The Economics of Shared Digital Infrastructures: A framework for assessing societal value

Policy Report — March 2025

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Launched in 2018, the Bennett Institute is committed to interdisciplinary academic and policy research into the major challenges facing the world, and to high-quality teaching of the knowledge and skills required in public service.

Our goal is to rethink public policy in an era of turbulence and inequality. Our research connects the world-leading work in technology and science at Cambridge with the economic and political dimensions of policymaking. We are committed to outstanding teaching, policy engagement, and to devising sustainable and long-lasting solutions.

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Executive Summary

Digital technologies are now the backbone of modern societies, underpinning everything from service delivery to financial transactions. Yet in most countries, many of these critical services remain fragmented, duplicative, and designed in silos — tied to individual programs or agencies rather than treated as infrastructure. This fragmentation leads to costly inefficiencies, missed opportunities for cross-sector innovation, and barriers to inclusion. These costs are not only technical. They are social, economic, and political. Governments continue to invest in multiple digital systems without capturing economies of scale or the spillovers and externalities digital infrastructure can generate.

One reason this problem persists is that we lack the tools to think *horizontally* — to see digital not just as service delivery or technology, but as a foundational layer that enables interactions across government, markets, and society. Some recent efforts have attempted to think this way — including the India Stack, the Eurostack and Digital Public Infrastructure. However, traditional investment and evaluation tools, such as cost-benefit analysis or value-for-money metrics, are poorly suited to measuring the long-term, indirect, and systemic effects of infrastructure — digital or otherwise.

To fill this gap, this paper proposes **four significant contributions:**

1. **It defines the infrastructural nature of digital systems.** We identify the characteristics that make digital systems and services to function as infrastructure. This helps policymakers and funders evaluate whether their digital investments are likely to generate long-term public value.

2. **It analyses how digital infrastructure shapes economic dynamics.** We explore how each infrastructural characteristic — such as reusability, interoperability, standards, high-value data and public oversight — can influence markets, inclusion, and public service delivery, highlighting both the potential gains and associated risks.

3. **It proposes a public value measurement framework for DPI.** We introduce a structured approach to assessing DPI's direct, dynamic,

and market-shaping effects, considering outcomes for individuals, governments, and the private sector. This provides an alternative to traditional cost-benefit approaches, especially in complex or uncertain environments.

4. **It identifies additional factors that influence value creation.** The framework integrates contextual, institutional, and political economy considerations — such as trust in data, inclusion gaps, and governance structures — crucial to realising DPI's full potential.

Policy Implications:

1. **Treat essential digital services as infrastructure.** DPI should be governed, funded, and evaluated as a public infrastructure — long-lived, cross-cutting, and foundational to both state capability and economic dynamism.
2. **Design for value from the start.** Value is not automatic. It depends on technical choices, governance, procuring and financing models. Measurement frameworks must reflect this.
3. **Expand the role of finance ministries.** Finance and planning authorities need to move beyond project-based logic and take a strategic role in shaping DPI ecosystems, ensuring coordination, avoiding duplication, and steering systemic investments.
4. **Build in dynamic measurement beyond efficiency.** Governments should move past basic adoption and cost-saving metrics. The framework provides tools to assess systemic value, long-term outcomes, and the trade-offs that shape who benefits — and who may be left behind.

1. Beyond fragmentation: rethinking and measuring digital systems as public infrastructure

Digital technologies are now the backbone of modern societies, underpinning everything from service delivery to financial transactions. Yet, despite decades of investment, many public digital systems remain fragmented and inefficient.

This fragmentation is costly. Governments invest billions in IT, yet many systems remain incompatible, leading to duplication, inefficiencies and fiscal waste. In 2021, the UK government reported 44 different identity verification systems (UK GDS, 2025). Similarly, Nigeria's overlapping ID systems are estimated to have generated an additional cost of $4.3 billion over several years (World Bank, 2018). Disjointed data systems also weaken crisis response. In the US, only 23-34% of the $800 billion Paycheck Protection Programme directly reached workers at risk of job loss due to fraud and data mismatches (Autor et al, 2022). **These inefficiencies and missed opportunities for impact are prompting governments to rethink their approach to digital transformation.**

In response, many governments are shifting from fragmented digitalisation to shared digital infrastructure — often referred to as digital public infrastructure (DPI) — as a foundational approach. Like roads and energy grids, these systems provide shared, reusable systems that facilitate interoperability, efficiency and innovation. They are built on modular software components that enable broad participation in society and markets — whether as citizens, entrepreneurs or consumers (Eaves and Sandman, 2023). Three capabilities are widely recognised as foundational to DPI, though others are emerging: digital identity and authentication (e.g. Ethiopia's Fayda, a biometric ID system), secure data exchange (e.g. Estonia's X-Road) and real-time digital payments (e.g. Cambodia's Bakong System). These shared systems promise to reduce duplication, streamline public services and enable private-sector innovation. While some define DPI narrowly around these three core capabilities, this paper takes a broader approach, considering all digital systems with public infrastructural characteristics as DPI.

DPI is increasingly seen as a strategic economic asset, modernising governance and improving service delivery, but

like traditional infrastructure, its full economic impact is difficult to measure. Standard cost-benefit analysis, designed for physical infrastructure, often fails to capture the spillover effects, scalability and long-term social value of digital infrastructure. To make informed investment decisions, policymakers need a more comprehensive framework — one that accounts for DPI's economic and societal impact beyond immediate efficiencies.

This report aims to bridge these conceptual and practical gaps. Sections 2 and 3 define infrastructural characteristics, examine how they manifest in the digital space and explore how they generate economic value. Section 4 introduces a preliminary framework to help policymakers assess DPI's economic impact. Finally, Section 5 explores additional factors and trade-offs that affect value creation. **This report equips policymakers, funders, auditors and implementers with the tools needed to assess trade-offs, maximise public value and guide digital infrastructure investments towards sustainable and inclusive growth.**

2. Why shared digital components can be infrastructure — and how they differ from traditional digitalisation

2.1 Infrastructure and the challenge of measuring its value

Governments and development institutions have long prioritised infrastructure as critical to society functioning. As a backbone of modern economies and societies, infrastructure enables essential services like transport, energy and communication. Traditional infrastructure investments, such as roads and power grids, are justified not only by their direct benefits but by the **dynamic, long-term economic effects they enable** — spillovers, new market creation and efficiency gains. However, quantifying these broader effects remains a challenge, particularly through conventional cost-benefit analysis.

Two approaches are commonly used to define infrastructure:

The functional approach defines infrastructure by the essential functions it enables for individuals and societies, such as:

- transportation (roads, rail)
- utilities (electricity, water) and
- communications (telecom networks).

Such functional assets are long-lived, often complementary to each other and create spillovers. Therefore, where and how infrastructure is built affects broader decision-making and outcomes in the long-run. For instance, economic activity is still concentrated around Roman roads (Dalgaard et al, 2022). The functional concept of infrastructure has been increasingly expanded, for example, it now includes broadband. Moreover, as society becomes more complex, its functions are not just physical, but increasingly include social technologies, such as legal or social systems (Alexandrova et al, 2024; Kelsey and Kenny, 2021). For example, while a park may not seem to fulfil a basic function like a highway or electrical grid, it provides a basis for various social, economic and environmental interactions. This is equally true for digital infrastructures, which are crucial in today's economy and society. These can range from the 'traditional' physical infrastructure elements of data centres and subsea cables to intangible assets such as databases.

