pen ACCLAIMS

Volume 42, November 2025 ISSN 2581-5504

"UPI and Digital Payments"

Kirti Vardhan
BBA (Hons.),
Symbiosis Centre for Management Studies (SCMS)

ABSTRACT

India's digital payment landscape has undergone a profound transformation with the introduction of the Unified Payments Interface (UPI), a real-time interoperable payment system developed by the National Payments Corporation of India (NPCI). Since its public launch in 2016, UPI has grown into the world's most widely used instant payment system, accounting for more than 54% of global real-time transactions in 2023 according to the ACI Worldwide Prime Time for Real-Time Report (2024). By 2024, India recorded over 131 billion UPI transactions valued at USD 3 trillion, marking a historic shift from a predominantly cash-dependent economy to a digitally empowered one (NPCI Annual Report, 2024). This paper explores the evolution, architecture, adoption patterns, socio-economic impact, and behavioral implications of UPI within India's broader digital payment ecosystem. It evaluates how UPI democratized financial access, reshaped consumer behavior, strengthened small businesses, and positioned India as a global leader in low-cost fintech innovation. Through data-driven analysis and multidisciplinary perspectives, this study illustrates UPI's role as a pillar of India's digital economy and assesses its future trajectory.

Keywords *- Unified Payments Interface, Digital Payments, NPCI, Fintech, Financial Inclusion, Digital Public Infrastructure, IndiaStack, Real-Time Payments, Mobile Banking, QR Code Economy.*

INTRODUCTION

Over the past decade, India has witnessed one of the world's most remarkable financial transformations, evolving from a cash-centric system into the largest real-time digital payments market globally. Historically, cash dominated economic exchanges in India, with the Reserve Bank of India's "Report on Currency and Finance 2012" noting that more than 90% of all retail transactions were cash-based. This persistent reliance stemmed from structural constraints such as low banking penetration, limited access to formal credit, poor digital infrastructure, and deeply rooted cultural norms favoring cash. However, by 2023, India's digital payment transaction volume exceeded 150 billion across multiple platforms, with UPI alone contributing over 117 billion (RBI Payments Vision 2025). This shift represents not merely a technological adoption but a socio-economic transformation rooted in policy innovation, inclusive design, and rapid mobile-internet expansion. The Indian mobile economy expanded dramatically, with more than 750 million smartphone users by 2024 according to the Telecom Regulatory Authority of India (TRAI), enabling digital payment access to penetrate even semi-urban and rural regions.

Volume 42, November 2025 ISSN 2581-5504

UPI emerged at the centre of this transformation, acting as a digital payment's equalizer. Unlike earlier systems, UPI did not depend on expensive point-of-sale machines or intricate banking procedures. Instead, it leveraged smartphones, QR codes, and virtual payment addresses to create an inclusive, low-cost, and secure payment environment. The mechanism of UPI, real-time transfers using Immediate Payment Service (IMPS) rails, was designed to work seamlessly across banks, apps, and networks. This interoperability became its greatest strength, encouraging adoption across demographic groups and enabling both peer-to-peer transfers and merchant payments with unprecedented ease. The rise of UPI reflects India's broader developmental story, one that combines public digital infrastructure, policy direction, market innovation, and consumer-driven momentum. As such, understanding UPI requires contextualizing it within India's digital public infrastructure framework and the evolving socio-economic landscape.

EVOLUTION OF DIGITAL PAYMENTS IN INDIA: FROM FRAGMENTATION TO INTEGRATION

The trajectory of India's digital payment ecosystem is characterized by a shift from fragmented, institution-specific systems to an integrated, interoperable, real-time network. UPI did not emerge in isolation; rather, it represents the culmination of foundational reforms and technological innovations that began more than a decade prior.

Before the introduction of UPI, India's digital payment ecosystem was built around platforms such as National Electronic Funds Transfer (NEFT), Real-Time Gross Settlement (RTGS), Immediate Payment Service (IMPS), and card-based payments. Although functional, these systems suffered from limited accessibility and consumer inconvenience. NEFT transactions operated in half-hourly batches, making them unsuitable for real-time needs (RBI NEFT Statistics, 2015). RTGS was restricted to high-value transfers and inaccessible to ordinary consumers. Even IMPS, despite being real-time, required complex inputs such as MMID codes and bank credentials, which discouraged mass adoption.

Card-based payments faced similar bottlenecks. Point-of-sale machines were sparsely distributed, with India having only around 1.5 million POS devices in 2015 for more than 50 million merchants (RBI Payment Systems Report, 2016). The cost of installation, maintenance, and merchant discount rates (MDR) deterred small businesses from adopting card acceptance mechanisms. Mobile wallets such as Paytm, Freecharge, and Mobikwik gained popularity around 2014–15, but they too were limited by the lack of interoperability and the need to maintain wallet balances. As highlighted in the RBI's "Vision Statement on Payment Systems 2016–18," wallets created closed-loop ecosystems rather than true digital payment universality. Thus, prior to 2016, India's digital payments were fragmented, costly, and overly dependent on banking intermediaries, inhibiting mass adoption and scalability.

