FOUNDATIONS OF DIGITAL PUBLIC INFRASTRUCTURE

RIS
Research and Information System for Developing Countries
विकासशील देशों की अनुसंधान एवं सूचना प्रणाली

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Rajeev Chawala

Arun Iyer

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Zone IV B, 4th Floor, India Habitat Centre
Lodhi Road, New Delhi 110 003, India
Tel.: +91-11-24682177-80
E-mail: dgoffice@ris.org.in, Website: www.ris.org.in

Note: This document is designed for practitioners engaged in DPI initiatives (including advisors, consultants, senior officials, bureaucrats, technocrats, and architects) both within India and in international collaborations.

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Preface

Professor Sachin Chaturvedi
Vice-Chancellor, Nalanda University and Director General, RIS

Over three decades of practice of development economics globally, it has been observed that the focus of infrastructure development has shifted from physical to digital infrastructure as a key driver of socio-economic growth. The COVID-19 pandemic fundamentally altered our understanding of infrastructure's role in economic and social systems. As supply chains collapsed and aggregate demand shifted dramatically worldwide, India stood as a remarkable counterpoint. Its robust digital infrastructure enabled the country not only to battle the pandemic effectively by helping in vaccine administration, but also to sustain the economy by facilitating direct benefits transfers and accelerating digital commerce during the crisis. While global digital payment systems struggled, India witnessed a more than 50 per cent increase in monthly transaction volumes across its digital payment platforms within six months of the initial lockdown.

RIS in the past has undertaken studies on digitally enhanced infrastructures, systems that leverage digital technology to create significant improvements in decision-making, financing, and governance outcomes. India's layered approach to digital public infrastructure (DPI) might be one of the most grounded, real-world application of this concept. What strikes most about the framework described in this handbook, is the interoperable and inclusive nature of its three main layers - identity, payments, and data exchange, combined with a design that allows space for private sector innovation within a governance-led ecosystem.

For policymakers across Africa, Latin America, and Southeast Asia, many of whom grapple with similar infrastructure constraints, the insights presented here offer a practical approach for building digitally enhanced infrastructures that serve national development goals. The emphasis on modular design, institutional safeguards, and ecosystem thinking presents a compelling framework for countries to adapt the DPI principles to their specific national contexts and development goals.

As we look ahead to the coming decade, navigating complex challenges will require institutions and countries to respond in a collaborative manner. The institutional innovations documented in this publication offer insights into designing digital infrastructure that embeds safeguards by design, promotes diverse participation, and is governed by principles of equity and inclusion. Development cooperation will increasingly depend on our capacity to create such infrastructure as genuine public goods.

We are glad that Mr Rajeev Chawla and Mr Arun Iyer have come out with this very interesting and useful paper. We are sure it will serve as an important reference for all stakeholders, practitioners, academicians and policy makers. Thanks are also due to RIS publication team for the elegant designing and printing of this publication.

Sachin Chaturvedi

Introduction

The past 25 years have seen starkly different trajectories of how digital transformation has shaped the world. Digital transformation has pervaded global boundaries and enabled all countries including developing nations to participate in the digital economy alongside developed countries.

In the United States, technology domination has been largely driven by innovative private corporations. Their growth, fueled by risk capital, platform-centric thinking, and minimal regulatory oversight, led to tech giants like Google, Meta, Microsoft, and Amazon achieving global dominance. However, this concentration of power with the BigTech has raised growing concerns around privacy, market concentration, digital sovereignty, and competitive fairness.

Unlike the United States, Europe and Japan adopted a more regulated approach, prioritizing digital sovereignty and consumer protection. Their model, shaped by legacy institutions and strong public oversight, led to slower platform development but prioritized ethical standards and citizen rights.

By contrast, China pursued a state-controlled yet commercially executed model. With strong national control over data, platforms, and digital infrastructure, China built a parallel, tightly governed ecosystem shielded from the global tech giants. It was characterized by data sovereignty laws, state-led innovation, and surveillance mechanisms deeply embedded into the digital infrastructure.

India carved out a hybrid path which included a state-led but market-friendly approach making it a digital-first nation in a decade. India's digital transformation has been powered by government-built public infrastructure, with private sector collaboration from startups, banks, and telecoms who innovated and delivered last-mile services. Pioneering platforms such as Aadhaar (a biometric digital identity system) and Unified Payments Interface, aka UPI (a real-time digital payments system) have gained widespread adoption. India's citizen-first model which focuses on being open, inclusive, and affordable by design, is now regarded as a global template for digitalisation led economic development.

Why This Matters to the Global South

These different trajectories of digital transformation offer valuable lessons to developing nations aiming to use technology for socio-economic advancement.

Many nations in the Global South face an innovation deficit or the inability to address local challenges due to weak infrastructure, limited technical talent, rigid regulations, low R&D spending, and limited collaboration between the public and private sectors.

Relying on privately controlled platforms to provide essential digital services can result in either millions being left behind, or included at a higher cost, financially or via loss of user agency and data privacy. For example, a rural entrepreneur in Africa may access digital payment only through a proprietary app like M-PESA, incurring high fees while surrendering personal data. In contrast, an Indian entrepreneur can use UPI, a government-designed infrastructure, at negligible costs.

Similarly, market-driven platforms may leave out entire communities if they do not see a return on investment, whereas India's model enables inclusive participation by ensuring open access to its digital infrastructure.

India's Inclusive Digital Model: A Global Template

India's experience demonstrates that a government-led approach, of building open (accessible equally to all service providers) and interoperable (allowing different systems to work together seamlessly) digital foundation, and designed with sovereignty, autonomy, security and public interest in mind, can enable the private sector to innovate and deliver essential services at population scale.

While India's approach has not been without challenges, including issues around scalability, and concerns about data privacy, and governance, these concerns have been progressively addressed as the ecosystem has matured. India's remarkable success in building a digital backbone that benefits the entire population, offers a compelling roadmap for other nations embarking on this journey.

In this handbook we explore key elements of India's digital transformation approach and its underlying architecture including.

- the key components of India's Digital Public Infrastructure (DPI)
- the role of public technology and institutional frameworks in enabling population-scale service delivery
- how interoperability of these DPIs has enabled public and private partnership to drive innovation
- how India's techno-legal approach ensures trust, privacy, and citizen empowerment
- and the five DPI Sutras (guiding principles) for a sustainable, inclusive, and future-ready digital ecosystem

Role of Digital Public Infrastructure in Nation Building - The India Story

The Challenge: Rajni's Story

Circa 2010, in the heartland of rural India a middle aged home-maker, Rajni, trying to earn additional income for her family via home-based tailoring, lived in the fringes of India's formal economy.

- She did not have a digital identity resulting in exclusion from a number of essential services and was vulnerable to exploitation.
- All of her daily payment transactions were conducted in cash.
- With the nearest bank located miles away, opening an account was burdensome, weighed down by layers of paperwork.

As her home-business grew, Rajni intended to purchase an electric sewing machine and other supplies which would have cost her ₹50,000 (approximately $1100 at that time). However, with no formal credit history available, a loan would be available only via a local money lender at an exorbitant interest rate.

Dreams of expanding her business remained just that.

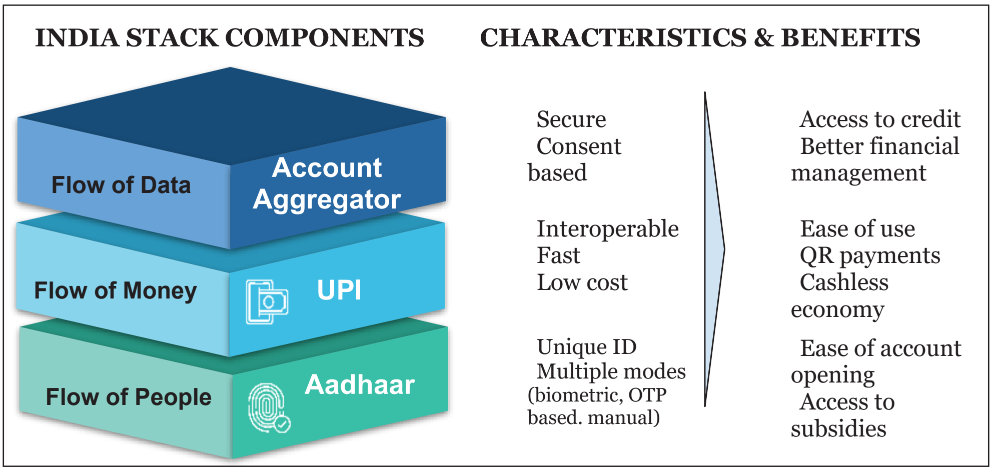
The Solution: India Stack

Change was on the horizon for Rajni and millions like her. India brought the JAM trinity, namely Jan Dhan bank accounts, Aadhaar identity, and Mobile connectivity, to life. This laid the groundwork for India Stack to reach every Indian citizen.