The attributes approach defines infrastructure based on its properties, which often include:

Relevance	**1. Inputs essential to a range of activities** that either facilitate market participation (e.g. transportation or identity services) or provide services deemed essential to participation in society or life (e.g. water or communication)
Financing Properties	**2. Long-lived collective assets**, often involving a higher upfront investment cost relative to the low marginal cost of supply
	3. Non-rival up to congestion limits, so many can use it without diminishing availability
	4. Collective and non-excludable, with access that is either universal or does not depend on personal relationships
	5. Generic or standardised capital services that can be used as inputs into a wide range of other activities
Dynamic	**6. Derived demand** (economic value created by downstream applications)
	7. Creates **spillovers and externalities**
Nature	**8.** Often **complements or substitutes** for other infrastructures

Source: Authors' elaboration, expansion of Frischmann (2012)

The first characteristic frames infrastructure as a capacity deemed essential to the functioning of society and thus of deep interest to — and possibly a core responsibility of — the state. This anchors the conversation about infrastructure in a primarily rights-based or state-capacity discourse as opposed to an economic discourse.

The following four characteristics focus on how infrastructure is financed, which may require government funding or coordination. Non-rivalry, as with other public goods, means there is a classic free rider problem. Universal access implies a need for cross-subsidy from profitable to non-profitable users, while the collective nature of the assets often requires government coordination or regulation, even if they are privately provided. The long-lived character of returns on investment requires an investor with a sufficiently low discount or hurdle rate.

The final three characteristics make it challenging to identify and estimate the economic returns to infrastructure investment and, indeed, the academic literature has failed to identify consistently positive returns even though no economy can function without infrastructure (Välilä, 2020; Coyle, 2022). Yet standard econometric approaches omit spillovers, a key feature of infrastructure (Agénor and Moreno-Dodson, 2006). The derived nature of demand means returns will often accrue downstream — for example, in sectors that use electricity. The externalities and correlations drive a wedge between social and private market returns.

The context of these attributes also matters. Importantly, investments in technology and infrastructure are not 'neutral' — values are embedded in what is invested in, where investments are made and through which channels investments are made (Coyle et al, 2023; Mazzucato et al, 2024). It is important for governments to proactively consider the distribution of costs and benefits within society, and actively define society-wide priorities. To do so, they must confront the political economy of decision-making around investment, including what to focus on, how such projects are funded and what metrics service providers are held accountable to. Historical examples, both in the traditional and digital realms, have shown the potential for benefits to accrue to a small group at the expense of those on the margins.

What are the limitations of traditional measurement models (e.g.: cost-benefit analysis)?

While a helpful starting point, popular economic measurement models have notable and well-documented shortcomings. These include, but are not limited to, **oversimplification of complex relationships** (Ackerman and Heinzerling, 2004); **short-termism** (Laverty, 1996; MacKenzie, 2016); a **preference for preventing government failures over proactive market-shaping** (Mazzucato et al, 2020); and **limited consideration of distributional effects** (Adler, 2011). Recent studies have also noted that traditional measurements have **not been updated for the digital economy** (Coyle, 2025) and may not be well-suited to measuring the full scope of potential benefits (Brynjolfsson and McAfee, 2014) and risks (Couldry and Mejias, 2020) in digital technologies.

Taken together, these attributes and the non-neutral context make standard cost-benefit analysis (CBA) an inappropriate method for appraising investment in infrastructure, although it is widely used

in policy practice. CBA, in principle, applies only to marginal changes, whereas infrastructure investments will often change relative prices, lead to a reallocation of factors of production, or change consumer preferences or business models. Infrastructure investment — including in DPI — needs to be considered more holistically. DPI's value is not just in what it does, but in what it enables — from expanding market access to reducing transaction costs. However, because digital systems scale differently, DPI's economic mechanisms differ significantly from physical infrastructure.

2.2 What is DPI and why is it different from traditional digitalisation?

For decades, government digitalisation efforts have focused on modernising individual services. Ministries and agencies often developed isolated IT solutions, leading to fragmented, inefficient and costly digital environments. While this approach aligned with traditional accountability structures — where each institution operates independently — it resulted in several economic challenges:

- **High duplication costs** → Ministries and agencies built separate IT systems, increasing procurement, maintenance and staffing expenses.
- **Vendor lock-in** → Proprietary software limited flexibility, making upgrades expensive and reducing competition.
- **Limited scalability** → Each system was built for a specific function, rather than allowing reuse across government and society.
- **High transaction costs** → Government and private sector services struggled to exchange data, leading to expensive verification processes (e.g. repeated know your customer (KYC) checks, excessive paperwork).
- **Information asymmetry** → Lack of interoperable data systems meant that businesses, citizens, and other ministries and layers of government had incomplete access to key information, leading to inefficiencies in decision-making.
- **Incomplete information** → Critical datasets (such as national ID, land registries or business records) were often inaccurate, outdated or inaccessible, increasing risks and limiting service delivery.

These limitations not only increased costs, but also hindered innovation and economic growth, creating barriers to service delivery, competition and inclusion.

DPI enables a fundamental shift from fragmented digitalisation towards shared infrastructure that underpins both public and private services, crytstallising gains from integration across sectors and users. Instead of treating IT systems as standalone projects, DPI is built with reusable, modular components that scale across government and society. This approach reduces duplication, enhances efficiency and creates network effects that drive economic value. In addition, concerns over a lack of competition in digital markets, and a wish for adequate sovereign control of core elements of a country's digital economy, also drive government interest in DPI. Although there is no universal definition of DPI, there is broad agreement on two core ideas:

1. DPI consists of essential software systems and their supporting infrastructure that are critical to modern digital societies (Eaves and Sandman, 2023).
2. DPI is deployed as a collective means to many ends, rather than being a single-use government IT project.

While digital ID, secure data exchange and real-time payments are commonly cited examples, what defines DPI is its systemic approach rather than any single set of components. DPI systems are not simply digital government upgrades — they represent an infrastructural layer that lowers transaction costs, enables market-wide innovation, scales beyond its original applications and generates society-wide value. Examples include Estonia's X-Road, which facilitates seamless data exchange between government agencies and private entities; India's Aadhaar, which provides biometric identity verification at scale; and Tanzania's TIPS, a real-time digital payments system. As of 2024, more than 57 digital ID systems, 93 real-time payment systems and 103 data exchange infrastructures with public-interest governance mechanisms are operational worldwide (Global State of DPI, 2024).

However, DPI's infrastructural nature does not guarantee positive outcomes — its impact depends on how it is designed and governed. If poorly implemented, DPI can reinforce monopolies, limit competition or create privacy risks, rather than fostering open and inclusive markets.

Table 1 compares DPI's key structural attributes with traditional digitalisation approaches, highlighting why design matters.

Table 1: Comparing DPI with siloed digitalisation efforts

Attributes	Siloed digitalisation	Digital public infrastructure
Essential inputs to wide range of activities (activities either essential for market participation or basic societal needs)	Limited	Present
Long-lived collective assets with high upfront costs relative to the low marginal cost of supply (requires long-term investment and governance)	Limited	Present[1]
Non-rival up to congestion limits (can be used by many without reducing availability)	Limited	Present
Collective and non-excludable (access is either universal or does not depend on personal relationships or identity)	Limited	Present
Generic or standardised capital services (used as inputs to 'many ends')	No	Present
Derived demand (value is created by downstream activities that use them as inputs)	No	Present
Creates spillovers or externalities (impacts beyond direct users)	No	Present
Interdependent/layered (complementary or substitutes for other types of infrastructure)	No	Present

Source: Authors' elaboration

The next section explores the specific DPI characteristics associated with infrastructural properties and economic value.

1 DPI-like systems are built with the intention of being long-lived, but it is still early to tell whether they will be, or if they will depreciate faster than traditional infrastructure or live longer.

3. The DPI design characteristics and mechanisms that enable an opportunity for value creation

As societies transition from fragmented digitalisation to shared digital infrastructure, DPI's design plays a critical role in determining its long-term economic and societal impact. The previous section established that DPI can function as infrastructure, but these benefits are not automatic. To generate economic value, promote inclusion and enhance competition, DPI must be designed with specific characteristics that shape its scalability, adaptability and governance.