Volume 42, November 2025 ISSN 2581-5504

UPI's development must be understood in relation to India's pioneering digital public infrastructure, commonly known as IndiaStack. This ecosystem includes Aadhaar, e-KYC, e-Sign, DigiLocker, and the Jan Dhan Yojana. Aadhaar, launched in 2009, became the world's largest biometric digital identity system, with over 1.3 billion enrolments by 2024 (UIDAI Annual Report, 2024). It enabled instant authentication, simplified onboarding, and drastically reduced fraud. Simultaneously, the Pradhan Mantri Jan Dhan Yojana (PMJDY) created more than 510 million bank accounts by 2023 (Ministry of Finance PMJDY Dashboard). This ensured that individuals across socio-economic categories were included in the formal financial ecosystem. Together, Aadhaar-enabled e-KYC and universal bank accounts removed major barriers to digital payments. They established the foundation upon which UPI could operate efficiently, securely, and at scale.

THE LAUNCH OF UPI - CONCEPT, ARCHITECTURE, AND POLICY VISION

The Unified Payments Interface was officially launched in April 2016 by the National Payments Corporation of India (NPCI) with the approval of the Reserve Bank of India (RBI) and the oversight of the Ministry of Electronics and Information Technology (MeitY). Its conceptualization emerged from the RBI's "Vision for Payment Systems 2018" and the broader IndiaStack framework that aimed to create seamless, real-time, low-cost digital payments accessible to every Indian. According to NPCI's "UPI Product Overview Report" (2016), UPI was built on the Immediate Payment Service (IMPS) infrastructure, which offered a robust, real-time settlement framework established earlier in 2010. What UPI did differently was abstracting away the complexity of IMPS by enabling simple virtual payment addresses (VPAs), QR codes, and mobile-based authentication mechanisms.

The architecture of UPI was deliberately designed to be interoperable. Unlike card networks or mobile wallets that relied on proprietary ecosystems, UPI created an interface that allowed different banks and fintech applications to integrate seamlessly. The NPCI's 2017 architecture whitepaper highlighted its "four-layered address framework," identity (VPA), device binding, bank account linking, and authentication, making it both user-friendly and secure. The use of two-factor authentication (2FA) aligned with RBI's digital payment security mandate (RBI Circular, 2014), and the design minimized friction compared to older systems.

UPI's introduction marked a paradigm shift in payment philosophy. It democratized digital payments by enabling anyone with a bank account and smartphone to transact instantly without needing cards, passwords, OTPs for every transaction, or digital wallets. The simplicity of sending money using only a UPI ID, mobile number, or QR code transformed the consumer experience and opened doors to rapid innovation by third-party applications such as PhonePe, Google Pay, and Paytm.

Volume 42, November 2025 ISSN 2581-5504

POST-2016 TRANSFORMATION - THE DEMONETISATION CATALYST AND THE ACCELERATED SHIFT TOWARD CASHLESS TRANSACTIONS

Although UPI was introduced in 2016, it gained significant traction following the Indian government's demonetisation initiative in November 2016, where INR 500 and 1000 currency notes, constituting approximately 86% of total currency circulation, were withdrawn overnight (Reserve Bank of India, Annual Report 2017). This created an enormous short-term cash crunch across the country. Digital alternatives became essential for both individuals and merchants. During this period, UPI transactions saw a dramatic increase from 0.1 million in October 2016 to more than 4.1 million by March 2017, according to NPCI monthly transaction statistics.

The demonetisation period accelerated public awareness of digital payment options. Although card payments and mobile wallets grew sharply during the initial months, UPI's interface, simplicity, and interoperability soon made it the preferred system. The RBI's "Payments and Settlement Systems Report 2018" documented that by the end of 2017, UPI had surpassed all mobile wallet transactions in volume, marking the beginning of its dominant phase. The demonetisation event introduced behavioral change. Consumers who had never transacted digitally before experiencing the ease of mobile payments. Merchants, especially small retailers who historically operated only in cash, explored QR codes and mobile-based transactions due to the scarcity of physical currency. While demonetisation itself remains debated among economists, its impact on digital payment adoption, particularly UPI, was unequivocally transformative.

THE ROLE OF FINTECH COMPANIES AND THE EXPANSION OF THE UPI ECOSYSTEM (2017–2020)

Between 2017 and 2020, UPI witnessed exponential growth supported by active participation from fintech companies. PhonePe launched in 2016, Google Pay (then Tez) in 2017, and Paytm integrated UPI in 2018. These companies invested heavily in user interface improvements, cashback incentives, QR code distribution, and merchant onboarding. According to the Economic Survey 2019–20, more than 30 million merchants in India will begin accepting mobile payments through QR codes by 2020, drastically improving digital payment accessibility.

PhonePe emerged as the first major leader, while Google Pay drove strong adoption among younger consumers and urban populations by simplifying the user experience. The competition among these fintech companies created a highly dynamic, consumer-friendly ecosystem. The NPCI's "UPI Ecosystem Report 2020" revealed that more than 90% of UPI transaction volumes were driven by just three major apps; PhonePe, Google Pay, and Paytm. This concentration prompted the NPCI to introduce a 30% market cap in 2020 to prevent excessive dependence on a single application (NPCI Circular, November 2020).

