



Digital Public Infrastructure

Building Foundations for Empowering Inclusive Digital Nation Society

Executive Summary

Digital Public Infrastructure (DPI) refers to a set of shared, interoperable, and open digital systems and frameworks that provide foundational technology services to enable equitable access, innovation, and socio-economic development across a society.

Often built through public-private partnerships, DPI is designed to be inclusive, scalable, and accessible, serving as the digital equivalent of physical public infrastructure like roads or electricity grids.

DPI encompasses digital platforms and protocols that are typically open-source or standardized, allowing diverse stakeholders—governments, private companies, startups, and individuals—to build upon them.



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Introduction

Digital Public Infrastructure (DPI) refers to a set of shared, interoperable, and open digital systems and frameworks that provide foundational technology services to enable equitable access, innovation, and socio-economic development across a society.

Often built through public-private partnerships, DPI is designed to be inclusive, scalable, and accessible, serving as the digital equivalent of physical public infrastructure like roads or electricity grids.

It supports essential functions such as identity verification, payments, data exchange, and service delivery, empowering governments, businesses, and citizens to participate in a digital economy.

DPI encompasses digital platforms and protocols that are typically open-source or standardized, allowing diverse stakeholders—governments, private companies, startups, and individuals—to build upon them.

Unlike proprietary systems controlled by private corporations, DPI is often governed by public or collaborative entities to ensure transparency, affordability, and broad access.

A prime example is India's India Stack, which integrates layers like Aadhaar (digital identity), Unified Payments Interface (UPI) for payments, DigiLocker for document storage, and the Open Network for Digital Commerce (ONDC) for e-commerce. These components work together to provide seamless, secure, and scalable services, such as instant bank transactions or paperless identity verification, accessible even to rural populations.

Open Systems

The core characteristics of DPI include interoperability, openness, and inclusivity. Interoperability ensures that different systems can work together seamlessly, such as when UPI enables transactions across multiple banking apps.

Openness, often through open APIs or protocols, allows developers to innovate and create new applications, fostering a vibrant ecosystem of services. Inclusivity focuses on bridging the digital divide by ensuring access for underserved communities, such as

through low-cost mobile-based solutions. DPI also prioritizes trust, incorporating robust security and privacy measures, like India's Digital Personal Data Protection (DPDP) Act, which governs data consent and protects user information.

Digital Inclusion

DPI's significance lies in its ability to transform economies and societies by enabling rapid, cost-effective, and inclusive digitalization. For instance, in India, DPI has driven financial inclusion, with UPI facilitating 144 billion transactions in 2024 and Aadhaar enabling 80% of adults to access formal banking.

By reducing costs—such as lowering customer onboarding expenses for banks from \$15 to under \$0.50—DPI empowers small businesses and startups to compete in digital markets. It also streamlines governance, as seen in India's DigiLocker, which hosts billions of documents for efficient service delivery, or the Ayushman Bharat Digital Mission, which supports digital health records.

Globally, DPI is gaining traction as a model for development. Countries like Singapore, Estonia, and Ethiopia are adopting similar frameworks to enhance digital services, inspired by India Stack's success.

Empowering Economic Growth

The World Bank and other organizations recognize DPI's potential to unlock economic value—projected at \$700 billion for India by 2030—while addressing challenges like poverty and inequality.

However, DPI implementation faces hurdles, including the digital divide (e.g., India's 971.5 million internet subscribers in 2024 still leave rural gaps), cybersecurity risks, and privacy concerns, necessitating strong governance and continuous innovation.

In essence, Digital Public Infrastructure is a transformative framework that provides the digital backbone for inclusive, innovative, and efficient societies. By enabling universal access to critical services like identity, payments, and data exchange, DPI fosters

economic growth and social empowerment, serving as a catalyst for global digital transformation.

Comparing DPI Models

Digital Public Infrastructure (DPI) models vary globally, shaped by each country's unique socio-economic context, governance structures, and technological capabilities. While the core components of DPI—digital identity, payment systems, and data exchange—remain consistent, their implementation, scale, and outcomes differ significantly.

This comparison focuses on three prominent DPI models:

India's India Stack, Estonia's X-Road-based e-governance system, and Singapore's digital ecosystem, with references to emerging models in the Global South, such as Brazil and Ukraine. These models illustrate diverse approaches to DPI, highlighting strengths, challenges, and lessons for global adoption.

India Stack

India's India Stack is a comprehensive, scalable DPI framework that has become a global benchmark for inclusive digital transformation. Anchored by Aadhaar, the world's largest biometric identity system with over 1.4 billion registered users, it provides a secure digital ID for accessing services like banking and subsidies.