India Stack comprises three core public utilities - identity, payments, and data that are open, interoperable, inclusive and well governed:

- **Flow of People (Identity):** India's digital identity system - Aadhaar, enables seamless verification and authentication of its citizens providing them access to a variety of services across health, banking, and telecom.
- **Flow of Money (Payments):** India's digital payment system - UPI, a real-time payment system that facilitates money transfers between any two individuals/businesses.
- **Flow of Information (Data):** A secure data sharing protocol known as the Account Aggregator framework (based on Data Empowerment and Protection Architecture or DEPA), enables consent-based information sharing for services like credit, healthcare, and e-commerce.

Figure 1: India Stack - The Three Core Digital Public Utilities



Source: ProductNation – iSPIRT.

Today, due to India Stack, Rajni is now digitally visible:

- Aadhaar has given her a digital identity.
- She has opened a bank account at her local bank within minutes, with minimal paperwork by using Aadhaar eKYC (Know Your Customer)
- She has bought a basic mobile smartphone and uses UPI QR codes to receive real-time payments directly into her bank account.
- As her digital payment history gets gradually built, she has given the local Non Banking Financial Company (NBFC) consent, i.e. permission, to access her financial transactions using the Account Aggregator framework and assess her credit worthiness.
- Finally, she has obtained a working capital loan from the NBFC to set up her independent business.

Like Ranjni the India Stack has enabled billions of Indians to become digital-first citizens and get access to a variety of digitally enabled services across social benefits, finance, telecom, and health.

Figure 2: Benefits of India Stack

Authenticated Citizens	=	1.4B	People with Digital identity	=	27.07B Aadhaar authentications in FY 2024-25
Financially Included Society	=	$280B	Monthly UPI transaction by value	=	185.86B UPI transactions in FY 2024-25
		45%	Increase in bank accounts in 7 years	=	Reduction in onboarding costs $7 to $0.4
A Healthy Nation	=	2.2B	COVID-19 vaccines administered using CoWIN	=	739M ABHA Health IDs created
Financially Included Society	=	8.5B	Documents issued on Digilocker	=	533M registered users on Digilocker
		14M	GST registered taxpayers	=	18.5% Combined tax-GDP ratio in FY 2023-24
	=	A Digital First Nation			

Source: Citizen's Stack - India's DPI Journey.

How Has India Stack Managed to Achieve This?

India Stack's interoperable architecture ensures users can seamlessly choose any service provider across banking, payments, and data sharing without being locked into specific platforms or institutions.

Rajni can use Aadhaar authentication to open an account with any bank of her choice. Similarly, she can link one or more bank accounts with any UPI application of her choice. She can give consent to share her financial data with more than one financial institution via any Account Aggregator. There is no tie-in with any entity to avail any of the India Stack enabled services.

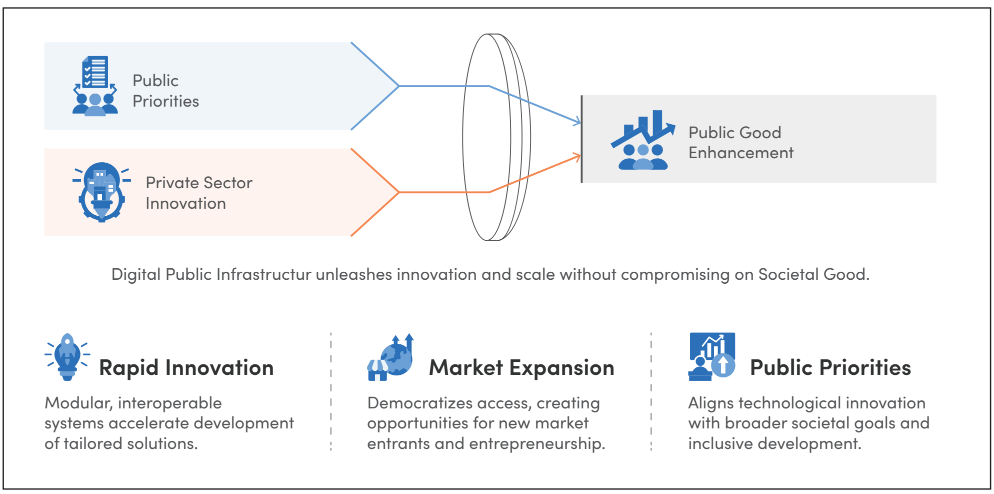
- This interoperability is enabled by an open, standards based design and supported by an ecosystem of private and public entities (tech innovators, startups, fintechs, banks etc.) that are allowed to build value-added services on top of the platform. This makes India Stack a privately provisioned, yet publicly accessible (refer Glossary) utility, extending its reach to remote populations.
- Widespread accessibility makes the utilities inclusive, as they are non-excludable (all citizens have an equal right to access them) and non-rivalrous (usage by one citizen does not diminish the availability to others).

- These public utilities are owned/managed by an appropriately structured, non-profit operating entity, namely Unique Identification Authority of India (UIDAI) for Aadhaar, National Payments Corporation of India (NPCI) for UPI and *Sahamati* for Account Aggregation. Each entity provides operational oversight and ensures accountability.
- Overall governance is ensured by a regulator through the issuance of regulatory policies and guidelines.
- These public utilities are designed on the guiding principles of sovereignty, autonomy, safety and security.

The Impact: Digital Public Infrastructure DPI

The above-mentioned characteristics qualify the India Stack utilities as Digital Public Infrastructure (DPI). The model is akin to that of modern airports: private entities operate them using their technical and operational expertise, while the government sets transparent rules and incentive mechanisms to ensure that they function under public oversight - serving all citizens and not just premium users.

Figure 3: India Stack Approach of Combining Public Infrastructure With Private Innovation



Source: ProductNation – iSPIRT.

One might wonder why SWIFT, a globally accepted financial messaging protocol enabling bank interoperability, is not considered a DPI. SWIFT is a privately owned, membership-based cooperative that is not open-source, not non-excludable (access is restricted to approved members), and not governed by a public regulatory or legal framework. It falls short of DPI's open, inclusive, and publicly governed principles.

Another common misconception is using the terms Digital Public Good (DPG) and DPI interchangeably. While similar, they are fundamentally different. As list below.

DPGs are **technological assets** - open-source software adhering to principles like privacy, inclusivity, ethical design, and Sustainable Development Goals (SDG) alignment.

DPI has a broader scope, involving population-scale implementation of digital systems encompassing technology, legal & regulatory frameworks, policy decisions, funding mechanisms, institutional governance, and ecosystem building.

Aadhaar qualifies as a DPI as it incorporates all these elements. In contrast, Modular Open Source Identity Platform (MOSIP) is an open-source foundational building block (refer Glossary) for digital identity systems and is formally classified as a DPG. MOSIP has been adopted and extended by several countries to build their own digital identity platform as a DPI.

Building Digital Public Infrastructure

Establishing a DPI goes far beyond building and deploying digital technology. It involves a comprehensive set of considerations including regulatory governance, institutional capacity, policy decisions, and ecosystem development.

India Stack shows how a DPI can be systematically constructed, by taking a 4-layered approach.

The Layers of DPI Ecosystem

1. Layer 1 - Public Tech

At the core of any DPI lies public technology. Public tech (refer Glossary) refers to foundational technologies that are accessible and available for public use, development, or broader societal benefits.