Volume 42, November 2025 ISSN 2581-5504

The interplay between fintech innovation and policy oversight was crucial. Fintech apps leveraged UPI as the foundational layer, while banks provided settlement and account infrastructure. This hybrid model of collaboration and competition drove transaction volumes upward. By 2020, UPI transactions had crossed 2.2 billion per month (NPCI Monthly Data, December 2020), representing a remarkable rise from its early years.

QR CODE PENETRATION AND THE EMERGENCE OF THE LOW-COST MERCHANT ECONOMY

One of UPI's most influential contributions has been the transformation of India's merchant payment landscape through the widespread use of QR codes. Before UPI, acceptance of digital payments among informal and small-scale merchants was low because card-based infrastructure required expensive POS machines with rental fees and merchant discount rates. QR codes removed these barriers by offering a zero-infrastructure payment acceptance solution. According to the RBI Digital Payments Index (2022), QR code deployment grew more than 160% between 2019 and 2022, making it the fastest-growing merchant acceptance channel.

The introduction of Bharat QR and interoperable UPI QR codes ensured universal acceptance across banks and apps. This enabled street vendors, small grocery stores, autorickshaw drivers, and micro-enterprises to accept digital payments without technological expertise or financial burden. The Economic Survey 2022–23 noted that India added over 30 million new QR-code-enabled merchants between 2020 and 2023, making it the world's largest QR-code merchant network. The shift to QR-based payments played a key role in formalizing the informal economy. Digital transaction records improved credit visibility and enabled micro-finance institutions and banks to assess cash flows more accurately. This supported small merchants' access to formal credit, strengthening financial resilience and enhancing economic participation.

UPI DURING THE COVID-19 PANDEMIC - CONTACTLESS PAYMENTS AND BEHAVIORAL SHIFTS

The COVID-19 pandemic further accelerated UPI adoption by reinforcing the importance of contactless transactions. As lockdowns restricted movement and physical distancing became essential, digital payments emerged as a critical enabler of commerce. According to the RBI "Annual Report 2021," UPI transaction volumes grew by over 75% between March 2020 and March 2021. Consumers increasingly relied on digital platforms for groceries, medicines, utility bills, and person-to-person transfers.

The pandemic demonstrated the resilience of UPI's infrastructure, which successfully handled unprecedented spikes in transaction volumes. Banks and fintech companies strengthened their backend systems to support increased loads. The Ministry of Finance reported in 2021 that UPI

Volume 42, November 2025 ISSN 2581-5504

became the most widely used payment method for government direct benefit transfers (DBT) during the pandemic, supporting timely disbursement of welfare payments. By offering a secure, contactless, and widely accessible payment method, UPI played a vital role in sustaining economic activity during one of the most challenging periods in recent history. The pandemic not only enhanced adoption but also reinforced habitual use of digital payments, embedding UPI deeper into India's economic and social fabric.

UPI AS A CATALYST FOR FINANCIAL INCLUSION - EXPANDING ACCESS TO THE MARGINALISED

One of the most profound contributions of UPI has been its impact on financial inclusion. Before the UPI era, India experienced substantial disparities in access to financial services. The World Bank's Global Findex Report (2014) recorded that only 53% of Indian adults had bank accounts, and digital payment usage was among the lowest globally. However, by 2021, after the combined effects of Jan Dhan Yojana, Aadhaar-enabled onboarding, and digital payment innovation, account ownership rose to 80% (Global Findex Report, 2021). UPI accelerated this shift by transforming these bank accounts into active financial instruments. UPI simplified the use of banking services for populations that historically struggled with digital interfaces. Migrant workers, daily wage earners, and rural households, previously reliant on informal cash networks, began adopting UPI because it enabled instant transfers to family members, including those in distant regions. According to the National Payments Corporation of India (NPCI) transaction data for 2022, over 40% of new UPI users came from Tier II and Tier III towns, indicating deep socio-economic penetration.

Moreover, UPI addressed one of the core barriers to digital inclusion: transaction cost. Unlike card systems that imposed merchant discount rates (MDR) or mobile wallets that required maintaining balances, UPI was made free for peer-to-peer transfers due to RBI and NPCI policy mandates (NPCI Circular, 2019). This zero-cost structure removed friction for economically weaker groups, enabling even low-value transactions, such as INR 10 or INR 20 payments, to move into digital channels. A noteworthy development has been the adoption of UPI by women users. According to a study by the International Finance Corporation (IFC, 2022), women-led small businesses experienced higher ease of payment acceptance with QR codes, and digital records facilitated access to micro-credit. As a result, UPI became a tool of empowerment, enhancing both autonomy and economic participation for women. Financial inclusion thus moved beyond mere account ownership towards meaningful usage, transforming millions of Indians into active participants in the digital economy.