The Unified Payments Interface (UPI) powers real-time, low-cost digital payments, handling 144 billion transactions in 2024 and achieving over 80% financial inclusion in six years, compared to an estimated 46 years without DPI. Data exchange is facilitated through systems like DigiLocker, which hosts billions of documents, and the Open Network for Digital Commerce (ONDC), which promotes inclusive e-commerce.

India Stack's strength lies in its "bottom-up" approach, leveraging open APIs and public-private partnerships to foster innovation.

Its governance, led by entities like the National Payments Corporation of India (NPCI), emphasizes interoperability and accessibility, though privacy concerns around Aadhaar and the digital divide (971.5 million internet subscribers in 2024, with rural gaps) remain challenges. India's model excels in addressing large, diverse populations but requires robust cybersecurity and sustainable financing to maintain trust.

E-Estonia X-Road

Estonia's DPI, centered on the X-Road data exchange platform, is a model of efficient e-governance tailored to a small, tech-savvy population of 1.3 million. Launched in the 2000s, X-Road enables secure, interoperable data sharing between government and private databases, underpinning services like e-voting, e-health, and digital tax filing.

Over 99% of public services are available online, and citizens use digital IDs for seamless access. Estonia's approach prioritizes transparency, security, and citizen-centric design, with features like decentralized data storage to enhance privacy. Its compact size and high digital literacy (near-universal internet access) enable rapid implementation, unlike India's mass-scale challenges.

However, Estonia's model is less suited for large, diverse populations or low-resource settings due to its reliance on advanced infrastructure and technical expertise.

Singapore

Singapore's DPI model focuses on a highly integrated, government-led digital ecosystem optimized for efficiency and innovation in a small, urbanized population of 5.7 million.

Its digital identity system, SingPass, serves over 4 million users, enabling secure access to government and private services, from banking to healthcare. The city-state's payment systems, like PayNow, support instant transactions, while data-sharing frameworks like MyInfo streamline service delivery.

Singapore's strength lies in its robust governance, high trust in institutions, and advanced infrastructure, with near-100% broadband penetration. It emphasizes cybersecurity and privacy through strict regulations, making it a model for high-income economies. However, its top-down approach and resource-intensive infrastructure may not be replicable in low-income or less centralized countries.

Global South

Emerging models in the Global South, such as Brazil and Ukraine, offer additional perspectives. Brazil's DPI leverages digital payments and identity systems to enhance financial inclusion, with platforms like Pix enabling instant transactions for millions. Its focus on economic growth aligns with India's, but Brazil's implementation is less centralized, reflecting its federal structure. Ukraine's DPI, driven by the Diia platform and ProZorro e-procurement system, emphasizes transparency and anti-corruption, saving \$1 billion annually through digital procurement reforms. Both countries adapt DPI to local needs, but face challenges like uneven infrastructure and digital literacy gaps, similar to India.

Comparing these models, India's India Stack stands out for its scale and inclusivity, addressing a vast, diverse population with low-cost solutions, but it grapples with privacy and rural access issues.

Estonia's X-Road excels in efficiency and transparency for smaller, digitally mature populations, but lacks scalability for larger, less developed contexts. Singapore's model offers unmatched integration and trust but requires significant resources, limiting its applicability in resource-constrained settings. Brazil and Vini provide adaptive, context-specific solutions but are still evolving.

Common challenges across models include ensuring equitable access, managing cybersecurity risks, and securing sustainable financing. The United Nations Development Programme notes that DPI could boost Global South GDP by 20–33% by 2030, but success depends on tailoring solutions to local contexts, as seen in Estonia's citizen-centric design versus India's population-scale approach.

Global adoption of DPI, as seen in initiatives like the G20's 2023 consensus and the 50-in-5 campaign (aiming to support 50 countries by 2028), highlights the need for flexible models. India's open-source, modular approach contrasts with Singapore's centralized system, while Estonia's decentralized data exchange offers a middle ground.

For effective DPI, countries must balance interoperability, governance, and inclusivity, learning from these diverse models to address local needs while leveraging global standards.

DPI Design Model

Legal Entity Identifiers (LEIs)

Implementing [Legal Entity Identifiers](#) (LEIs) using open-source platforms as part of a Digital Public Infrastructure (DPI) strategy involves creating a robust, transparent, and accessible system for issuing, managing, and verifying LEIs to uniquely identify legal entities participating in financial and official transactions.

LEIs, based on the ISO 17442 standard, enhance transparency, reduce counterparty risk, and support regulatory compliance.

Integrating open-source platforms into a DPI framework ensures cost-effectiveness, scalability, interoperability, and alignment with the principles of open data and public good, as championed by the Global Legal Entity Identifier Foundation (GLEIF).

LEIs, based on the ISO 17442 standard, are 20-character alphanumeric codes that uniquely identify entities like companies, funds, or government organizations, providing Level 1 data (entity details such as name and address) and Level 2 data (ownership structures).