Public tech can be protocols (a set of rules and standards that enable digital systems to communicate and operate together) and/or platforms (systems that enable service delivery). Public tech can function as standalone components or be integrated into various digital systems.

In the case of India Stack, the underlying public techs include:

- **Aadhaar:** The public tech consists of the centralized identity layer and biometric-based identity authentication APIs (Application Programming Interface). They enable secure, real-time verification of individuals.
- **UPI:** The core public tech consists of the Virtual Private Address (VPA) based payment routing protocol, user authentication APIs, and the underlying Immediate Payment Service (IMPS) rails that enable instant, 24/7 fund transfers between any two bank accounts.

- **Account Aggregator:** Here, the public tech consists of consent-based data sharing APIs that facilitate secure and user-controlled exchange of financial data.

Public Tech provides the foundational building blocks that enable open, interoperable, and scalable digital systems. When a public tech meets the formal criteria, such as alignment with a Sustainable Development Goal, do-no-harm principles, privacy and inclusivity it becomes a DPG.

MOSIP is an example of a public tech that demonstrates a strong sustainable model by combining open-source architecture, modularity, privacy compliance, in-built consent mechanism and alignment with SDG 16.9 - 'provide legal identity for all'. This qualifies MOSIP to also be classified as a Digital Public Good.

In this document, 'public tech' and 'DPG' are used interchangeably for simplicity.

2. Layer 2 - Digital Public Infrastructure

There is often confusion in defining what constitutes a DPI. Take UPI as an example:

- Some may consider the underlying payment routing protocol of the UPI as the DPI itself.
- Others might see UPI more broadly, encompassing the entire infrastructure including NPCI's backend servers, the switches, APIs, and protocols that facilitate the transactions.
- Some may even include consumer-facing UPI apps to be part of the DPI.

This variation in interpretation highlights an important distinction between public tech and DPI. Whereas a DPI's core technology may be implemented using one or more public tech, the DPI in itself is much more than the technology.

A robust DPI represents an integrated framework that enables citizen-centric service delivery at population scale and is defined by four essential characteristics:

- **Interoperability:** Integrates seamlessly with other systems and platforms, enabling secure and efficient data exchange.
- **Scalability:** Designed for large-scale adoption, capable of handling millions or like in India's case, billions of users.
- **Inclusivity:** Upholds the non-excludable and non-rivalrous principles of a public good, ensuring unrestricted access for governments, businesses, and individuals, including marginalized communities.
- **Governance:** Requires robust governance through transparent institutional

frameworks, accountable oversight, and participatory policymaking that safeguard public interest.

- There are several approaches to provisioning any digital infrastructure / utility, each with its own benefits and limitations:
- **Privately Run Digital Utilities:** Commercial platforms developed by private entities often provide superior user experience, faster product cycles, and continuous innovation. However, they optimize for profit maximization, which can prioritize high-value users. This model risks evolving into toll collector monopoly marked by high fees, limited access, and weakened data privacy.
- **Government Technology aka GovTech:** Digital utilities developed and operated by governments offer high public legitimacy, legal authority, and accountability. However, they risk ossification—becoming inflexible, outdated, and resistant to innovation over time.
- **DPI Approach:** Centers on establishing a robust governance framework that balances regulatory oversight with operational autonomy and institutional accountability, while fostering a vibrant private sector ecosystem around the core DPI platform to drive innovation, enhance service delivery, and accelerate adoption.

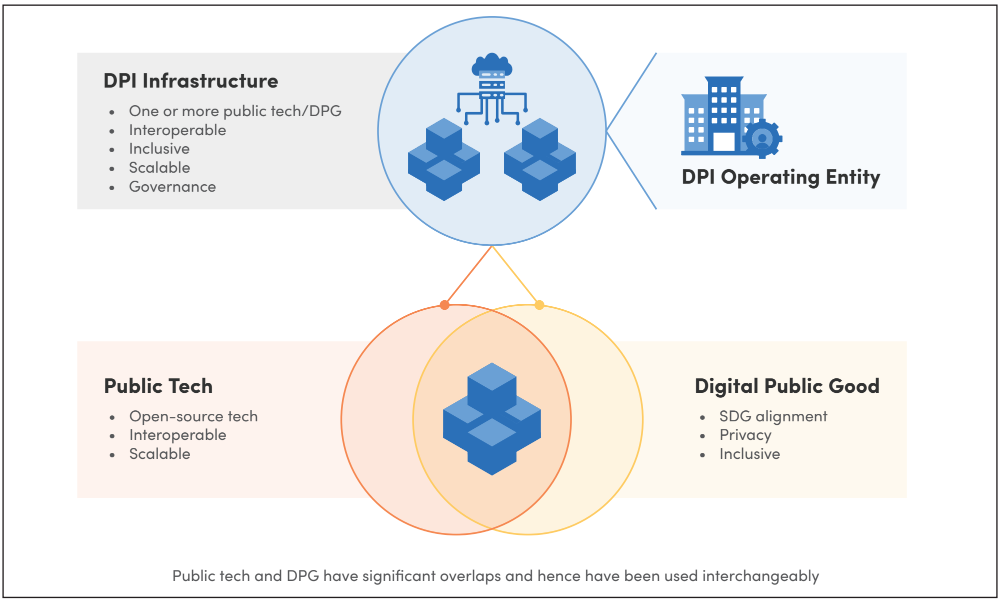
The DPI Approach is unique in that the institutional governance by an independent and accountable DPI Operating Entity is crucial to its success. These are typically purpose-built entities that may adopt one of many institutional architectures tailored to the specific DPI function. Importantly, they are neither traditional government agencies nor conventional private enterprises, but entities designed to combine public purpose with operational agility.

Thus in case of India Stack:

- **UIDAI** is a statutory government entity under the Ministry of Electronics and Information Technology. It is both a regulator (under the Aadhaar Act) and operator of the Aadhaar infrastructure. It oversees other players in the Aadhaar ecosystem and ensures compliance.
- **NPCI** is a not-for-profit organization owned by a consortium of banks. It owns and operates the UPI infrastructure while establishing technical and operational standards, and security protocols. However, it does not perform regulatory functions, which are instead overseen by the Reserve Bank of India (RBI).
- '**Sahamati**' is a not-for-profit private limited company, promoted by a member-driven industry alliance. Despite not hosting infrastructure or offering direct-to-user services, it operates as a Self Regulated Organization by developing and enforcing standards, enabling collaboration and fostering growth of the Account Aggregator ecosystem.

- This institutional diversity demonstrates one of the core principles of DPI: a flexible governance architecture that adapts to each of India Stack's unique requirements — ensuring innovation, accountability, and sustainability.
- To summarize, Digital Public Infrastructure comprises the following key elements:
  - » **DPI Platform:** A foundational technology layer that may be built using one or more public tech components designed for scale, interoperability, and inclusion.
  - » **DPI Operating Entity:** A dedicated organization that provides institutional governance, ensures technical reliability, and upholds accountability to the public interest.

Figure 4: Public Tech vs DPG vs DPI



Source: Adapted from Govstack Definitions, Digital Public Goods Alliance.

3. Layer 3 - DPI Network (Market Place)

The DPI Network extends beyond the core infrastructure to form an interconnected ecosystem of entities. It comprises the following key components:

A. Market Participants:

These include banks, fintechs, startups, technology providers, and service providers that leverage the DPI to develop innovative solutions. By lowering entry barriers and enabling seamless collaboration, India Stack has fostered a vibrant ecosystem where startups and institutions can co-create innovative services and new business models.

India's approach has effectively democratized digital innovation, making it accessible not only to governments and big techs but also to small businesses and grassroots innovators.

B. Interoperability with Other DPIs:

The true potential of DPIs is unlocked through combinatorial innovation – when multiple DPIs operate together to create entirely new services, markets, and business models.

This interoperability has enabled the emergence of next-generation, marketplace DPIs, in crucial areas like flow of credit and flow of commerce:

- **Flow of credit:** Open Credit Enablement Network (OCEN) is a standardized lending protocol that connects lenders and borrowers via digital marketplaces. It enables use of alternative data sources and custom credit models to expand credit access to underserved individuals and small businesses.
- **Flow of commerce:** Open Network for Digital Commerce (ONDC) democratizes e-commerce by enabling buyers and sellers to transact across interoperable platforms. By using standards and protocols, it promotes competition, better price discovery, and levels the playing field for smaller businesses.