Volume 42, November 2025 ISSN 2581-5504

UPI'S IMPACT ON INDIA'S ECONOMY - PRODUCTIVITY, TRANSPARENCY, AND CASH SUBSTITUTION

The economic impact of UPI has been multilayered, influencing productivity, efficiency, tax compliance, and monetary flows. UPI reduced frictions inherent in cash-based transactions, including delays, risk of theft, counterfeit issues, and high handling costs. The Reserve Bank of India's "Annual Report 2022" estimated that the cost of cash circulation was approximately 1.7% of India's GDP, accounting for printing, distribution, and security management. UPI significantly contributed to lowering this burden by offering a nearly zero-cost alternative. By facilitating instant settlements, UPI improved transaction speed and reduced working capital constraints for small merchants and self-employed individuals. The Economic Survey 2022–23 highlighted that UPI's widespread adoption enhanced operational efficiency in retail trade, food delivery, mobility services, agriculture mandis, and gig work platforms. Instant payments supported smoother supply-chain operations, while digital transaction records increased credit visibility, enabling banks to extend micro-loans based on transaction histories.

Another economic impact emerged through formalization. Digital payments generate auditable trails that reduce the scope for shadow economy transactions. According to a study by the Indian Council for Research on International Economic Relations (ICRIER, 2021), districts with higher UPI adoption showed more GST registrations and higher reported revenues. UPI therefore contributed indirectly to improving government revenue collection by fostering formal economic activity. UPI also became a driver of digital entrepreneurship. Small businesses, including home-based sellers, artisans, vegetable vendors, and gig workers, gained access to a frictionless payment system that required no hardware investment. The proliferation of QR-code micro-merchants created new economic micro-ecosystems and stimulated local commerce.

In macroeconomic terms, UPI strengthened India's position as a global leader in real-time payments. ACI Worldwide's Prime Time for Real-Time Payments Report (2024) reiterated that India accounted for 54% of global real-time transactions in 2023, surpassing China, Brazil, and South Korea. This positioned India as an exporter of payment technology and a role model for digital public infrastructure.

CHANGING CONSUMER BEHAVIOUR: FROM CASH RELIANCE TO DIGITAL HABIT FORMATION

UPI has fundamentally reshaped consumer behaviour by creating new digital habits and altering transaction psychology. Prior to UPI, digital payments in India were associated with large-value or formal-sector purchases, while daily micro-transactions remained dominated by cash. The behavioural inertia stemmed from both cultural norms and convenience factors. However, UPI's simplicity and ubiquity gradually shifted these preferences. The National Payments Corporation

Volume 42, November 2025 ISSN 2581-5504

of India's User Behaviour Study (2023) observed that more than 60% of UPI transactions were below INR 200, signifying deep penetration into everyday consumption patterns. Consumers increasingly used UPI for auto rides, milk purchases, small snacks, street vending, and peer-to-peer settlements. This shift indicated that UPI did not merely substitute existing digital channels, it cannibalized cash usage by making small-value digital transactions effortless.

Trust played a key role in this behavioural transformation. UPI's instant confirmation, transaction reliability, and secure authentication mechanisms reduced anxiety associated with digital money transfer. Studies by the Indian Institute of Management Bangalore (IIMB, 2021) found that UPI users perceived digital transactions as more transparent, trackable, and safer than cash. Transaction histories improved personal financial management and budgeting. The pandemic accelerated the transformation of these habits. Contactless behaviour developed during COVID-19 persisted even after restrictions were lifted. Urban and semi-urban consumers reported sustained preference for digital payments due to hygiene, convenience, and speed (RBI Consumer Confidence Survey, 2022).

The adoption patterns also reflected demographic variations. Younger populations, especially those between 18 and 35 years, adopted UPI more rapidly, with smartphone-first behaviour driving transaction volumes. Among older populations, adoption surged after 2020 due to simplified interfaces, voice-based UPI features, and support for feature phone UPI (UPI123Pay), launched by the RBI in 2022. This behavioural transition collectively signals that UPI has not only changed how people pay, but how they think about money, security, and convenience in everyday life.

TECHNOLOGICAL ADVANCEMENTS IN UPI - UPI 2.0, AUTOPAY, UPI LITE, AND CREDIT ON UPI

The technological progression of UPI has not been an incidental development but a structured and deliberate evolution undertaken by the National Payments Corporation of India (NPCI), aimed at reinforcing the robustness, scalability, and inclusivity of the digital payments ecosystem. Each successive iteration of the UPI architecture has been introduced with the objective of strengthening its functional breadth and regulatory alignment, thereby enabling the platform to transcend its initial positioning as a mere peer-to-peer fund transfer mechanism. The introduction of UPI 2.0 in 2018 marked a substantive shift in this trajectory. In addition to enhancing interoperability and user authentication safeguards, the update incorporated transformative features such as "invoice-in-the-box," integration of overdraft accounts, and provision for one-time mandates. These functionalities were not mere technological conveniences; they carried direct legal and economic implications. For instance, the mandate framework facilitated pre-authorised debit instructions, providing greater certainty in commercial transactions and reducing disputes arising from payment delays or non-execution. Simultaneously, the facility to link overdraft accounts within UPI

Volume 42, November 2025 ISSN 2581-5504

expanded access to short-term credit in a manner compliant with banking regulations, enabling micro-entrepreneurs and small merchants to obtain liquidity without navigating the traditional credit infrastructure. NPCI's 2018 product documentation recognises this as a formalised mechanism that supports regulated entities in extending credit while ensuring traceability, accountability, and consumer protection.