A growing body of work has been tackling issues related to either DPI design or considerations around value. An excellent example is the Centre for Digital Public Infrastructure's five architectural principles for DPI, which allude to some economic characteristics. UNDP's 2023 report on *The Human and Economic Impact of Digital Public Infrastructures* is another example which outlines theories of change for impact. Recent work by Mazzucato, Eaves and Vasconcellos (2024) identified interoperability, open standards and reusable building blocks as key enablers of DPI's value. This section builds on these contributions and extends them in three ways:

1. **It systematically maps DPI design choices to infrastructural characteristics,** strengthening the link between digital architecture and economic mechanisms.
2. **It refines and expands the framework** by separating standardisation from interoperability and introducing two additional characteristics — data as a high-value input, and public oversight and governance — that play crucial roles in shaping DPI's economic and societal impact.
3. **It deepens the discussion on economic mechanisms,** providing a structured approach to understanding how different DPI design choices influence competition, innovation and inclusion.

By integrating these refinements, this framework provides a more comprehensive and structured foundation for assessing the economic role of DPI. Table 2 summarises the five key DPI design characteristics and their associated economic mechanisms, followed by a deeper discussion of each.

Table 2. Potential sources of economic value with DPI

DPI Design Characteristics	What it means	How it potentially changes the economy
Standardisation	Establishes common rules, formats and protocols that create consistency across systems and processes	▪ **Reduces transaction and compliance costs** by simplifying integration and regulatory requirements ▪ **Prevents vendor lock-in** by lowering the cost of switching suppliers (if the standard is not proprietary) ▪ **Affects market participation** — may enable more participation by lowering entry barriers or discourage new market entrants if standards favour dominant players
Interoperability beyond immediate applications	Often enabled by standardisation, ensures that different systems and organisations can exchange and make use of data, even in sectors beyond their original design	▪ **Breaks down information silos and reduces information asymmetries,** improving efficiency in both public and private service delivery ▪ **Minimises redundant IT spending** by enabling compatibility across multiple agencies and sectors ▪ **Facilitates spillovers and combinatorial innovation** by allowing firms to build on common infrastructure layers without requiring direct coordination ▪ **Shapes market competition** — interoperability can encourage cross-sector business models and innovation, but if standards or data flows are controlled by dominant players, it may entrench monopolies
Minimal and reusable building blocks	Uses modular digital components that can be repurposed across different services, reducing the need to build from scratch	▪ **Reduces redundant infrastructure costs** by allowing shared components to be reused across multiple services ▪ **Supports rapid scaling and cross-sector expansion** by enabling adaptable, modular digital services ▪ **Lowers the cost of innovation** by shortening development cycles and enabling customisability, allowing services to be adapted without full redesign ▪ **Enhances long-term sustainability and resilience** by enabling targeted upgrades instead of full system overhauls, reducing systemic risks associated with large, inflexible digital systems
Data as a high-value input	Establishes trustworthy data systems that functions both as an enabler of more efficient services (input) and as an economic and governance asset (output)	*If the data is reliable and well-governed[2]:* ▪ **Reduces information asymmetry and incomplete data gaps,** improving decision-making in public services, markets and regulatory enforcement ▪ **Minimises risks and uncertainty** across finance and public services by improving identity verification, eligibility assessments, cybersecurity and fraud detection ▪ **Enhances efficiency and targeting** in government programmes and private sector services, reducing administrative burdens and leakages ▪ **Supports economic forecasting, AI-driven analytics and crisis response** by improving access to structured, interoperable data across sectors ▪ **May strengthen public accountability** by enabling transparency in digital transactions, limiting data monopolisation, and protecting individual rights — depending on governance and oversight mechanisms
Public oversight and governance	Implements governance mechanisms (regulatory frameworks, open standards, public-private coordination) to ensure DPI operates in the public interest, balancing private sector participation with equitable access and accountability	▪ **Creates fair market conditions** by preventing monopolisation, excessive rent extraction and anti-competitive practices ▪ **Ensures DPI remains a public good** by fostering universal adoption, inclusion and trust, while maintaining affordability for users and businesses ▪ **Protects rights and security** through regulations on data privacy, cybersecurity, and ethical data use

Source: Authors' elaboration

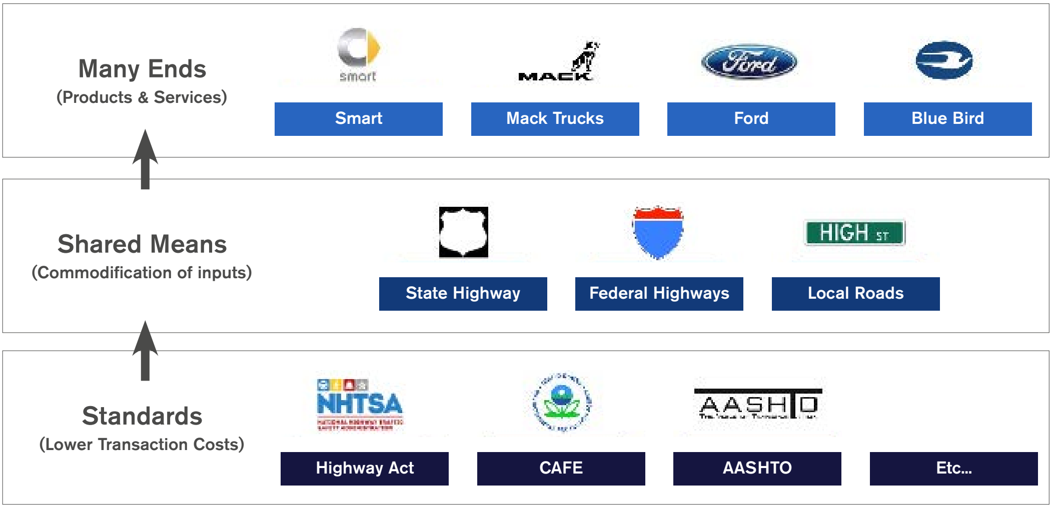
2 If a system fails to identify an individual or is unable to connect relevant data for an individual due to poor data quality, there are risks and compounding effects of exclusion.

3.1 Standardisation

Standardisation establishes common rules, formats and protocols that create consistency across systems and processes, reducing transaction costs and enabling the potential for interoperability. By defining shared frameworks, standardisation can lower compliance costs, prevent vendor lock-in and create a more competitive marketplace. However, standardisation alone does not guarantee interoperability — successful adoption, implementation and governance determine whether standardised systems function seamlessly across sectors and services. The economic value of standardisation depends on how widely a standard is adopted and whether it enables cross-sector reuse. If governments establish multiple, disconnected standards for the same function — such as different identity verification protocols across ministries — fragmentation may persist despite technical consistency. In contrast, a well-standardised foundational system, such as a national digital ID, can provide a single, reusable credential for financial, healthcare and other essential services, reducing redundancy and improving efficiency. Similarly, a common digital signature standard can facilitate seamless transactions across banks, legal services and public administration.

Infrastructure is most effective when it standardises components in ways that make them durable, low-cost, widely applicable and scalable. This principle applies to both physical and digital infrastructure. For example, road networks (see Figure 1) rely on uniform standards — such as lane width, signage and toll systems — which not only facilitate predictable road use for drivers, but also create efficiencies for car manufacturers, logistics companies and urban planners. A sometimes-overlooked benefit of standardisation is its ability to commodify components of an ecosystem, reducing costs and enabling entirely new industries, such as modern supply chain logistics.

Figure 1: Standardisation in road networks



Source: Authors' elaboration

The same principle applies to digital infrastructure. Digital identity standards, for instance, are governed by international, national and industry-specific frameworks that ensure reliability and security across multiple services. These standards cover authentication methods, such as cryptographic keys, mobile-based authentication and biometrics; digital signatures, which define algorithms and secure hash functions to verify the integrity and authenticity of digital transactions; and data exchange protocols. When properly designed, open standards — such as FIDO2 for password-less authentication — ensure that DPI systems function across diverse regulatory and market environments. Standardisation also plays a crucial role in facilitating cross-border interoperability (Shapiro and Varian, 1998), allowing DPI systems to function in diverse regulatory and market environments.