Both OCEN and ONDC demonstrate the combinatorial power of DPI. Built using core public tech components and leveraging open APIs and services from Aadhaar, UPI, and Account Aggregator framework, these marketplace DPIs unlock entirely new use-cases.

4. Layer 4 - Digital Economy (Playground)

While the DPI Network forms the core of a digitally empowered society, it operates within a larger digital economy comprising a diverse stakeholders:

A. Regulators: Ensuring Compliance, Fairness, and Public Interest

Regulators are responsible for creating the legal and institutional framework that governs all participants and protects user interests. Their responsibilities include:

- Establishing policy and regulatory frameworks for both the DPI platform and its operating entity.
- Governing the network participants to ensure fair competition, transparency, and ethical conduct.
- Protecting end-user rights, including accessibility, data privacy, security, grievance redressal, and freedom of choice.

B. Parallel Networks: Coexisting with DPI

While DPI's unique proposition is its low-cost, and inclusive digital infrastructure aimed at greater public good, it does not exist in isolation. DPIs coexist harmoniously alongside other parallel networks. These privately owned networks may prioritize profitability or market dominance while often sharing the same stakeholders as the DPI.

Examples of such coexistence are listed in the Table 1. These examples illustrate that DPI and private ecosystems are not mutually exclusive, but rather part of a pluralistic digital economy that offers users flexibility and choice.

C. Other Enablers: Supporting Ecosystem Growth

A variety of entities play crucial roles in supporting the incubation, development, and adoption of the DPI:

- Service Providers - Offer technology services, infrastructure, system integration, certification, audit services, and consulting to support DPI operations and innovation.
- Academia and Think Tank - Serve as intellectual anchors by contributing

Table 1: Coexisting Ecosystems

Coexisting Ecosystems	DPI Network's Objective	Parallel Network's Objective	Shared Stakeholder
UPI vs. **Visa/ Mastercard**	UPI is designed to promote financial inclusion, autonomy, and low-cost digital payments.	Visa and Mastercard are global payment platforms focused on profitability and market share.	Banks act as Issuers or acquirers in both cases
OCEN vs. **Traditional Lending Networks**	OCEN enables underbanked borrowers to participate in the Credit economy by leveraging alternative data sources (invoices, GST, bank statements, etc.) via a decentralized market place.	The traditional lending networks rely on creditworthiness based underwriting and direct relationships with borrowers.	Banks act as lenders in both cases
ONDC vs. **Amazon/ Flipkart**	ONDC promotes an open, decentralized e-commerce network that fosters inclusive market participation for businesses of all sizes.	Amazon and Flipkart, on the other hand, operate closed, proprietary ecosystems at scale, focused on market share and profitability.	Buyers and sellers may use both networks

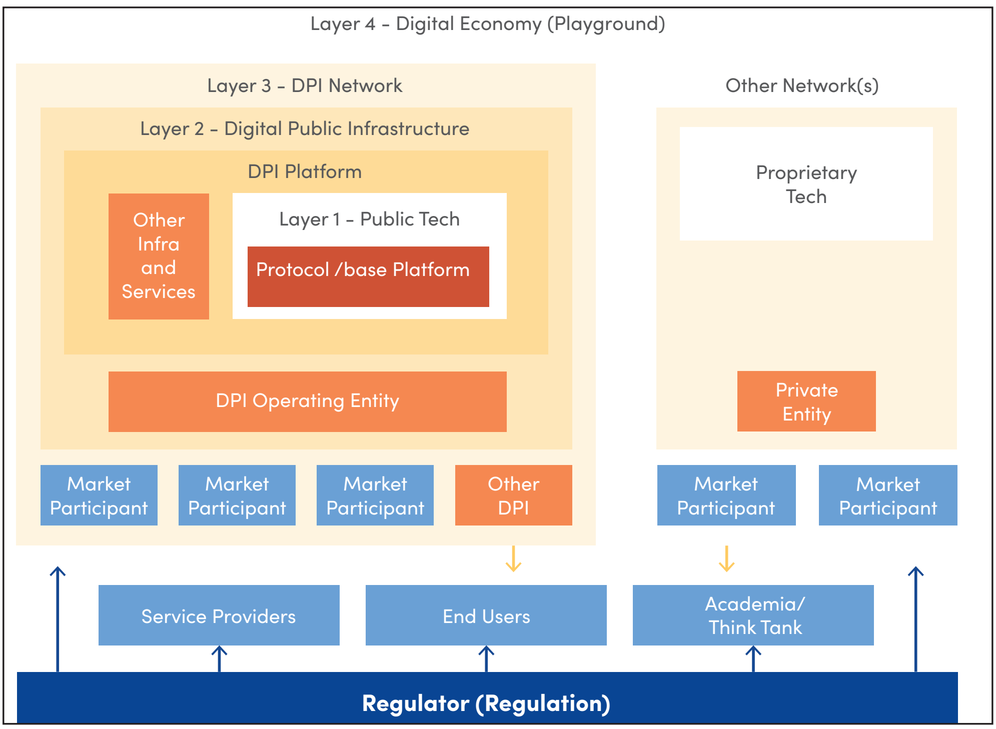
Source: Author's compilation.

to research & knowledge generation, policy formulation, capacity building and training, standards development and benchmarking, and ecosystem design and facilitation. For Example, iSPIRT - a volunteer-led think tank is instrumental in conceptualizing and evangelizing India's DPIs, and International Institute of Information Technology (IIIT), Bangalore - a premier technology and research institute that has incubated MOSIP, an open-source identity platform now adopted globally in 26+ countries.

D. End Users: The Beneficiaries

End users including individuals, businesses, merchants, and government entities are the ultimate beneficiaries of the digital economy. They have the freedom to choose the most suitable platforms or services based on factors like cost, trust, accessibility, and convenience.

Figure 5: The Four Layers of a DPI Ecosystem



Source: Author's compilation.

The Four Layers of the UPI Ecosystem: A DPI in Action

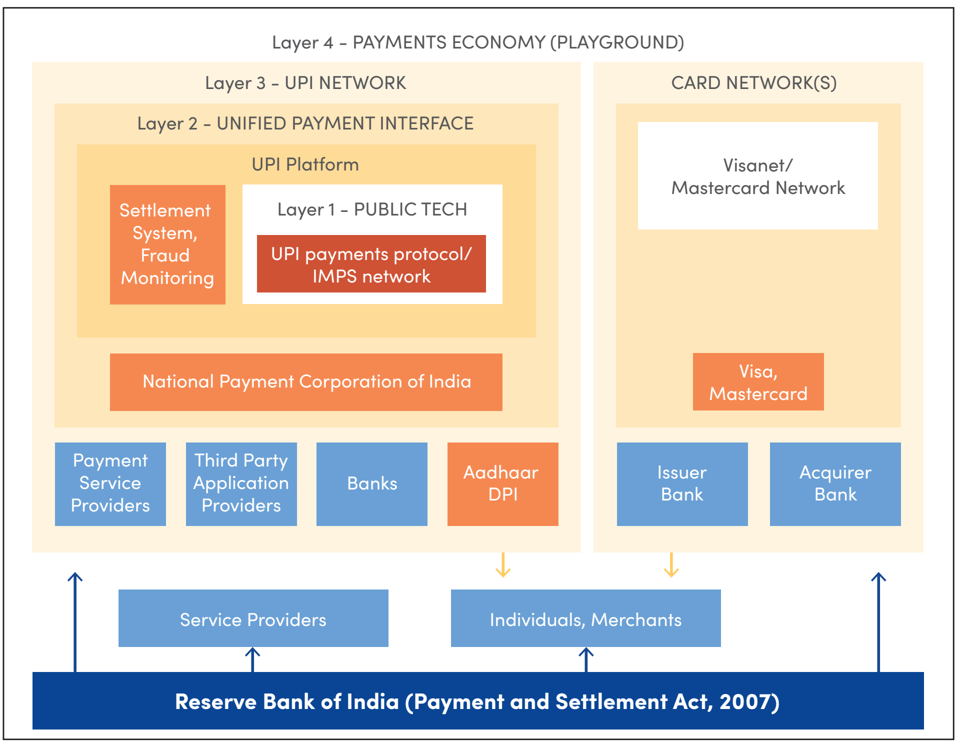
UPI is a powerful example of digital utility that functions as a full-fledged DPI. Its design and implementation span the four distinct but interconnected layers:

- **UPI Public Tech**: The foundational layer comprises the messaging standards & payment routing protocols, IMPS payments rails and

Standardized payment APIs. Together they enable seamless integration and interoperability.