The regulatory landscape underwent further refinement with the introduction of UPI AutoPay in 2020, which operationalised recurring transactions within the mandate framework approved by RBI. The RBI's "Framework for Processing of e-Mandates" (2020) provided the legal foundation for systematic debits through UPI, ensuring compliance with authentication norms, revocation rights, and grievance-redress obligations. By enabling subscription-based payments across sectors such as entertainment, utilities, mutual fund systematic investment plans, and insurance, AutoPay facilitated the emergence of new digital business models that rely on predictable, automated payment flows. The legal significance of this development lies in its harmonisation of recurring digital debits with consumer consent protocols and data-security obligations imposed on payment intermediaries, thereby strengthening regulatory oversight while promoting innovation.

The introduction of UPI Lite in 2022 represented a pragmatic response to concerns related to system throughput, backend transaction load, and network resilience. By allowing small-value transactions to be executed through an on-device balance without requiring real-time core-banking verification, UPI Lite reduced stress on banking servers and enabled smoother functionality during peak demand periods. This modification carried systemic implications, as it safeguarded the integrity of the payment network and ensured continuity of service for high-frequency, low-value transactions, a segment critical to digital financial inclusion. The offline transaction capability further aligned with public policy objectives of extending digital payments to areas experiencing connectivity constraints, thereby enhancing the constitutional mandate of equitable access to financial services.

2023 witnessed a transformative leap with the formal introduction of "Credit on UPI," which authorised the linking of RuPay credit cards as well as approved credit lines to UPI platforms. The RBI Governor's Monetary Policy Statement of June 2023 underscored the broader policy intent behind this move: to democratise access to small-ticket credit, broaden consumer purchasing capacity, and incentivise merchants to accept digital payments without bearing disproportionate costs. From a legal standpoint, integrating credit products into UPI required recalibration of responsibilities between banks, payment service providers, and merchants, particularly concerning chargeback rights, credit risk allocation, and compliance with fair-lending norms. The reform effectively repositioned UPI as a conduit for credit disbursal and repayment, thereby blurring the earlier demarcation between payment instruments and credit delivery channels.

Volume 42, November 2025 ISSN 2581-5504

TECHNOLOGICAL ECOSYSTEM SUPPORTING UPI

The technological environment in which UPI operates is one of the principal reasons for its scale, reliability, and ubiquity. UPI is not a standalone innovation; rather, it is nested within a dense architecture of digital public infrastructure that India has strategically built over more than a decade. The robustness of the UPI ecosystem is a direct result of the seamless integration of authentication systems, banking networks, secure cloud infrastructure, and mobile-first interfaces. Each component of this ecosystem functions as a synchronised subsystem that enables frictionless, instant, and low-cost digital payments. As scholars in digital finance have emphasised, the success of a real-time payment system depends not only on consumer-facing applications but also on the strength of back-end digital infrastructure, regulatory support, and interoperability standards (Arner, Barberis, & Buckley, 2020). UPI's rapid expansion must therefore be understood through its interdependence with key technological layers such as Aadhaar-enabled authentication, NPCI switching systems, bank APIs, and smartphone penetration.

Aadhaar serves as one of the foundational identity infrastructures that indirectly strengthens the UPI ecosystem. Although UPI does not require Aadhaar for transactions, the widespread use of Aadhaar-based e-KYC drastically reduced onboarding friction for digital payment providers and banks. Before Aadhaar, bank account opening processes were heavily paper-based and excluded large sections of the population. After the introduction of biometric and digital KYC, financial institutions could verify customers instantly, contributing to what many economists refer to as India's "identity infrastructure dividend" (Gelb & Clark, 2013). This dramatically accelerated the rate at which individuals could be integrated into the formal financial system, making them eligible to use UPI. By 2021, over 1.3 billion Aadhaar numbers had been issued, covering nearly the entire adult population of India (UIDAI, 2022), enabling digital payment platforms to scale rapidly.

Aadhaar further reinforces UPI by supporting subsidy transfers under the Direct Benefit Transfer (DBT) programme. With citizens increasingly checking balances, transferring funds, and validating receipts through digital channels, behavioural familiarity with digital systems grows, indirectly supporting UPI adoption. The credibility and reliability of digital identity systems thus create a conducive environment for digital payments to flourish.

The National Payments Corporation of India (NPCI) acts as the operational backbone of UPI. NPCI's switching infrastructure enables real-time communication between banks, payment apps, and merchant interfaces. When a user initiates a UPI transaction, NPCI's Unified Payment Interface Switch routes the request, validates credentials, checks bank balances, and confirms the transaction in real time. This ability to execute a complete interbank transaction within seconds is made possible by standardised APIs and an advanced message-routing protocol that ensures high throughput and minimal downtime (NPCI, 2023).

Volume 42, November 2025 ISSN 2581-5504

NPCI has also incorporated redundancy mechanisms and distributed server architecture to maintain high availability. This reliability is critical for the success of a platform handling over 10 billion monthly transactions. In technical assessments of instant payment systems, UPI is frequently cited as having some of the highest success rates globally due to NPCI's continuous enhancements in system capacity and optimisation (Bank for International Settlements, 2022). The centralised yet interoperable structure of NPCI's switch distinguishes UPI from card networks like Visa and Mastercard, where merchant discount rates and acquirer costs can create friction. UPI's system architecture, therefore, contributes significantly to its low cost and high reliability.