While standardisation can drive efficiency, competition and scalability, it also carries risks. Premature or rigid standards can limit innovation by locking in specific technologies before markets fully develop (Kerber et al, 2017). Dominant firms may shape standards to reinforce market power, making it difficult for smaller players to compete (Farrell and Klemperer, 2007). Poorly coordinated standardisation can also result in fragmentation, as seen in the EU's eIDAS framework, where national variations in digital identity implementation hindered seamless cross-border use. Additionally, standardisation without strong governance can still lead to siloed systems, reducing the benefits of shared digital infrastructure.

To **maximise its benefits and mitigate risks**, governments should:

- **Ensure foundational DPI standards enable cross-sector and cross-border reuse** to avoid fragmented adoption.
- **Adopt minimalist standards** that commodify generic and widely used activities.
- **Prioritise public-interest governance in standard-setting** to prevent undue influence by dominant firms.

Standardisation should be designed with long-term adaptability in mind, allowing systems to remain competitive, inclusive and responsive to future technological shifts.

3.2 Interoperability beyond immediate applications

Interoperability ensures that different systems and organisations can exchange and make use of data, even in sectors beyond their original design. This enables efficiencies, reduces duplication and creates opportunities for new services and innovations. Unlike standardisation, which defines common rules and formats, interoperability is about how systems function and interact together. Standardised protocols may exist, but without effective implementation, enforcement and governance, interoperability may not be achieved.

A well-designed DPI can drive competition and innovation through interoperability by enabling common infrastructure layers that multiple services can build upon. Estonia's X-Road, initially developed for secure government data exchange, later facilitated integration across banking, healthcare and private-sector applications. Brazil's PIX, designed as an instant payments platform, has since enabled new financial services such as bill splitting and alternative credit scoring. These cases illustrate how interoperability can unlock market opportunities, reduce transaction costs and foster innovation across industries. However, the extent to which interoperability benefits society depends on governance.

While interoperability reduces duplication and enhances efficiency, poorly managed interoperability can create privacy vulnerabilities,

reinforce monopolies or entrench existing inequalities. Without regulatory oversight, dominant players may influence technical or operational standards to entrench their market power, making it difficult for smaller firms to compete (Russell, 2014). Inadequate governance can also create privacy and security risks, particularly in sensitive areas such as health data-sharing. To ensure interoperability delivers broad public benefits rather than concentrating power, governments must establish oversight mechanisms that guarantee fair access, security and competition.

To **maximise its benefits and mitigate risks**, governments should:

- **Ensure regulatory oversight** to prevent dominant firms from controlling access to shared infrastructure layers.
- **Protect privacy and security** by embedding safeguards into interoperable systems, particularly in cross-sector data exchanges.
- **Encourage cross-sector adoption** by fostering ecosystems that enable businesses, public services and communities to build on interoperable DPI.

By carefully managing both the technical and governance dimensions of interoperability, policymakers can ensure that DPI enhances innovation, competition and public value, rather than reinforcing existing market concentration.

3.3 Minimal and reusable building blocks

Minimal and reusable building blocks enable digital infrastructure components to be repurposed across multiple services, reducing duplication and supporting scalable solutions. Unlike traditional IT systems that require bespoke development for each use case, modular DPI components can be designed once and applied repeatedly, lowering costs and accelerating deployment. Instead of building entirely new systems from scratch, agencies can integrate pre-existing digital components, much like how modern web applications reuse payment gateways or identity verification services. This modular approach improves efficiency by reducing redundant investments, enables rapid scaling across sectors and fosters combinatorial innovation — the ability to create new solutions by reconfiguring existing components (Brynjolfsson and McAfee, 2017).

A strong example of modular DPI in practice is GOV.UK Notify, a notification service that connects public agencies with users via email, text messages and letters. Rather than requiring each agency to develop its own messaging infrastructure, Notify provides a reusable solution that any service can integrate. As of March 2025 over 1600 organisations and 10,000 services were using Notify. This demonstrates the scalability and cross-sector applicability of reusable digital building blocks when designed with flexibility.

While modular building blocks improve efficiency and long-term sustainability, they also introduce risks. Poorly governed modular systems can lead to vendor lock-in, where dominant providers control key components, limiting competition and public-sector bargaining power. Additionally, fragmentation risks arise if different agencies or jurisdictions develop similar components without ensuring interoperability, reducing the intended efficiency gains. Over-reliance on pre-existing components can also create security vulnerabilities, as widely used building blocks become attractive targets for cyber threats.

To **maximise its benefits and mitigate risks,** governments should:

- Ensure modular components adhere to open or common standards to prevent vendor dependency and maximise reusability.
- Encourage public-sector control or oversight over critical reusable components to avoid market concentration in foundational digital infrastructure.
- Embed security-by-design principles into modular systems to reduce vulnerabilities stemming from widespread use.

By designing modular DPI with strong governance and technical safeguards, policymakers can enhance efficiency, adaptability and resilience while ensuring that these systems remain inclusive, secure and responsive to future technological shifts.

3.4 Data as a high-value input

As **established in Table 1, one of the key factors distinguishing DPI from traditional infrastructure is the role of data as both an input and output of DPI services.** Reliable and well-governed data systems have the potential to address information asymmetries, improve decision-making, and enable more efficient and inclusive public and private services. Interoperable systems are a platform for securely sharing and verifying information across multiple sectors, allowing policymakers, businesses and service providers to make more informed, lower-risk decisions.

By ensuring accurate and secure verification of users' identities in known formats and using interoperable standards, DPI also allows service providers to make informed decisions with reduced risk, increasing financial inclusion and economic growth. Financial institutions and fintech companies, for example, leverage DPI to offer personalised loans and micro-insurance products, reaching individuals previously excluded due to insufficient credit histories or higher risk. Expanding services through DPI can ultimately drive innovation and inclusion, and contribute to economic development. Beyond risk mitigation, DPI can be a foundation for responsible AI development, ensuring that AI models used in public services are trained on high-quality, interoperable and accountable datasets.

Enhancing supply chain resilience through data-sharing — US' Freight Logistics Optimization Works (FLOW)

Supply chain disruptions have led to product shortages and rising shipping costs, in part due to limited data availability, that could help improve resilience. In response to the 2021 supply chain crisis, the US Department of Transportation (DOT) used its convening power to develop Freight Logistics Optimization Works (FLOW) — a data-sharing initiative designed to improve visibility into supply, demand and freight movement. Inspired by early data trust models, such as those pioneered by the Federal Aviation Administration (FAA) in the 1990s, FLOW provides a secure platform for companies to voluntarily share logistics data, helping identify bottlenecks, enhance forecasting and reduce inefficiencies. Since its launch in March 2022 with 15 members and three participating ports, FLOW has expanded to 85 members as of December 2024. The initiative has since been used to improve business planning, optimise cargo movement and reduce operational uncertainty, demonstrating how shared data infrastructure can enhance supply chain resilience.

Source: Forthcoming IIPP case study by Jordyn Fetter and David Eaves, and US DOT website

While data is a critical asset in DPI, its governance shapes whether it drives inclusion or entrenches inequalities. For example, if there are 'invisible' individuals not represented in a dataset, it can lead to compounding effects related to a variety of important use cases, like social protection payments on the government side (Alston, 2019) and transport and finance on the commercial side (Coyle et al, 2023). The 'spectrum of visibility' could lead to an environment where the 'rights and entitlements of… "high-resolution citizens" are expanded, while those of "low-resolution citizens" are curtailed' (Singh and Jackson, 2021). Conversely, digital systems (depending on the design) may help enable selective permissioning and proportionality of data access and use (Birch, 2008; Reidenberg, 2014).