As a foundational component of DPI—shared digital systems designed for security, interoperability, and inclusivity—LEIs enhance trust in digital transactions, streamline regulatory compliance, and support use cases like KYC, AML, cross-border payments, and digital identity verification.

Leveraging open-source platforms aligns with DPI's principles of open standards and public good, as championed by the Global Legal Entity Identifier Foundation (GLEIF), ensuring cost-effectiveness and broad adoption.

Open Source Platform

Selecting appropriate open-source platforms and tools is critical for building an LEI system.

GLEIF provides valuable open-source resources under the CC0 license, such as Lenu, a Python library for assigning ISO 20275 Entity Legal Form codes using machine learning, and the GLEIF Level 2 Client/Server for visualizing ownership hierarchies.

Blockchain platforms like Hyperledger Fabric or Corda can support decentralized LEI issuance and vLEI integration, ensuring immutability and trust. OpenAPI can be used to build APIs for accessing GLEIF's Global LEI Index, a public repository of LEI records available via web, API, or downloadable datasets like Golden Copy or Delta Files.

Open-source databases like PostgreSQL or MongoDB can store and query LEI data locally, while tools like Keycloak or OpenID Connect enable integration with digital identity wallets, such as the EU Digital Identity Wallet. GLEIF's mapping tools, which link LEIs to identifiers like OpenCorporates IDs or ISINs, further enhance interoperability.

System Architecture

The system architecture should include core components like an LEI issuance module to interface with GLEIF-accredited LOUs, a verification module using GLEIF's LEI Search API for real-time validation, and a data management module to handle Level 1 and Level 2 data in compliance with GLEIF's Common Data File Format.

Integrating LEIs into digital certificates using open-source cryptography libraries like OpenSSL strengthens transaction security, while vLEIs, built on the KERI protocol, enable decentralized identity verification. The system should align with standards like ISO 20022 for financial messaging and support DPI components like digital wallets or supply chain platforms.

Scalability can be achieved using containerized platforms like Docker or Kubernetes, with robust security measures like encryption and decentralized identifiers (DIDs) to protect data integrity.

Use Cases

Integrating LEIs into DPI use cases unlocks significant value. In cross-border payments, embedding LEIs in ISO 20022 messages, as seen in the Bank of England's CHAPS

system, improves transparency and reduces costs. For KYC and AML compliance, LEIs streamline entity verification by linking to the Global LEI Index, potentially saving billions annually, as estimated by McKinsey.

In supply chains, LEIs support digital platforms like EBSI-ELSA for verifying entities and intellectual property rights, facilitating paperless trade. For digital identity, vLEIs enable secure authentication in systems like digital wallets, while in sustainability reporting, LEIs ensure transparency in ESG frameworks. These use cases demonstrate the versatility of LEIs in enhancing trust and efficiency across DPI applications.

Data Quality

Ensuring data quality and accessibility is paramount. GLEIF's data quality management program, supported by monthly reports and a centralized challenge facility, helps maintain accurate LEI records.

Open-source automation can streamline annual renewals to prevent lapsed LEIs, which could disrupt compliance. The Global LEI Index should be freely accessible via APIs or web-based tools, with support for multilingual records and formats like QR codes or digital signatures to drive adoption.

Implementation and Roadmap

To bring the system to life, pilot projects can test LEI integration within DPI, such as embedding LEIs in digital wallets or supply chain platforms.

A national DPI system, for example, could use Hyperledger Fabric for decentralized issuance, PostgreSQL for data storage, and OpenAPI for LEI Search integration, automating registration, verification, and renewals while visualizing ownership data for regulators. Scaling this system globally requires leveraging GLEIF's LOU network and open-source platforms like Kubernetes.

Challenges like interoperability with existing identifiers, data quality, or resistance to mandatory LEI use can be addressed by using GLEIF's mapping tools, automating data updates, and demonstrating clear benefits like cost savings and faster transactions.

Reference Models

The India Stack

India Stack is a comprehensive set of digital public infrastructure (DPI) layers designed to empower India's digital economy by providing scalable, interoperable, and open-source technology frameworks. It is not a single platform but a collection of APIs, systems, and protocols that enable seamless digital services across government, businesses, and citizens.

Developed through a public-private partnership under the leadership of organizations like the Ministry of Electronics and Information Technology (MeitY) and the National Payments Corporation of India (NPCI), India Stack aims to foster financial inclusion, streamline governance, and drive innovation. Below is an explanation of its key components, significance, and impact, presented in a concise and structured narrative.

What is the India Stack?

India Stack comprises interconnected digital layers that provide foundational infrastructure for identity, payments, data exchange, and digital services. These layers are designed to be modular, allowing developers, businesses, and government entities to build innovative solutions on top of them.