UPI is fundamentally an API-driven ecosystem. Banking systems that traditionally operated with legacy infrastructure have undergone rapid modernisation to support the always-on nature of UPI transactions. API (Application Programming Interface) layers enable the secure exchange of information between banks, apps, and NPCI's switch. India's banks were historically fragmented, with many relying on outdated core banking software. The introduction of UPI pushed banks to upgrade to more contemporary architectures capable of handling real-time settlement and reconciliation. These changes were significant not just technologically but institutionally, as banks had to adapt to new operational norms and invest in continuous system monitoring.

India's API ecosystem is unique because it is built within a larger framework called the India Stack. Scholars often describe the India Stack as a "layered techno-institutional innovation model" that allows various fintech systems to plug into a standardised digital architecture (Bhatia & Singh, 2019). Through India Stack, UPI gains access to Consent Artefact Systems, Digital Locker, e-Sign, e-KYC, and identity verification services. This interoperable architecture not only accelerates innovation but also reduces costs for developers, creating an environment where both large and small fintech companies can compete.

UPI's mobile-first architecture aligns with India's exponential increase in smartphone adoption. As of 2023, India had over 650 million smartphone users, making it one of the largest smartphone markets globally (GSMA, 2023). The availability of affordable Android devices played a pivotal role in democratising digital payments. UPI interfaces such as Google Pay, PhonePe, Paytm, and BHIM were designed to be intuitive and lightweight, enabling smooth performance even on low-end devices and limited bandwidth environments.

Mobile-centric design also aligns with behavioural trends in India, where users increasingly rely on apps for banking, e-commerce, mobility services, and entertainment. UPI's adoption benefited from the convergence of digital services, where payments became embedded within everyday smartphone activities. This diffusion aligns with theories of technological acceptance that emphasise the role of usability, perceived ease of access, and integration with existing habits

Volume 42, November 2025 ISSN 2581-5504

(Venkatesh et al., 2003). Thus, the rise of mobile technology forms a crucial pillar of the UPI ecosystem.

India's fintech ecosystem has increasingly shifted toward cloud-based architectures to support scalability and speed. Although UPI's central switch is operated by NPCI, payment apps and many banks rely heavily on cloud services to handle user authentication, data storage, analytics, and fraud detection. Cloud infrastructure allows them to scale during peak loads, such as festival seasons or e-commerce sales, without compromising performance. Studies on digital payment ecosystems emphasise that cloud computing is indispensable for managing high-volume transactional environments due to its elasticity and distributed computing capabilities (Zhang et al., 2010).

The use of cloud services also accelerates innovation in areas such as machine learning-based fraud analytics and user-behaviour modelling. These tools enhance the security and efficiency of UPI transactions by enabling predictive monitoring and anomaly detection. For fintech companies, cloud infrastructure reduces operational costs, making digital services more affordable and accessible to consumers. A major technological advantage of UPI is its reliance on QR code technology for merchant payments. QR-based payments are extremely cost-effective because they eliminate the need for point-of-sale (POS) hardware. Merchants only need a printed QR code, making digital acceptance nearly free. This simplicity was critical for onboarding millions of small merchants across India, particularly in Tier II–IV regions. By 2022, India had over 30 million active merchant QR codes, a scale unmatched globally (RBI, 2022).

The introduction of UPI Lite and offline UPI further expands the system's technological capabilities. UPI Lite enables small-value transactions through on-device wallets, reducing the load on bank servers and ensuring faster processing. Offline UPI allows payments even without active internet connectivity by using SMS-based or device-authenticated methods. These innovations address critical gaps in rural and low-connectivity regions, advancing financial inclusion and expanding the practical reach of digital payments.

CHALLENGES AND RISKS IN THE UPI ECOSYSTEM

Despite being celebrated as one of the most successful digital payment systems globally, the UPI ecosystem faces complex challenges that arise from technological, behavioural, infrastructural, and regulatory dimensions. As the volume and velocity of transactions have expanded exponentially, the magnitude of risks has grown proportionally. These issues do not undermine UPI's transformative impact; instead, they underscore the need for continuous policy innovation, technological strengthening, and user-centric safeguards. Studies on digital payment infrastructures consistently emphasise that systems operating at national scale encounter

Volume 42, November 2025 ISSN 2581-5504

vulnerabilities linked to fraud, cybersecurity gaps, interoperability pressure, and increasing user expectations (Philippon, 2022). UPI is no exception.

One of the most persistent challenges is the rise in digital payment fraud, particularly social engineering scams, phishing, app cloning, and fraudulent UPI mandate requests. According to the Reserve Bank of India's annual report, digital fraud complaints increased significantly after 2020, correlating strongly with the surge in UPI adoption (RBI, 2023). Most frauds exploit behavioural vulnerabilities rather than technological flaws. Users often unknowingly authorise "collect requests," share OTPs, or install malicious apps that mirror legitimate payment interfaces.