To **maximise its benefits and mitigate risks,** governments should:

- **Implement mechanisms to improve data accuracy and universality,** ensuring that underserved populations are not made invisible through incomplete datasets.
- **Promote interoperable, structured data formats** that support the use of analytics tools and reduce information asymmetries.
- **Ensure data systems funded with public money** create public benefits and do not reinforce corporate dominance.

By embedding strong governance and equity-focused design choices, policymakers can ensure that DPI's data ecosystems drive innovation, improve efficiency and enhance public value, while avoiding the risks of exclusion, bias and excessive concentration of power.

3.5 Public governance and oversight

Public oversight and governance ensure that DPI systems operate in the public interest, orchestrating private sector participation with equitable access, security and accountability. Effective governance mechanisms can prevent monopolisation, excessive rent-seeking and systemic risks while fostering trust, inclusion and long-term sustainability. However, weak governance can lead to market concentration, opaque decision-making and a lack of public recourse when digital infrastructure fails or excludes certain users.

Unlike private digital platforms, public infrastructures are expected to serve as a collective good with economic properties that make governance particularly important. Its non-rival nature means many users can benefit without reducing its availability — yet without sustainable financing mechanisms, free-rider problems may emerge. Universal access implies that governments may need to introduce cross-subsidies from profitable to non-profitable users, ensuring affordability and equitable distribution. Additionally, DPI's long-lived character means that it requires an investor with a sufficiently low discount rate — such as the state or a public-private partnership — willing to fund long-term infrastructure without immediate returns. These economic characteristics make governance and public oversight essential to ensuring DPI remains accessible, financially sustainable and resistant to capture by dominant players.

No infrastructure is neutral and DPI is no exception (Mazzucato, Eaves and Vasconcellos, 2024). The 'publicness' of DPI is not only about its technical characteristics, as outlined in this section, but also about the governance structures that direct its development and use towards maximising public value. The UNDP DPI Safeguards Framework (2023) is a good benchmark for public governance. It emphasises the need for interoperability mandates, governance transparency and security-by-design principles to prevent DPI from becoming extractive or exclusionary. Without such safeguards, DPI risks reinforcing digital monopolisation, weakening competition or creating unintended barriers for marginalised populations.

Governments must take an active role in governing DPI to ensure it serves both economic efficiency and social equity. Effective oversight could include mandatory interoperability frameworks to prevent dominant players from restricting market access, regulatory sandboxes to test new services while maintaining safeguards and data fiduciary models that balance private innovation with strong public oversight. Participatory governance processes — such as multi-stakeholder boards or public accountability mechanisms — can further ensure that DPI remains a publicly accountable infrastructure rather than a system driven primarily by corporate interests.

In addition to points on governance made in previous sections, government should also seek to **maximise the benefits and mitigate risks** of DPI by:

- **Ensuring long-term financial sustainability** by designing funding models that prevent DPI from becoming underfunded or captured by private interests.

- **Developing adaptive governance structures** that allow for iterative improvements, regulatory flexibility, transparency and public accountability, and redress mechanisms for the rapid correction of errors.

By proactively shaping governance structures that account for DPI's economic properties, policymakers can ensure that digital infrastructure remains inclusive, competitive and financially sustainable over the long term.

DPI's economic benefits depend not only on design, but also on how governments evaluate and measure their impact. While this chapter has outlined how DPI characteristics enable value creation, policymakers need a structured approach to measuring DPI's economic and societal contributions. The next section introduces a new measurement framework, moving beyond standard cost-benefit analysis to a public value-driven assessment of DPI.

4. From design to impact: a public value framework for DPI evaluation

As governments worldwide invest in digital public infrastructure (DPI), current evaluation methods fail to capture its full impact. As discussed earlier, infrastructure's value lies not in the asset itself, but in what it enables. Traditional cost-benefit analysis (CBA) overlooks long-term spillovers and market-wide transformations (see box in Section 2), requiring a more holistic assessment framework. While emergent frameworks, such as UNDP's (2023) theory of change, attempt to capture DPI's impact on finance, climate and justice, measuring the economic effects of infrastructure remains challenging. A broader public value framework is needed to capture DPI's systemic role in enabling economic and social outcomes.

To address this gap, this section provides policymakers with a structured framework to assess DPI's direct, dynamic and market-shaping effects (see Table 3). The framework was developed using two complementary approaches:

- **Conceptual:** Reviewing existing frameworks (e.g. RQIV and public value models) to define dimensions and measurement categories.
- **Empirical:** Conducting a literature review of 69 policy and research papers, and interviewing policymakers from eight countries.

The conceptual approach involved reviewing existing models to define key measurement dimensions. The framework builds on the RQIV model, assessing reach (service usage), quality (service service technical strengths), impact (broader benefits) and value for money (Coyle and Woolard, 2010). Beyond efficiency and effectiveness, it also incorporates justice and fairness considerations. While our framework does not explicitly refer to the RQIV, the chosen metrics are associated with the model's dimensions (see subsections below). In addition, we further drew on the public value approach for measuring dynamic value creation in public sector efforts (Mazzucato et al, 2020). It captures three perspectives: public sector, individuals and industry (vertical axis) and three types of effects: direct (efficiency), dynamic (spillovers) and market-shaping (horizontal axis). Each dimension is explored further below.

The empirical process included reviewing 69 policy and research papers, alongside interviews with policymakers from eight DPI-implementing countries. Given the scarcity of peer-reviewed studies — most focusing on digital payments — we relied on policy reports to identify patterns in DPI impact. While often methodologically limited, these reports highlighted key themes, including DPI's role in financial inclusion and administrative efficiency. Policymakers also expressed concerns about long-term sustainability and measuring impacts beyond immediate applications.

To ensure a structured and comprehensive assessment, the framework synthesises conceptual insights and empirical findings into three key perspectives and three types of effects. Table 3 presents these dimensions and corresponding characteristics, which are expanded through their associated measurements in Table 4. Notably, the framework does not assume the direction of economic change. Costs, competition and other economic aspects may increase, decrease or stay the same, depending on a government's starting point and the design choices associated with the DPI. Taken together, these measures can help governments proactively consider how value might be created and to whom the value might accrue. As the examples in this section illustrate, a public value framework highlights that differentiated effects can have implications for the project's overall economic value.

the three dimensions of the DPI public value measurement framework

Direct	Dynamic	Market-Shaping
Operational and service efficiency gains within core DPI functions	**Network effects, spillovers and cross-sector externalities expanding DPI impact**	**Structural transformation in industries, societies and market dynamics**
▪ Directly tied to DPI functionality (e.g. more secure/reliable authentication) ▪ Efficiency and accessibility gains within primary users ▪ Emerges even without large-scale adoption ▪ Often measurable immediately	▪ New use cases beyond original intent ▪ Interoperability and reusability expand effects across sectors ▪ Typically medium-term effects, but can emerge quickly	▪ Structural industry and state capacity shifts ▪ Alters power dynamics between governments, firms and individuals ▪ Effects are often durable and harder to reverse
▪ Faster processing of government services ▪ Increased authentication speed and accuracy ▪ Public sector cost-savings (e.g. IT consolidation, reduced paperwork)	▪ Financial services integrating e-ID for faster credit scoring ▪ Private sector using DPI for secure authentication ▪ Cross-agency data-sharing for better service coordination	▪ Shift from cash to digital payments, increasing tax compliance ▪ Growth of DPI-driven financial ecosystems ▪ More competition, new monopolies or market dependencies forming around DPI services
▪ Key for demonstrating DPI's short-term benefits ▪ Helps justify early investments ▪ Informs risk mitigation in early rollout	▪ Determines if DPI adoption will scale effectively ▪ Requires safeguards for fair access and preventing exclusion ▪ Anticipating spillover risks is key for regulation	▪ Governments must proactively manage market dependencies ▪ Long-term policy strategy must align with economic shifts DPI creates ▪ DPI ecosystems need governance to ensure fair competition and sovereignty

A few clarifications help explain the distinctions between the categories and the choices we made:

Categories are not rigid and some effects span multiple categories

Effects can fit into more than one category depending on how they emerge and scale. For example, fraud and leakage reduction can be direct, dynamic or market-shaping. It is direct when DPI immediately prevents unauthorised access to government benefit programmes. It can be dynamic when DPI is scaled across sectors and reduces fraud against or improves access to financial institutions who can verify identities more reliably. Finally, DPI can change the costs of inputs in ways that might reshape markets. For example, lower cost and universal KYC facilitated by DPI may expand access to credit for underserved populations by lowering costs to existing players, drawing in new competitors or enabling new business models. Since some effects unfold across multiple layers, it's important to assess not just where an effect starts, but how it evolves. The same logic applies to efficiency gains, cost reductions and economic formalisation — some begin as direct gains, but expand dynamically as DPI adoption grows.

