોય છે.

કુદરતી સંપત્તિનો અવિચારી વપરાશ: વધુ નિકાસ કરવાની લાલચમાં દેશો પોતાની કુદરતી સંપત્તિ (ખનીજ, જંગલો)નો ઝડપથી નાશ કરવા લાગે છે, જે ભવિષ્ય માટે જોખમી છે. જે અલ્પવિકસિત દેશના અર્થતંત્રને નુકસાન કરે છે.

ચુકવણીની તુલામાં અસમતુલા: જો દેશ નિકાસ ઓછી કરે અને આયાત વધારે કરે, તો દેશનું દેવું વધી જાય છે અને વિદેશી હૂડિયામાણ ઘટે છે. જે લેણદણની તુલાને અસંતુલિત બનાવી દેશના અર્થતંત્ર પર ગંભીર અસર નું સર્જન કરે છે.

રાજકીય ગુલામીનો ડર: ઈતિહાસ સાક્ષી છે કે ઘણીવાર વ્યાપાર કરવા આવેલી વિદેશી કંપનીઓ ધીમે ધીમે દેશના રાજકારણમાં દખલગીરી કરવા લાગે છે અને ગુલામ બનવાનો વારો આવે છે દાખલા તરીકે અંગ્રેજો વેપાર કરવા આવ્યા હતા અને ભારતને ગુલામ બનાવીને ગયા હતા.

વિદેશી સાંસ્કૃતિક આક્રમણ: વિદેશી વસ્તુઓના વધુ પડતા વપરાશથી સ્થાનિક સંસ્કૃતિ, ખાણી-પીણી અને પહેરવેશ પર પશ્ચિમી સંસ્કૃતિની નકારાત્મક અસર પડે છે. જે આયાતો નું સર્જન કરે છે અને વિદેશી હૂડિયામાં ખર્ચાઈ જતા લેણદણની તુલા પર ગંભીર અસર સર્જાય છે તેમ જ દેશના અર્થતંત્રને અસ્તવ્યસ્ત કરી નાખે છે.

નિષ્કર્ષ:

"પરસ્પર નિર્ભરતા એ જ અનિવાર્યતા" આ સંદર્ભમાં આંતરરાષ્ટ્રીય વેપાર ના કેટલાક નિષ્કર્ષો નીચે પ્રમાણે જોઈ શકાય છે.

૧. **વૈશ્વિક વહેંચણી અને વિશેષીકરણ:** કોઈ પણ દેશ સંપૂર્ણપણે આત્મનિર્ભર બની શકતો નથી કારણ કે કુદરતી સાધનોની વહેંચણી અસમાન છે. આથી, દરેક દેશે જે વસ્તુમાં તેની પાસે તુલનાત્મક લાભ હોય તેનું ઉત્પાદન કરવું જોઈએ અને અન્ય વસ્તુઓની આયાત કરવી જોઈએ. આનાથી વિશ્વ સ્તરે સાધનોનો ઈષ્ટતમ ઉપયોગ થાય છે.
૨. **વૃદ્ધિ માટે ટેકનોલોજીનું મહત્વ:** આંતરરાષ્ટ્રીય વેપાર માત્ર વસ્તુઓની લે-વેચ નથી, પણ તે જ્ઞાન અને ટેકનોલોજીના આદાન-પ્રદાનનું માધ્યમ છે. વિકાસશીલ દેશો આ વેપાર દ્વારા જ ટેકનોલોજીકલ અંતર ઘટાડી શકે છે.
૩. **સંતુલિત અભિગમની જરૂરિયાત:** વેપારની મર્યાદાઓને જોતા, કોઈ પણ દેશે "મુક્ત વ્યાપાર" અને "રક્ષણાત્મક નીતિ" વચ્ચે સંતુલન જાળવવું જરૂરી છે. સ્થાનિક ઉદ્યોગોને બચાવવા સાથે વૈશ્વિક સ્પર્ધામાં ટકી રહેવું એ જ સફળ આર્થિક નીતિ છે.
૪. **માનવ કલ્યાણમાં વધારો:** અંતે, આંતરરાષ્ટ્રીય વેપારનો મુખ્ય ઉદ્દેશ્ય દુનિયાભરના ગ્રાહકોને ઓછી કિંમતે વૈવિધ્યસભર અને ગુણવત્તાયુક્ત ચીજવસ્તુઓ પૂરી પાડીને તેમનું જીવનધોરણ સુધારવાનો છે.

ટૂંકમાં: આંતરરાષ્ટ્રીય વેપાર એ વિશ્વની અમર્યાદિત જરૂરિયાતો અને મર્યાદિત સાધનો વચ્ચે સેતુ બાંધવાનું કામ કરે છે. તે માત્ર આર્થિક જરૂરિયાત નથી, પરંતુ વૈશ્વિક શાંતિ અને સહકાર માટેનો પાયો પણ છે. જુદાજુદા દેશો આંતરરાષ્ટ્રીય વેપારથી શામાટે જોડાય છે આંતરરાષ્ટ્રીય વેપારથી જોડવાથી લાભ થશે કે નુકસાન તેનો અભ્યાસ આંતરરાષ્ટ્રીય અર્થશાસ્ત્રમાં કરવામાં આવતો હોય છે. સમગ્ર રીતે જોતાં દેશના વિકાસ માટે મહત્વની બાબત હોય છે.

સંદર્ભ સૂચિ:

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