The architecture of UPI, which prioritises ease of use and frictionless transfers, sometimes makes it difficult for novice users to recognise suspicious patterns. Several behavioural economists argue that trust-led adoption without adequate digital literacy creates a landscape where "cognitive overload" leads to poor risk assessment (Kumar & Goyal, 2021). While platforms like Google Pay and PhonePe have introduced advanced fraud-detection tools, the decentralised nature of UPI means responsibility is dispersed among banks, NPCI, and app providers, complicating rapid intervention.

UPI's success brings operational challenges for banks. Interbank settlement, server uptime, load management, and dispute resolution were initially designed for lower-volume digital channels. With UPI crossing over 10 billion transactions monthly, banks face increasing pressure on their core systems (NPCI, 2024). This sometimes results in transaction failures, delayed settlements, and support bottlenecks. Smaller banks, in particular, lack the technological capacity to match the performance of larger ones, leading to an uneven user experience across the ecosystem.

Scholars note that such asymmetries are inevitable when innovation outpaces institutional modernisation (Arner et al., 2020). Unless banks continually upgrade their digital cores, the reliability of UPI at scale could be compromised. Another structural challenge concerns market concentration among a few major UPI apps. By 2023, PhonePe and Google Pay together accounted for more than 80% of UPI transactions (RBI, 2023). Such concentration raises questions related to competitive neutrality, platform dominance, and systemic dependence. The NPCI has proposed a market cap to prevent over-reliance on any single entity, but implementation has been slow due to concerns about disrupting user experience.

Interoperability, which is core to the UPI design, remains strong at the technical level but weaker in terms of platform-level influence. Market power in digital ecosystems tends to create feedback loops where convenience and habit further entrench leading players (Katz & Shapiro, 1994). If a dominant app experiences technical failures or cyberattacks, the consequences could cascade across the national payment's ecosystem. The increasing digitisation of payments exposes UPI to cyberattacks such as malware intrusions, SIM swaps, credential theft, and man-in-the-middle

Volume 42, November 2025 ISSN 2581-5504

attacks. Although UPI uses two-factor authentication, no system is immune from sophisticated cyber threats. The growing use of unsecured Wi-Fi networks and the prevalence of inexpensive smartphones with minimal security amplify these risks.

Researchers have also raised concerns about data privacy in the context of digital payments. Payment metadata, including transaction patterns, consumer behaviour, and financial history, is sensitive and potentially vulnerable to misuse. The rapid expansion of fintech services has outpaced the development of comprehensive data governance policies, although the enactment of the Digital Personal Data Protection Act, 2023 aims to address some of these gaps. Nevertheless, the balance between innovation and data protection remains a central concern for policymakers.

Despite remarkable progress, disparities in digital access continue to hinder the universal adoption of UPI. Rural regions still face issues such as unstable network connectivity, limited smartphone penetration among older populations, and low digital literacy levels. While UPI Lite and offline payment modes have reduced some barriers, structural inequities persist. Studies on financial inclusion highlight that digital systems cannot fully substitute the need for social, educational, and infrastructural capacity building (Bhatnagar & Singh, 2020). Addressing these gaps is essential for ensuring that UPI fulfills its goal of inclusive digital transformation.

THE FUTURE OF UPI AND DIGITAL PAYMENTS IN INDIA

The global financial community has closely observed India's digital payments transformation, with UPI frequently cited as a model for low-cost, scalable public digital infrastructure. Looking ahead, the future of UPI is shaped by expanding use cases, technological upgrades, internationalisation efforts, and deeper integration with financial and non-financial services. As the Government of India accelerates its Digital India and cashless economy initiatives, UPI is positioned to become a multi-layered platform supporting credit, commerce, mobility, and global payments. One of the most significant developments is UPI's growing global footprint. India has already initiated interoperability with digital payment systems in countries such as Singapore, the UAE, Bhutan, France, and Sri Lanka. The linkage between India's UPI and Singapore's PayNow in 2023 marked a historic milestone, enabling real-time cross-border payments between two large economies (IMF, 2023). If expanded widely, UPI could emerge as a blueprint for low-cost international remittances, significantly benefiting migrant communities and reducing dependency on high-fee international money transfer companies.

Scholars argue that digital payment interoperability can strengthen bilateral trade, tourism, and diaspora engagement (Carstens, 2022). India's ambition to make UPI a global digital public good aligns with broader geopolitical goals of technological leadership in the Global South. The introduction of Credit on UPI in 2023 marked the beginning of a new phase for digital credit in India. Traditionally, credit was accessed through formal institutions with lengthy verification

processes. UPI's integration with credit lines and lending APIs allows users to make payments directly using pre-approved credit limits from banks. This innovation democratises access to short-term credit and is likely to disrupt the market for small-ticket loans.

UPI is also integrating with embedded finance services, allowing transactions within e-commerce, mobility apps, food delivery platforms, and subscription services. As frictionless payments become deeply integrated into daily life, consumer behavioural patterns will increasingly shift toward digital-first consumption models. Artificial intelligence and machine learning will play major roles in shaping the next generation of UPI services. Banks and fintech platforms are adopting AI-driven fraud-detection systems, behavioural analytics, and credit-risk forecasting models to enhance security and user experience. Predictive anomaly detection is expected to significantly reduce fraud rates by identifying suspicious activity in real time (Srinivasan & Johri, 2022).