Policymakers should thus treat these categories as a framework and not as fixed silos when assessing sequencing and scaling effects. Any measurement framework should recognise that some short-term efficiency gains (direct) can expand (dynamic) and, eventually, enable transformative market shifts (market-shaping).

Some DPI effects are unique, but others are amplified effects of traditional digitalisation

While DPI has distinct effects, some effects overlap with broader digitalisation efforts. For example, simplifying paper processes or improving efficiency via digitisation are not unique to DPI; these are generic effects of digital transformation. However, DPI can accelerate, amplify or shape these effects in specific ways. For instance, government digitalisation alone might streamline public services, but DPI structurally changes how multiple actors interact — by providing shared platforms, ensuring interoperability and reducing duplicative investments. Similarly, cybersecurity risks exist in any digital system, but DPI introduces specific risks and mitigation strategies tied to centralised or federated architectures.

To distinguish DPI-specific effects, we focus on three dimensions: infrastructure-level enablers (if DPI provides shared, foundational services), cross-sector adoption patterns (if DPI enables new interactions across sectors) and ecosystem dependencies (if DPI creates dependencies that shape market structures).

Time horizon is correlated with categories, but is not a defining factor

While direct effects often emerge first, dynamic ones later and market-shaping ones last, time is not the defining characteristic of these categories. Some market-shaping effects can occur quickly, while some direct effects may require long-term adoption. For example, market-shaping effects can be rapid if a government mandates DPI use for payments and entire industries rapidly shift from cash to digital transactions. Likewise, direct effects can take time. If DPI aims to reduce administrative costs, these savings might only materialise over years as legacy systems phase out.

Thus, while time horizons often correlate with the categories, policymakers should not assume a strict sequence. Instead, they should analyse the conditions that accelerate or delay these effects, such as policy design, adoption speed and complementary infrastructure.

4.1 Measuring DPI's potential impact

With the distinctions above in mind, Table 3 provides a structured, though non-exhaustive, set of measurements for assessing DPI's impact across direct, dynamic and market-shaping effects. These categories help policymakers track the short-term efficiency of DPI implementation, anticipate cross-sectoral adoption patterns and understand its broader structural implications over time. The measurements are designed to be flexible and suited to the jurisdiction's political and economic context and the available offerings for DPI solutions.

Table 4: Proposed measurements for DPI value creation

Type	Public sector (society)	
Direct Operational and service efficiency gains within core DPI functions	▪ **Uptake and use** of a given DPI-enabled service ▪ **Operational cost-savings** from reduced IT expenses, procurement ▪ **Government programme leakages** (e.g. fraud, duplication, inefficiencies) ▪ **Tax revenue** (e.g. reduced avoidance and evasion) ▪ **Public servants' time saved in processing service requests** (e.g. digital workflows vs manual)	▪ **Coverage o** geographical ▪ **Administrat services** (e.g ▪ **Citizen satis** (e.g. responsi ▪ **User experi** ease of use) ▪ Incidents of **f** ▪ **Reduction i support** (wit
Dynamic Network effects, spillovers, and cross-sector externalities expanding DPI impact	▪ **Extent of interoperability** across government systems ▪ **Cost savings from digital interoperability** (e.g. shared data infrastructure) ▪ Increase in government **ability to detect and prevent corruption** ▪ **Improved targeting** of government policies ▪ **Time/cost-savings in launching new public-sector services** by leveraging existing systems ▪ **Net environmental impact of DPI adoption** (e.g. reduction in paper use vs increased cloud infrastructure energy)	▪ Public **perce transparenc** ▪ Public **trust i** ▪ **Citizen ado** digital payme
Market-shaping Structural transformation in industries, societies and market dynamics	▪ **Government capacity to respond to crises** (e.g. cash transfers, crisis relief) ▪ **Shifts in government reliance on private sector DPI components** (e.g. risks of vendor lock-in vs digital sovereignty) ▪ **DPI's role in economic formalisation** (e.g. increased tax base via digital transactions) ▪ Changes in **government leverage** over digital markets ▪ Shifts in **public-private governance models** due to DPI integration	▪ **Expansion** previously un ▪ **Psychosoci in service d** digital service ▪ **Longer-term** enhanced tra ▪ Shifts in **citiz responsiver**

Source: Authors' elaboration

To translate this framework into actionable insights for policymakers, the next sections examine how these different dimensions of impact can be assessed in practice, with some practical illustrations. We begin with direct measures, which are the most immediate and often serve as the foundation for evaluating government investment efficiency.

4.2 Direct measures

Direct measures, or first-order effects, provide the most immediate and tangible assessment of a DPI system's value. Governments often prioritise these indicators, as they capture short-term efficiency gains, cost-savings and service reach. These measures answer key questions across four dimensions:

- **Reach:** Who is using the DPI-enabled service and how has adoption varied across different groups? What is the projected take-up and usage over time?
- **Quality**: How reliable, accessible, and user-friendly is the DPI-enabled service? How robust and easy-to-use is the technology?
- **Impact:** How do individuals and society benefit from DPI adoption and what challenges remain?
- **Value for Money:** How much will the proposed DPI cost to deliver (both actual and contingent) and which savings will it generate? How does DPI's cost-effectiveness compare to alternatives and what are the financial returns?

Direct indicators establish a baseline for evaluating DPI's early-stage effectiveness before broader spillover effects emerge. Studies have used multiple approaches to measure DPI's direct impacts. The following sections illustrate how DPI's direct impacts can be measured using the RQIV model (reach, quality, impact, value for money), with evidence from existing implementations.

Reach (e.g. take-up, usage, accessibility)

One approach to measuring reach is through publicly available transaction data, such as those provided by the Banco Central do Brasil (BCB) and the National Payments Corporation of India (NPCI), who keep detailed and publicly available statistics on PIX and UPI **usage**. The PIX statistics cover the amount and volume of transactions, types of transactions, forms of initiation and the number and types of users (Banco Central do Brasil, 2024). The NPCI tracks similar figures, including 'product statistics' like the daily volume and value of transactions on UPI and 'ecosystem statistics' like the volume and transaction amounts per UPI app and remitter (NPCI, 2024). Such measurements help policymakers assess not only uptake, but also patterns of usage — for instance, whether lower-income groups, small businesses or rural users are benefiting at the same rate as urban, wealthier users. By examining these trends over time, governments can evaluate whether DPI systems are achieving equitable adoption and financial inclusion goals.

Beyond aggregate usage statistics, assessing the **distribution of DPI access** provides deeper insights into equity and inclusion. For instance, in South Africa the adoption of the SmartID varied from 61% for the population over 60 years old vs 38% for those between 46 and 60 years old (Howson and Partridge, 2022). The gap is most likely explained by the strong incentives for elders to have a digital ID to receive a pension. The same research reveals that the cost of accessing the ID was deemed as a barrier by 31% of rural dwellers without access vs 18% of urban dwellers.