- **UPI Digital Public Infrastructure:** This layer combines the core UPI platform (including backend servers, settlement infrastructure, and service APIs) and the UPI operating entity, namely NPCI
- **UPI Network**: This includes all the stakeholders that interact with or make up the UPI ecosystem, such as the Issuer and Acquirer banks, Payment Service Providers (banks offering UPI settlement services), Third Party Application Providers (like PhonePe, Google Pay, Paytm and marketplace DPIs such as ONDC (for commerce) and OCEN (for credit), which integrate with UPI to enable payments.
- **Payments Digital Economy**: This layer encompasses all components of the UPI ecosystem and Proprietary payment networks like Visa, Mastercard, and Rupay.

Figure 6: The Four Layers of Unified Payment Interface Ecosystem



Source: Author's compilation.

This positions UPI as a privately provisioned, publicly governed payments DPI, operating alongside privately run payment networks such as Visa and Mastercard. The four layered UPI ecosystem collectively ensures inclusivity, interoperability, and innovation for digital payments. It is underpinned by a robust governance framework that maintains transparency, security, and fair competition across the ecosystem. (Refer Glossary for more examples of the four layered ecosystem for India Stack)

IV

Governance Structure of Digital Public Infrastructure

Techno-legal regulation

Imagine a scenario where the government intends to build a state-of-the-art expressway that spans the length of the country, designed to handle millions of private and commercial vehicles while ensuring safe, efficient, and comfortable travel. For such a system to function effectively, rules of the road must be clear, enforced, and fair for all service providers and users.

To function effectively at scale Digital Public Infrastructure must serve two key stakeholders:

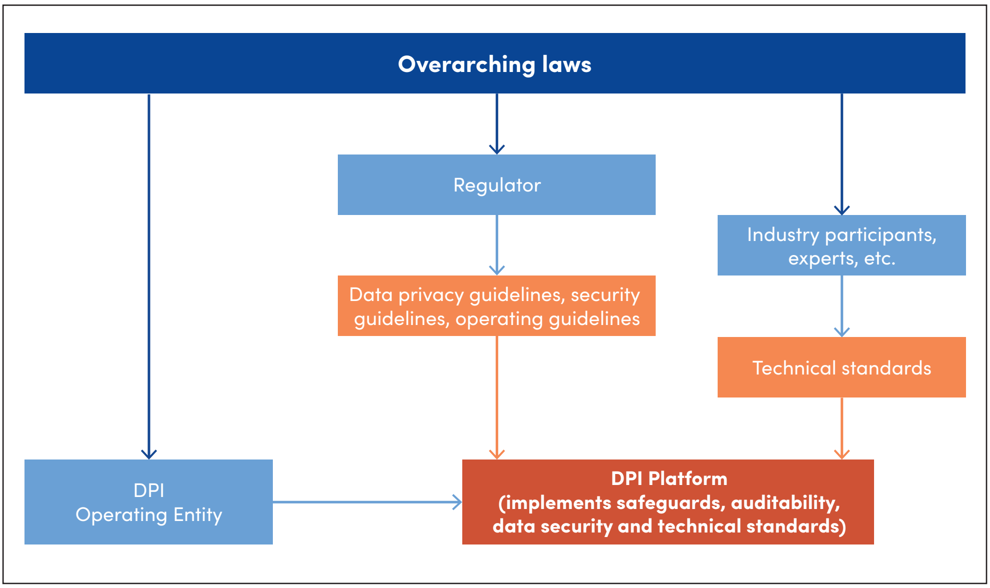
- Innovators, who need open, reliable, and low-friction systems to build upon and deliver value. Think of the expressway enabling private enterprises to set up toll booths, GPS services, fueling stations, rest stops, and more.
- Regulators, who ensure that the DPI operates in alignment with public interest, through mechanisms for accountability, compliance, and enforcement. Just as traffic laws, pollution checks, and safety standards are enforced on highways, digital infrastructure needs clear governance frameworks and built-in safeguards to protect rights and maintain systemic integrity.

The privately provisioned, publicly governed model for DPI, as seen in India Stack, requires regulatory mechanisms to be embedded directly into the DPI. This fusion of public technology and public policy is known as techno-legal regulation. This approach ensures that compliance is not an afterthought but an integral part of system design.

A commonly adopted structure includes the following components:

- Regulators set broad principles for data privacy, accountability, competition, and inclusion and define high-level guidelines for implementation, rather than micromanaging.
- Technical standards are co-developed through multi-stakeholder collaboration between industry experts, academia, civil society, and government. They translate these principles into practical and scalable standards.
- The DPI Operating Entity implements these standards keeping the regulatory principles as a compass. This is achieved by embedding checks, safeguards, and auditability into the infrastructure itself.

Figure 7: Techno-legal Regulation



Source: Author's compilation.

Techno-Legal Regulation in Practice: The Case of UPI and DEPA

- Techno-legal regulation is not just a theoretical concept. It is already at work in the India Stack ecosystem, delivering real-world impact at scale for its 1.4 billion citizens.

Case 1: UPI

In the UPI ecosystem, techno-legal governance is implemented through a layered, collaborative model:

- **Regulatory Oversight:** RBI lays down the regulatory framework, licensing authorization principles, security compliance requirements and ensures consumer protection.
- **Operational Governance:** NPCI acts as the UPI operating entity that designs and implements the UPI platform's technical architecture, defines the messaging standards while ensuring alignment with regulatory guidelines especially around data privacy, transaction security, and auditability.
- **Ecosystem Collaboration:** Banks, fintechs, and technology providers actively participate in the evolution of technical and operational standards thus ensuring that the ecosystem stays innovative while remaining compliant.

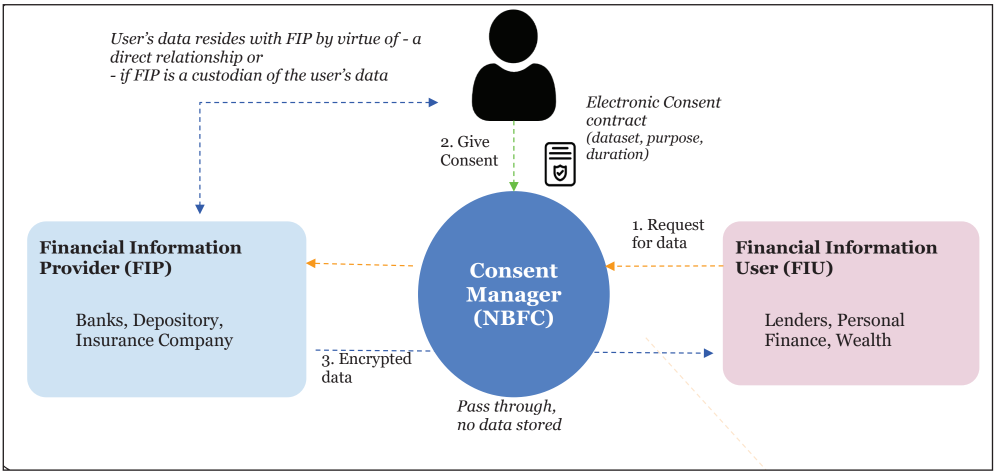
Case 2: DEPA:

A more advanced approach to integrate technology with regulations is to embed regulations directly into the design and code of the DPI. A notable example is the DEPA that powers India's Account Aggregator framework and enables citizens to securely share their financial data on the basis of explicit, revocable, and granular consent.