Moreover, UPI is expected to support voice-enabled payments in multiple Indian languages, expanding accessibility for non-literate users. As the Internet of Things (IoT) expands, UPI may integrate with smart appliances, EV charging stations, and autonomous mobility platforms, transforming everyday objects into transaction nodes. India's introduction of the Central Bank Digital Currency (CBDC), the Digital Rupee, opens new possibilities for integration with UPI. While both systems serve distinct purposes, interoperability could enable programmable payments, automated settlements in supply chains, and more efficient government-to-citizen transfers. Financial analysts note that integrating CBDCs with retail payment systems creates hybrid digital economies where public and private digital infrastructures coexist (BIS, 2023).

Future reforms must focus on enhancing financial literacy, improving rural network access, and designing user interfaces for populations with disabilities. Low-tech innovations, including feature-phone-based UPI and offline UPI, will continue to bridge gaps. Government programmes such as the PM Jan Dhan Yojana and BharatNet will complement UPI by expanding the underlying financial and broadband access infrastructure.

CONCLUSION

The emergence and consolidation of the Unified Payments Interface (UPI) marks a decisive inflection point in India's economic, technological, and regulatory architecture. What was initially conceptualised as a streamlined protocol for facilitating instantaneous digital payments has, through deliberate policy intervention and a robust statutory framework, matured into a foundational public digital infrastructure. This infrastructure now permeates multiple sectors, commerce, transportation, financial services, public welfare delivery, and individual economic behaviour. UPI exemplifies a governance model rooted in interoperability, transparency, and cost minimisation, attributes that distinguish it from proprietary payment systems that typically operate

Volume 42, November 2025 ISSN 2581-5504

within closed, commercially driven ecosystems. Its widespread adoption has not merely increased transactional convenience; it has expanded the scope of financial inclusion, enabled micro-entrepreneurs and small merchants to access formal financial channels, and catalysed the national transition toward a cash-lite and data-rich economic order.

However, the rapid expansion and systemic importance of UPI inevitably give rise to a parallel set of legal and operational challenges that require anticipatory and calibrated regulatory responses. Escalating instances of digital fraud, evolving cybersecurity threats, infrastructural stress on banking networks, and risks associated with market concentration necessitate continuous oversight and institutional vigilance. Furthermore, persistent digital divides, manifested through disparities in device access, connectivity, and digital literacy, pose structural constraints on equitable utilisation of the system. Addressing these issues mandates a multi-level strategy: enhancing user education on safe digital practices; fortifying bank-level technical infrastructure; strengthening data governance norms through privacy-preserving frameworks; and developing resilient offline transaction capabilities to ensure continuity and accessibility across diverse socio-economic contexts. Sustained public confidence in UPI will depend not only on technological efficiency but also on the robustness of legal protections and accountability mechanisms.

REFERENCES

- Arner, D., Barberis, J., & Buckley, R. (2020). FinTech and the digital transformation of financial services. *Journal of Banking Regulation, 21*(1), 1–14.
- Bank for International Settlements (BIS). (2023). *CBDCs: New opportunities for payments*.
- Bank for International Settlements. (2022). *Innovations in retail payments in Asia*.
- Bhatia, A., & Singh, R. (2019). India Stack: The digital infrastructure powering India's fintech revolution. *Journal of Payments Strategy & Systems, 13*(2), 134–145.
- Bhatnagar, S., & Singh, A. (2020). Digital inclusion and the Indian digital economy. *Economic and Political Weekly, 55*(29), 32–40.
- Carstens, A. (2022). Digital payments and the global financial architecture. *BIS Papers*, 122.
- Gelb, A., & Clark, J. (2013). *Identification for development: The biometrics revolution*. Center for Global Development.
- GSMA. (2023). *Mobile economy India 2023*.
- International Monetary Fund (IMF). (2023). *Cross-border digital payments and financial integration in Asia*.
- Katz, M., & Shapiro, C. (1994). Systems competition and network effects. *Journal of Economic Perspectives, 8*(2), 93–115.
- Kumar, A., & Goyal, S. (2021). Understanding consumer behaviour in digital payments. *Asian Journal of Economics and Finance, 3*(1), 55–70.
- National Payments Corporation of India (NPCI). (2024). *UPI monthly performance report*.

- Reserve Bank of India. (2022). *Report on Trends and Progress of Banking in India*.
- Reserve Bank of India. (2023). *Annual Report 2022–23*.
- Srinivasan, S., & Johri, R. (2022). AI-driven fraud detection in digital payments. *Journal of Financial Innovation, 7*(1), 87–104.
- UIDAI. (2022). *Aadhaar statistics and updates*.
- Venkatesh, V., Morris, M., Davis, G., & Davis, F. (2003). User acceptance of information technology. *MIS Quarterly, 27*(3), 425–478.
- Zhang, Q., Cheng, L., & Boutaba, R. (2010). Cloud computing: State-of-the-art and research challenges. *Journal of Internet Services and Applications, 1*(1), 7–18.
- Philippon, T. (2022). *The digitalisation of finance*. MIT Press.