Meanwhile, **geography** may play a role in some contexts. For example, in India, while Aadhaar penetration is reported to be 95% as of January 2025, adoption is 62.9% in Nagaland, 78.8% in Arunachal Pradesh and 79.9% in Meghalaya. Country-level record-keeping by the relevant ID authorities may also provide additional insights, such as which specific provinces may need additional targeting or resourcing.

In terms of economic value, considering both overall coverage and distributional considerations in direct measurements is essential in considering the long-term impacts. For example, at the individual level, the 'spectrum of resolution' that results from inclusion or exclusion has significant knock-on effects (Singh and Jackson, 2021) that can ultimately affect dynamic and market-shaping outcomes.

Additional measurements for reach could include, for example, **number of businesses leveraging DPI** for service provision.

Quality (e.g. technological robustness, perceptions, service quality)

Direct measurements may also consider the **satisfaction** with the given service. For example, a pulse survey of 147,868 respondents across 28 Indian states found that 92% of surveyed individuals were very or somewhat satisfied with Aadhaar and 81% of those with Aadhaar said they would use Aadhaar when given a choice of which ID to use (Sonderegger et al, 2019). However, beyond user perception, **service quality metrics** — such as authentication failure rates, system downtime and accessibility for low-tech users — are equally critical for evaluating DPI effectiveness. For instance, India's Aadhaar system faced initial concerns about biometric mismatches, particularly for elderly and manual labourer populations, raising the need for alternative authentication methods.

Impact (e.g. broader social and economic benefits)

Beyond service delivery improvements, DPI adoption can directly impact outcomes like fraud detection, leakage in social programmes, revenue collection and citizen interactions with public services. These effects are observable early on and influence how well DPI serves its intended function within government and society. For example, in India, **revenue collection** via the goods and services tax has grown by more than 50 basis points of GDP since 2018 (Chandra, Vaid and Varma, 2024). As outlined in one report, jurisdictions have taken different approaches to fees and, therefore, will have different projected revenues (World Bank ID4D, 2019).

Another potential measurement of direct impacts could be **changes in time spent accessing services**. For instance, one study of the Estonian X-Road system estimates its impacts in terms of time saved. Under a 'conservative' estimate of 15 minutes saved per transaction, they find savings of 3225 years across the 13 million transactions completed in 2014 (Vassil, 2015). A study of cash transfers in Niger found that recipients saved approximately one hour in travel time and three hours and 30 minutes in waiting times per cash transfer for those who received the payment via mobile money (vs via manual cash disbursement) (Aker et al, 2016). Finally, a study found that digital ID integration in the Philippines was estimated to reduce time for new business permits by 80% (World Bank ID4D Annual Report, 2023). The study highlights potential improvements in efficiency, data accuracy and customer experience across financial services, local government and social protection sectors.

These direct impacts primarily reflect efficiency gains within government and immediate economic benefits, distinct from longer-term market shifts covered in later sections. Several other measurements for impact could emerge, particularly in specific domains or sectors that leverage the DPI. Some of the most cited in policy reports and academic papers are potential **reductions in leakage in social programmes, fraud reduction** in tax filling, frequency and scale of **data breaches** and **revenue generation from DPI-based services**, like ID verification fees and KYC cost reduction.

Value for money (e.g. savings, reduction in intermediaries, operational cost reduction)

Measurement of costs and (projected) benefits are also often used to understand direct effects. Costs may be measured as a **percentage of a department or government's budget or on a per-person basis**. For example, the rollout of the Aadhaar project is estimated to have cost less than $1.50 per enrolment (using the estimated $1.5 billion total spent between 2009 and 2013) (GSMA, 2017). Given the size of India's population, high upfront investment and low marginal costs made for a cost-effective calculus in their case. Notably, this may not be the case in other contexts. The calculus may depend, for instance, on the size of the population, the existing infrastructure (and accordingly, what would need to be built up to enable DPI and on what timeline), the state capacity for effective procurement and oversight.

Additional measurements for value for money could include, for example, **operational cost-savings** with IT systems and procurement, monetary effects on **number of human intermediaries** between the beneficiaries and the service providers, and **time spent by citizens trying to access DPI-enabled digital services**, among others.

While direct indicators capture DPI's immediate operational benefits, its full potential emerges as it scales across sectors. The following section explores how DPI integration generates network effects, externalities and broader economic transformations over time.

4.3 Dynamic measures

Dynamic measures, or second-order effects, consider the spillovers and externalities often characteristic of infrastructure projects. This could be due to network effects or reusability effects, for instance. Unlike direct measures, which focus on immediate efficiencies, dynamic measures capture how DPI expands across sectors, facilitates interoperability, and influences public and private sector behaviours. These effects are often nonlinear — meaning their impact grows as more entities adopt DPI services. Dynamic measures address key questions across the RQIV dimensions:

- **Reach:** How does DPI adoption influence the usage of services that build on it? Are new users and underserved populations benefiting?
- **Quality**: How does DPI improve interoperability and decision-making in cross-sector services?
- **Impact:** How does DPI reduce transaction costs, improve service efficiency or reshape governance?
- **Value for Money:** How does DPI lower costs across government and industry sectors? What economic efficiencies does it unlock?

As DPI adoption expands, its effects go beyond individual transactions or isolated efficiencies. The extent to which DPI enables services across sectors determines its true infrastructural value. Measuring reach helps assess whether DPI is fostering broader adoption and inclusion or remaining underutilised within siloed applications.

Reach (e.g. cross-sector take-up, usage, accessibility)

The DPI approach is distinct in its explicit focus on enabling multiple public and private sector services. Leveraging the information and certainty a DPI provides can enable a range of sectoral cases – for instance, financial services, healthcare and education. One measure might be the **number of sectoral use cases enabled** and, within these use cases, how many players are operating and at what volumes. For instance, of the 115 jurisdictions included in the IIPP's DPI Map of publicly available data on DPI internal uptake of digital identity systems, only in 62 jurisdictions the identity infrastructure enables at least two sectoral use cases (DPI Map, 2024). This means that in almost half of the implementations, the digital identity is not fulfilling any infrastructural role.

Reach metrics associated with businesses leveraging the interoperable systems could also be calculated.

Quality (e.g. improved decision-making)

The access and design of the system, in turn, affect the **quality and value of the data within the system**. As the Open Data Institute's 'data spectrum' illustrates the different uses and access rights associated with datasets have implications for their use and economic value (Open Data Institute, 2020). DPIs may offer various configurations for data access based on data type (small, medium, big) and entity type (personal, commercial, government). Who has access to what data and in what form has implications for the potential services that can be built on top of DPIs, and the available data combinations for profiling and decision-making. These design choices would, in turn, affect the aggregate economic value of the DPI.

Impact (e.g. transaction costs, GDP impact, efficacy of service provision)

Some studies have also begun to measure the overall economic impacts of DPI implementation. For instance, exploiting the heterogeneous uptake of UPI, one study found that the relaxation of borrowing constraints and **reduction in transaction costs** associated with payments led to better economic outcomes in terms of household income and small business activities in many Indian jurisdictions (Dubey and Purnanandam, 2023). Some studies have also attempted to quantify DPI's impact on **changes to domestic GDP**, but numbers vary widely. DPI efforts may benefit from a more structured approach to this quantification.

Another measurement might be the **efficacy of service provision**. One of the ways in which this happens is through reducing information asymmetries, leading to more efficient resource allocation. Further in the life cycle of financial services, for instance, a randomised control trial in Malawi found that introducing a biometric identification system allowed lenders to verify borrowers' identities accurately, reducing the risk of default and increasing lenders' willingness to extend credit. This effect was only observed for borrowers with the highest ex-ante default risk (Giné et al, 2012). For MSMEs and individuals, data generated via digital payments may also increase access to credit through creating a digital footprint (Chhabra and Sankaranarayanan, 2019).