This techno-legal compliance-by-design model works with the help of:

- **Consent Managers:** Special entities called Consent Managers act as digital notaries and facilitate consent-based data-sharing. This 'data blind' (consent managers do not see or store the data shared) approach ensures neutrality, and prevents data exploitation or value-based pricing. The Financial Information Users are charged on a pay per usage basis.
- **Machine-Readable Consent Contracts:** Consent rules are embedded in digitally signed contracts that are legally enforceable and auditable. These contract definitions are entity and purpose specific, i.e. what data is shared, for what purpose, with who and for how long, putting control in the user's hands.
- **Embedded Regulatory Compliance:** The system is aligned with India's Digital Personal Data Protection Act implementing requirements such as data minimization, security safeguards, purpose limitation, and revocability of consent (i.e. users can revoke consent anytime, with systems enforcing automatic expiry of permissions.

Figure 8: Use DEPA of Techno-legal Regulation in Account Aggregator



Source: Sahamati **-** Participants in the Account Aggregator Ecosystem.

Outcomes and Impact

The 'compliance by design' approach has proven both scalable and innovation-friendly. For instance:

- The Account Aggregator ecosystem saw over 100 million consents processed in 2024-25.
- Businesses and financial institutions have been able to rapidly innovate, developing new lending models and personal finance services, without violating user rights or increasing security risks.

Case 3: Applying Techno-legal Regulations of DEPA for Artificial Intelligence (AI)

AI adds a layer of complexity to DPI because AI systems need large volumes of high-quality data for training and deploying AI models. However, this data is often concentrated within a few large entities, limiting innovation and competition. For example, IRCTC India's national railway booking platform, holds India's largest dataset on domestic travel patterns. For startups to create AI-driven travel solutions, they need access to this data, but such access requires careful privacy, accountability, and security management.

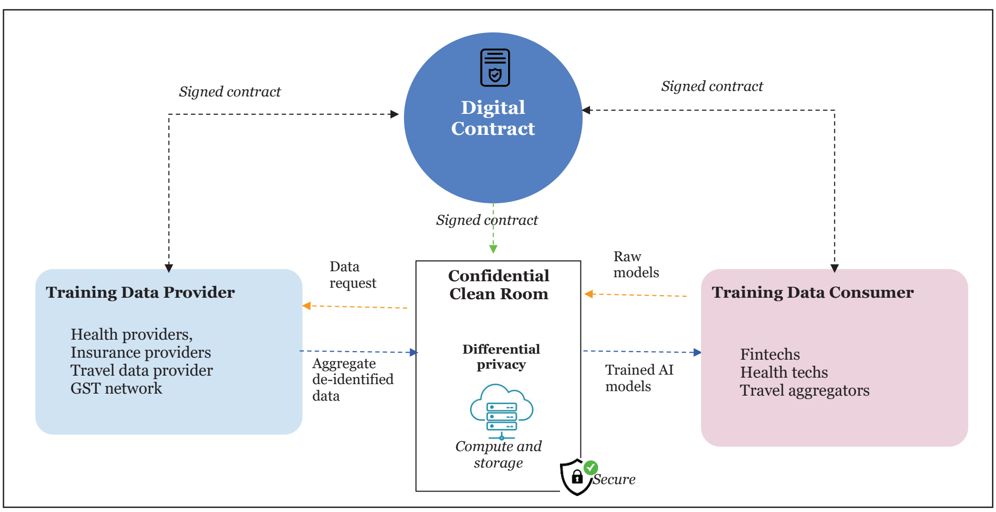
Role of Techno-Legal Infrastructure in AI

The techno-legal approach pioneered by DEPA offers a blueprint for managing this complexity via advanced data governance and technological tools working in tandem:

- **Differential Privacy:** A set of mathematical techniques that introduce noise into datasets to protect individual-level privacy (Think of it as adding a soft blur to an image, enough to see the overall picture but not individual faces). This ensures that no individual can be re-identified from the data or AI outputs.
- **Contract Service:** A multi-layered digital contract that facilitates secure and conditional data sharing between organizations. It encodes what data is shared, for what purpose, by whom and with whom, and for how long (Think of it as a digitally signed and enforceable 'terms of usage' document).
- **Confidential Clean Rooms:** A secure technology environment where multiple parties can bring their datasets and collaboratively train AI models without exposing the underlying data (Think of it as a digital safety vault, where entities can work with datasets as per contract rules, but cannot extract or misuse the data). This protects sensitive information while still enabling AI experimentation and development.

DEPA's proven consent-driven framework serves as a robust model for managing data flows where user autonomy and regulatory compliance are both essential. In the context of AI, DEPA's approach offers a compelling foundation for addressing the complex data governance challenges that arise across the AI lifecycle.

Figure 9: How DEPA Techno-legal Framework is Used in AI for Training Models



Source: DEPA Global - Data Sharing in DEPA | DEPA World.

AI as a Value Chain: A Multi-Layered Governance Challenge

Aggregate data sharing is just one of the aspects of AI ecosystems that are inherently complex and adaptive. AI systems do not operate in isolation. They must be viewed as a value chain with dependent but distinct layers:

- **Personal Data:** Raw user data, sensitive and legally protected
- **Aggregate Data:** Anonymized and structured datasets used for model training
- **Models:** AI algorithms developed through training data, often opaque and difficult to audit
- **Applications**: User facing AI services such as recommendation engines, chatbots, etc.
- **Artifacts:** Outputs such as decisions, insights, or generative content
- **Distribution:** Platforms and channels that disseminate AI outputs at scale

Each layer presents unique risks and ethical concerns that range from privacy violations, algorithmic bias to misinformation and monopolistic control. This requires a dynamic, adaptive, and layered governance to mitigate these risks.

Rethinking Regulation: The Role of DPI in AI Governance

Conventional regulatory approaches struggle to keep pace with the speed, complexity, and adaptability of AI systems. Instead of rigid, one-size-fits-all policies, regulators need:

- Technology-implemented principles that are embedded directly into AI infrastructure.
- Granular oversight that adapts to evolving risks and use-cases.
- Built-in compliance that allows regulators to intervene at the right time, with the right scope.

This is where techno-legal protocols like DEPA, operating through a state provided, privacy-preserving DPI utility can make a transformative impact.

For a DPI based framework to facilitate responsible AI governance it must:

- Embed regulatory safeguards within the architecture, not just on top of it.
- Enable consent-driven, privacy-first data sharing, for high-risk use cases like AI model training.
- Provide regulators with visibility and intervention tools across the AI value chain, without stifling innovation.
- Facilitate an ecosystem where businesses can innovate in a regulated yet permissive environment.

This approach is human-centric, privacy-preserving, transparent and accountable, flexible yet enforceable, and supportive of innovation. This is the equivalent of building a well-lit, rule-abiding expressway where agility and safety is ensured, guided by clear rules and embedded protections.

Citizen Stack and DPI Sutras

The fundamental purpose of any DPI is to serve the public good. As Socrates, the Greek philosopher famously stated, “The beginning of wisdom lies in definitions.” Keeping this in context, we have laid out clear definitions for the key components of a DPI ecosystem. Yet, beyond definitions, what truly matters is the set of guiding principles that enable us to evaluate and define a well governed DPI.

Drawing from lessons of the India Stack implementation, the Government of India has proposed Citizen Stack—a trusted DPI ecosystem guided by a set of five guiding principles known as the DPI Sutras. These are:

- **Citizen Agency and Privacy:** Uphold citizens’ relationship with the market and the state, free from adverse influences. Safeguard citizen empowerment and privacy through a consent-based system of sharing data.
- **Interoperability:** Prevent the lock-in of citizens by enabling different systems to work together.
- **Techno-legal Regulation**: Combine public technology and law to govern ethical tech use, ensuring innovation, security and societal rights in the digital age.
- **Prevention of Monopolization:** Future roadmap of DPI should not be controlled by corporate or monopoly interests and must encourage public-private collaboration for the greater public good.
- **Safeguards Against Weaponization:** Technology implementation should prevent hooks for weaponization by state or corporate actors.