The core idea is to create a “bottom-up” digital ecosystem that prioritizes accessibility, affordability, and inclusivity, enabling India to leapfrog traditional infrastructure challenges. Each layer is interoperable, ensuring seamless integration across sectors like finance, healthcare, education, and governance.

Key Components of India Stack

Aadhaar

The first pillar is Aadhaar, India's biometric-based digital identity system, launched in 2009 by the Unique Identification Authority of India (UIDAI).

Aadhaar assigns a unique 12-digit number to over 1.4 billion residents, verified through biometrics like fingerprints and iris scans. It enables secure, paperless identity verification, supporting services like banking, subsidies, and e-governance. Aadhaar's eKYC (electronic Know Your Customer) API simplifies user onboarding for businesses, reducing costs and fraud.

Unified Payments Interface

The second layer is the Unified Payments Interface (UPI), managed by NPCI, which revolutionized digital payments in India. Launched in 2016, UPI enables real-time, bank-to-bank transactions via mobile devices using simple identifiers like virtual payment addresses.

With over 500 million users and 144 billion transactions in 2024, UPI accounts for nearly 80% of India's retail digital payment volume, making it a global leader in fintech innovation. It powers apps like Google Pay and PhonePe, fostering financial inclusion even in rural areas.

DigiLocker

The third component is DigiLocker, a cloud-based platform for storing and sharing digital documents, such as driving licenses, academic certificates, and government IDs.

Integrated with Aadhaar, it allows secure, paperless access to verified documents, streamlining processes like loan applications or government service requests. As of 2025, DigiLocker has over 300 million users and hosts billions of documents, enhancing efficiency in governance and citizen services.

Digital Personal Data Protection (DPDP) Act

Another critical layer is the Digital Personal Data Protection (DPDP) Act framework, which governs data privacy and consent management. The Data Empowerment and Protection Architecture (DEPA) enables individuals to control and share their data securely through consent managers, fostering trust in digital transactions. This is particularly vital for sectors like healthcare and finance, where sensitive data exchange is common.

Open Network for Digital Commerce

The Open Network for Digital Commerce (ONDC), launched in 2021, is an emerging layer aimed at democratizing e-commerce. ONDC creates an open protocol for buyers and sellers to connect across platforms, reducing reliance on monopolistic marketplaces like Amazon. It supports small businesses and local vendors, promoting inclusive digital commerce. By 2025, ONDC has onboarded thousands of sellers, with pilots in cities like Bengaluru showing significant growth potential.

Significance and Impact

India Stack's open APIs and interoperable design have transformed India's digital landscape by enabling rapid, cost-effective scaling of services. For instance, Aadhaar and UPI have reduced the cost of customer onboarding for banks from \$15 to less than \$0.50, while enabling 80% of Indian adults to access formal banking by 2024. The stack's infrastructure supports over 10 million daily eKYC verifications and processes 50% of global real-time payment transactions by volume, showcasing its global influence.

Economically, India Stack is projected to unlock \$700 billion in opportunities by 2030, as noted by experts like Arvind Gupta of the Digital India Foundation. It empowers startups and developers to innovate, with thousands of fintech, edtech, and healthtech solutions built on its APIs. Socially, it promotes inclusion by bringing unbanked populations, especially in rural areas, into the formal economy. For example, UPI's simplicity has enabled street vendors to accept digital payments, while Aadhaar-linked subsidies ensure direct benefit transfers, reducing leakage.

India Stack also enhances governance through initiatives like the Ayushman Bharat Digital Mission, which uses its infrastructure for digital health records, and eSign, which facilitates legally valid digital signatures.

These tools streamline public service delivery, making government interactions more transparent and efficient. Globally, India Stack serves as a model for DPI, with countries like Singapore and Ethiopia exploring similar frameworks.

Challenges and Criticisms

Despite its successes, India Stack faces challenges. Privacy concerns around Aadhaar's biometric data have sparked debates, though the DPDP Act aims to address these through robust consent mechanisms.

The digital divide remains a hurdle, with 971.5 million internet subscribers as of September 2024 but significant gaps in rural connectivity and digital literacy. Cybersecurity risks, such as Aadhaar-related frauds, necessitate ongoing innovations like UIDAI's Finger Minutiae Record-Finger Image Record system. Additionally, ONDC's adoption is still in early stages, facing competition from established e-commerce giants.

Conclusion

India Stack is a transformative digital framework that integrates identity, payments, data, and commerce to create an inclusive, scalable, and innovative ecosystem. By leveraging open APIs and public-private collaboration, it has redefined financial inclusion, governance, and economic opportunity in India, setting a global benchmark for DPI.

However, addressing privacy, security, and accessibility challenges is crucial to sustaining its impact. For more details, visit www.indiastack.org. If you'd like a deeper dive into a specific component, such as UPI or ONDC, let me know!