DPI Sutras are not Merely Aspirational Ideals. They constitute an actionable governance framework for building open, secure, scalable, and inclusive digital ecosystems. They ensure that DPIs empower citizens, bridge digital divides, protect national sovereignty, and equip nations to navigate a complex technological landscape through a model grounded in public ownership and collaborative public-private provisioning.

By embedding these principles into the very fabric of a DPI, Citizen Stack offers a future-proof approach to DPI governance. It safeguards against the centralization of power and ensures that technology continues to serve as a tool for public good.

V

Conclusion

India's journey in building Digital Public Infrastructure is a powerful testament to how a state-led, market-friendly approach can transform service delivery at population scale. By embedding core principles such as interoperability, openness, modularity, consent, and robust governance into the DPI architecture, India has created a model for building equitable and inclusive digital ecosystems.

As more countries look to build their own digital rails, India's approach offers not just inspiration, but also a practical playbook that demonstrates that when digital public infrastructure is combined with strong techno-legal safeguards and rooted in normative guiding principles (DPI Sutras), it can fuel innovation, strengthen sovereignty, and drive citizen-centric economic growth.

The true power of this playbook lies not in replication but in adaptation. Each nation must customize this framework and guiding principles to suit their unique regulatory landscape, cultural context and economic realities. India's contribution lies in sharing knowledge from its experiences and by fostering collaborative partnerships with nations to enable them to build their own digital sovereignty.

Glossary

VI

What is a Public Good?

In contemporary economics, a public good is a resource, service, or infrastructure that possesses two key characteristics:

- **Non-excludable:** No one can be effectively excluded from using the good.
- **Non-rivalrous:** One person's use of the good doesn't diminish its availability to others.

Classic examples of public goods include national defense, street lighting, public parks etc. For instance, street lighting illuminates public roads for everyone making it non-excludable. Moreover, one individual benefiting from the light does not reduce its availability to others, making it non-rivalrous.

It is important to distinguish between the nature of a public good and its provisioning. The absence of street lighting in certain regions of a country is a matter of provision failure. Not a contradiction of its status as a public good. The responsibility for the provisioning of such public goods typically lies with governments or collective institutions as private markets lack adequate incentives.

What is Public Tech?

Public tech refers to technologies that are accessible and open for public use, development, and societal benefit. It emphasizes inclusivity, transparency, scalability, and serves as the technical backbone of digital systems. Public Tech can be standalone or integrated into various digital systems.

Public tech can take several forms:

- **Protocol:** A set of rules and standards that enables systems and technologies to communicate and operate together. (For example, the TCP/IP protocol governs how data is transmitted over the internet).
- **Standard:** A formalized specification that ensures interoperability by requiring all consumers of a protocol to follow a consistent set of guidelines. (For example, the SMTP protocol for e-mail delivery is standardized through the RFC 5321 standard by the Internet Engineering Task Force, IETF).
- **Open Source Software**: These are software whose source code is publicly available and modifiable, allowing for community collaboration and transparency. (For example, Linux, an open-source operating system that powers many servers or the Signal Protocol, which provides end-to-end encryption for apps like WhatsApp).

- **Platform:** Digital systems that enable:
  - » **Interaction:** Citizens engage directly with the government. For example, MyGov.in, a citizen-centric platform, facilitates citizen participation in governance.
  - » **Participation:** Collaborative co-creation between citizens and state. For example, Indian Urban Data Exchange (IUDX) enables data-sharing across cities, citizens, public agencies, and private entities to foster innovation to address complex urban challenges.
  - » **Service delivery**:Enables Government to deliver public services to citizens. For example, DigiLocker, a cloud-based platform for storing and authenticating official documents such as IDs, certificates etc. Likewise, Agri Stack, a digital infrastructure that integrates farmer data to deliver personalized, efficient, and inclusive agricultural services such as access to affordable credit, tailored advisory services, and improved market access.

What is Digital Public Good (DPG)?

According to the Digital Public Goods Alliance, a multi-stakeholder, UN-endorsed initiative promoting open-source digital solutions, a Digital Public Good (DPG) is defined as:

"Any open-source software, open data, open AI models, open standards, and open content that adhere to privacy and other applicable laws and best practices, do no harm by design, and help attain the Sustainable Development Goals (SDGs)."

A Digital Public Good demonstrates the following attributes:

- **Open Access:** Offers inclusive and unrestricted access to everyone, following the economic principles of being non-excludable and non-rivalrous.
- **Open Standards and Protocols:** Builds upon widely accepted and transparent technical specifications.
- **Open-Source:** The software, data, or content must be openly licensed and modifiable.
- **Aligned with Sustainable Development Goals (SDGs):** Directly contributes to one or more of the SDGs.
- **Ethical and Privacy-Compliant:** Designed to "do no harm" and complies with data protection and privacy laws.
- **Governed in the Public Interest:** Overseen by communities, foundations, or independent institutions ensuring transparency and accountability.

- Thus, a Digital Public Good is a subset of public tech that meets specific formal criteria listed above. This means that all DPGs are public tech, but not all public tech qualify as a DPG. However for purposes of this document we have defined them to mean the same.
- The DPG Alliance maintains a DPG Registry which currently includes 199 certified DPGs. A few notable examples:
- **MOSIP (India):** Modular Open Source Identity System, helps nations implement cost-effective, foundational digital identity systems while maintaining autonomy and inclusivity.
- **X-Road (Estonia):** An open-source software and ecosystem solution that provides unified and secure data exchange between organizations.

What is Digital Public Infrastructure (DPI)?

Digital Public Infrastructure (DPI) is a set of interoperable and scalable digital systems that provide core capabilities such as digital identity, digital payments, and data exchange to enable the secure, inclusive, and efficient delivery of essential public and private services at population scale. Unlike standalone tools or platforms, DPI functions as an integrated digital framework that supports entire ecosystems across sectors by enabling foundational digital capabilities.

The key characteristics of a DPI are:

- **Interoperability:** DPI systems are designed to integrate seamlessly with other systems and platforms. This is enabled via open APIs (Application Programming Interfaces - APIs are mechanisms that enable two software components to communicate with each other using a set of definitions and protocols. For example, the weather app on your phone "talks" to the weather bureau's software system that contains daily weather data, via APIs and shows you weather updates.) and open standards, which allow secure data exchange between the DPI and other systems and consequently its broad adoption.
- **Scalability:** DPI is designed to support large-scale adoption, capable of handling millions or like for India, billions, of users and transactions.
- **Inclusivity:** DPI follows the principles of non-excludable and non-rivalrous. It is accessible to all, namely governments, businesses, and individuals including those from marginalized communities.
- **Operated in Public Interest:** DPI is typically managed as a public utility, with governance and operational oversight provided by an entity that may adopt one of many possible institutional architectures -

- » **Government Agency:** For example, UIDAI for Aadhaar (India's digital Identity).
- » **Non-profit Consortium:** For example, NPCI for UPI.
- » **Multi-stakeholder Organization:** For example, Sahamati for the Account Aggregator ecosystem.

- Governed by a Legal and Regulatory Framework: A DPI is provided a robust oversight by a regulatory body and is governed by appropriate laws and policies that ensure data protection, trust, security, privacy, accountability, and public confidence.

Thus, Digital Public Infrastructure is not just about technology. While public tech provides the foundational building blocks, DPI is a much broader and holistic construct that incorporates foundational technology components, governance structures, legal frameworks, public and private entities, enabling ecosystems that together support digital transformation at scale.

Public Tech vs. Digital Public Good vs. Digital Public Infrastructure

In common usage, the terms Public Tech, DPG and DPIs are often used interchangeably, leading to confusion. However, each represents a distinct concept within the digital public ecosystem.

- Public Tech is the foundational layer of open and accessible technologies such as protocols, standards, open-source software, and platforms that are designed to be inclusive, transparent, and interoperable.
- DPG is a subset of public tech that meets specific ethical and developmental standards as defined by the Digital Public Goods Alliance (refer Glossary for formal attributes). In this document, "public tech" and "DPG" are used interchangeably for simplicity
- DPI refers to the foundational public tech (or DPGs) plus the institutional, and governance layers (refer Glossary for detailed definition) that enable scalable, inclusive, and interoperable service delivery of essential public services such as digital identity, payments, and data exchange. It acts as the "digital rails" of a nation, enabling both public service delivery and private sector innovation.

A country's DPI may integrate multiple proprietary and/or open-source solutions, including public tech and/or certified DPGs, depending on local context and governance needs.

Case Examples: Modular Open Source Identity Platform (MOSIP)

- MOSIP (Modular Open Source Identity Platform), is a modular, open-source technology that provides standardized identity protocols designed for accessibility and scalability. Thus, it is a perfect example of a public tech.
- MOSIP is formally recognized as a DPG embedding privacy-by-design, consent frameworks, and alignment with SDG 16.9 (legal identity for all).
- MOSIP provides interoperability via its APIs, is inclusive by supporting multiple authentication modes and can handle population scale deployments. In fact, MOSIP is already being implemented as the national digital identity DPI in countries like Morocco (National Population Registry), Philippines (PhilSys), Sri Lanka, Ethiopia, and several other countries with the appropriate local governance mechanism in place.

Building Blocks

According to GovStack, a global open-source community working to establish a standard toolkit for DPI, Building Blocks are:

"Building blocks are software code, platforms, and applications that are interoperable, provide a basic digital service at scale, and can be reused for multiple use cases and contexts."

Each building block is designed to work independently, but when combined, they can support more complex systems and services. Govstack outlines the characteristics of Building Blocks:

- **Autonomous:** A building block provides a standalone, reusable digital service or a set of services. It may consist of multiple modules or microservices.
- **Generic:** It is flexible across sectors and use cases, not built for a single, narrow function.
- **Interoperable:** It can connect, communicate, and integrate with other building blocks to form end-to-end solutions.
- **Iterative Evolvability:** It can be continuously improved or upgraded even while in active use, enabling sustainable innovation.

Thus,

- Public Tech can qualify as a Building Block if it is modular, reusable and designed to provide standalone functionality.
- DPGs can also be Building Blocks if they offer generic service at scale and meet interoperability and reuse standards.
- DPI is typically an implementation of one or more Building Blocks (Public Tech and/or DPGs), combined with governance, regulatory frameworks, and institutional structures.

For example,

Table 2: Public Tech/DPG to DPI

Public Tech / DPG	Definition	DPI implementation
Beckn Protocol (Public tech)	It is an open, interoperable protocol designed to enable decentralized digital commerce and service network	• Forms the technical foundation of ONDC (Open Network for Digital Commerce) in India • Enables a level playing field for sellers and buyers by unbundling e-commerce.
MOSIP (Public Tech and DPG)	It is a modular, open-source platform for implementing digital identity systems.	• Serves as the foundation for the national digital ID infrastructure in countries like Morocco (National Population Registry), Philippines (PhilSys), and others
X-Road (Public Tech and DPG)	It is an open-source, data exchange layer that facilitates secure and reliable information sharing between different information systems.	• It is a key component of Estonia's national DPI for digital data exchange • Enables secure interoperability between government agencies, businesses, and citizens

Source: Author's compilation.

Ownership and Provisioning of Digital Systems / DPI

- DPIs can be categorized based on
- Ownership: Who controls and holds rights over the DPI / digital system and
- Provisioning: Who funds and maintains the DPI / digital system, ensuring its availability for public use

Table 3: Ownership and Provisioning of Digital Systems / DPI

<table>
<tr><td>PRIVATE

Provisioning</td><td>Publicly owned, privately provisioned
• Infrastructure Ownership: State or a public institution
• Service Delivery: Private companies or vendors build, operate and deliver services
• DPI : Aadhaar, UPI, Account Aggregator</td><td>Privately owned, privately provisioned
• Infrastructure Ownership: Private company or consortium
• Service Delivery: Same or other private players operate and deliver services
• Proprietary Platforms : SWIFT, Visa, Mastercard</td></tr>
<tr><td>PUBLIC</td><td>Publicly owned, publicly provisioned
• Infrastructure Ownership: State or a public institution
• Service Delivery: State operated or by public sector agencies
• DPI : Estonia X-Road, Singpass</td><td>Privately owned, publicly provisioned
• Infrastructure Ownership: Private company
• Service Delivery: Government or public agency uses it to deliver services
• Privately owned public service: Whatsapp to deliver public health communication</td></tr>
<tr><td></td><td>PUBLIC</td><td>Ownership PRIVATE</td></tr>
</table>

Source: Author's compilation.

- As seen in the above matrix, in practice, a privately owned DPI is not feasible. This is because, if a system is privately owned, it usually implies control over data, or monetization objectives that prioritize private interest over public good and contradict the core principles of a DPI.
- Thus SWIFT, which is a privately owned, membership-based cooperative, not open-source, not non-excludable (access is restricted to approved members), and not governed by a public regulatory or legal framework is not a DPI. Likewise, Visa and WhatsApp based service delivery are not DPIs but privately owned global platforms/utilities that are commercially governed.
- 4 layered DPI ecosystem in India Stack
- The table below illustrates how India's approach of building open and interoperable DPIs - by leveraging public tech and combining them with other DPIs - has not only enabled a wide range of services to be developed around the core DPIs but has also helped in creating new marketplace DPIs, such as OCEN and ONDC.

Table 4: Four Layers of India Stack DPIs

	Public Tech	Digital Public Infrastructure	DPI Network	DPI Economy Participants
Identity (Aadhaar)	• Central identity layer • Biometric based identity authentication APIs	• Aadhaar infrastructure • Aadhaar services - eKYC, eSign, AEPS • **Operating Entity** - UIDAI	• Authentication Requesting Agency • Authentication Service Agency • Authentication User Agency	• Regulator - UIDAI • Users - Individuals, Corporates • Parallel Networks - None
Payments (UPI)	• VPA-based routing protocols • Issue / Collect API • Authentication APIs • IMPS payments rail for switching	• UPI Platform comprising the core backend + settlement infrastructure • UPI services - UPI Lite, Credit on UPI etc • **Operating Entity** - NPCI	• Issuer and Acquirer Banks • Third Party App Providers • Payment Service Providers (banks that connect TPAP to UPI network)	• Regulator - RBI • Users - Individuals, Merchants • Parallel Networks - Credit Card Visa / Mastercard
Data (Account Aggregator)	• Data Empowerment and Protection Architecture • Consent based data sharing APIs	• Account Aggregator Data Exchange Layer • **Operating Entity -** Sahamati	• Financial Information User • Financial Information Provider • Account Aggregator-NBFC	• Regulator - RBI, SEBI IRDA, PFRDA • Users - Individuals, MSME • Think Tank - iSPIRT • Parallel Networks - None
Credit **(**OCEN **-** Open Credit Enablement Network)	• OCEN 4.0 Protocol • Data Empowerment and Protection Architecture	• OCEN Credit Layer for credit access to MSME • GeM Sahay, GST Sahay • **Operating Entity -** Sahamati	• Loan Service Providers • Technology Service Providers • Account Aggregator • Lenders	• Regulator - RBI, SEBI IRDAI, PFRDA • Users - MSME • Think Tank - iSPIRT • Parallel Networks - Bank Lending
eCommerce (ONDC - Open Network for Digital Commerce)	• Beckn Protocol - Base Layer • Central participant registry • Reference implementations	• ONDC Network Extension Layer (Network policies, recon, governance, grievance redressal) • **Operating Entity** - ONDC	• Buyers • Sellers • Logistics Providers • Tech Service Provider • Settlement Agency	• Regulator - Dept. for Promotion of Industry & Internal Trade (DPIIT) • Users - Individuals, Businesses • Parallel Networks - Amazon, Flipkart

Source: Author's compilation.

- RBI - Reserve Bank of India
- SEBI - Securities and Exchange Board of India
- IRDAI - Insurance Regulatory and Development Authority of India
- PFRDA - Pension Fund Regulatory and Development Authority

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Core IV-B, Fourth Floor, India Habitat Centre
Lodhi Road, New Delhi-110 003, India
Tel.: +91-11-2468 2177-80, Fax: +91-11-2468 2173-74
E-mail: dgoffice@ris.org.in, Website: www.ris.org.in

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