Value for Money (e.g. savings by building services on top of DPI)

One way to measure a DPI's dynamic effects is to consider its impact on sectors that use the DPI service. One such measurement may be the **change in the costs of building services on top of a DPI**. For instance, KYC checks are a significant part of the cost and complexity associated with financial services. Estimates vary significantly, because the overall costs of KYC have not been systematically estimated to date and there is no consistent methodology for measuring KYC-related costs. However, industry estimates find it can range from $13 to $130 (Jendruszak, 2022). Still, some argue that electronic KYC via a centralised government database may lower the time and monetary costs associated with the KYC, and thereby increase competition within and access to financial services. For example, India's Economic Survey states that introducing e-KYC services reduced the cost of conducting KYC from 12 to 6 US cents. However, the methodology for calculating the figure was not included (India's Ministry of Finance, 2024).

While dynamic effects capture DPI's expanding influence across sectors, some impacts go further — fundamentally altering market structures, industry dynamics and state capacity. These market-shaping effects emerge as DPI changes how services are provided; how competition evolves; and how governments and private actors interact. The next section explores how DPI's role extends beyond operational efficiencies to shaping long-term economic and governance transformations.

4.4 Market-shaping effects

Measuring market-shaping effects considers **how DPI restructures industries, economic ecosystems and governance models**. These shifts occur through **competition, regulatory adaptation and industry-wide dependencies** that emerge as DPI adoption scales. Market-shaping effects might include:

- **How DPI reshapes industry structures and market** — does it enable more competition or reinforce dominant players?
- **How DPI transforms economic value chains** — including upstream infrastructure providers and downstream service delivery models.
- **What new business models, industries or regulatory frameworks emerge as a result of DPI adoption?**

Given the nascency of many DPI efforts, many market-shaping effects remain to be seen. However, there are early indications that DPI may contribute to market-shaping in contexts with more mature projects. For example, Estonia, India and Singapore — which have all been implementing DPIs for some time — have all established **'ecosystems' of service providers** dedicated explicitly to implementing DPIs domestically and abroad (e-Estonia, n.d.; Government Technology Agency of Singapore, n.d.; iSPIRIT, n.d.). DPI, then, in and of itself, may be considered a **new market opportunity** (Varma et al, 2024). Relatedly, a report from Bain cited India Stack as one of the four factors that have contributed to the rise of venture capital funding in India in the past few years (Sheth et al, 2022). Early evidence also suggests an association between DPI implementation and **financial inclusion**. According to the World Bank's Global Findex Database, the number of Indian adults with a bank account surged from 35% in 2011 to 77.53% in 2021. Studies suggest that this dramatic increase in financial inclusion can largely be attributed to the implementation of Aadhaar-based e-KYC, which streamlined the opening of bank accounts (D'Silva et al, 2019). By reducing information asymmetry, e-KYC made it easier for millions of previously unbanked individuals to access formal banking services, which is crucial in expanding financial access.

For inspiration, it may be useful to turn to historical examples of infrastructure-related market-shaping. For example, infrastructure and infrastructure policy is 'more than the sum of its physical parts' (Steele and Legacy, 2017). Rather, it 'shapes our cities socially, environmentally and politically' (ibid), playing a critical role in the fates of industries, who has access to what services and opportunities, and the nature of community relationships. Importantly, market-shaping proactively considers that how the infrastructure is facilitated and implemented has implications for the structure of markets.

These can, in turn, be used to set detailed objectives for the relevant government entity. A strength of the public value framework as applied to (digital public) infrastructure is its consideration of value beyond a simple cost-benefit analysis of a value-for-money calculation, though they are embedded within the broader measurement framework. Beginning, but not remaining constrained by, these direct measurements contribute to projecting wider value creation. From a process standpoint, considering the public value (in terms of the individual, market and societal impacts) is included at each stage.

The key features driving the economic importance of digital infrastructure described in Section 3 combine to facilitate rapid growth in the use of downstream activities enabled by DPI and to amplify the economic impact of these activities, which were outlined in Section 4. However, the real impact (including whether the direction is positive or not) will depend not only on the technical features, but also on contextual elements (like the size of the country), the decisions about governance and practical trade-offs, which will be expanded on in Section 5.

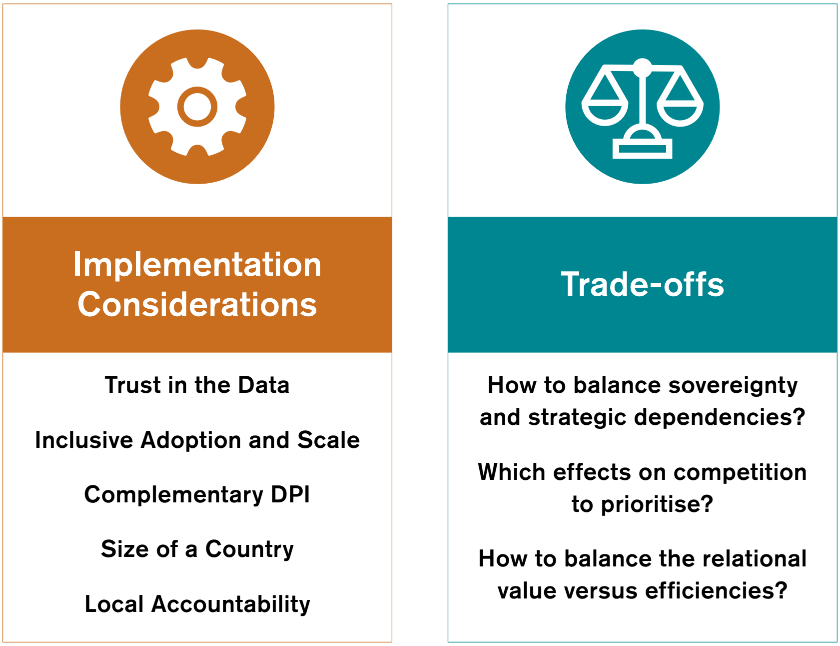
5. Additional factors that impact value creation and trade-offs

The measurements above highlight the importance of technology and programme design, and assess the distribution of costs and benefits. In practice, **the accurate picture of costs and benefits will likely be quite complex**. For example:

- **One meta-study of biometric welfare authentication in India** found that the implementation in Andhra Pradesh and Jharkhand both reduced leakage. However, while in the former the benefits were passed on to the beneficiaries (as funds displaced from corrupt intermediaries translated to more money received), in the latter it led to 'reduced disbursals from the government but did not improve the beneficiary experience in any way (and worsened it in some ways)' (Muralidharan et al, 2025).
- **A cross-country study of fast payment systems** (FPS) found that 'adoption of fast payments tends to be more widespread when the central bank owns the FPS, when non-banks participate and when the number of use cases and cross-border connections is greater.' Specifically, 'non-bank PSP participation is associated with an increase of 3.5% in the number of FPS transactions per capita. An additional use case offered by the FPS is associated with a 2% increase and an additional cross-border connection with an increase of the same magnitude. Public ownership of FPS entails an increase of 1.8% in FPS transactions' (Frost et al, 2024).
- **At the same time, DPIs can help enable new realities that do not have well-defined value measurements.** For instance, digital systems (depending on the design) may help enable selective permissioning and proportionality of data access and use (Birch, 2008; Reidenberg, 2014).

While some positive potential outcomes (such as easier retail payments) are clear, most will depend on implementation (Are there universal service obligations on private providers? Are there too many errors in personal identification? Do proprietary rather than open standards creep in?) **or may involve trade-offs** (Is there a dominant provider to enhance network effects, and what are the implications for market contestability and future innovation? Should all the data in the data layer be open or should some proprietary elements be maintained to incentivise private investment?). In this section, we offer some broad implementation considerations and trade-offs (Figure 2) to consider in the system's design choices.

Figure 2: Factors that impact value creation and trade-offs



Source: Authors' elaboration

5.1 Additional enablers that affect how much value can be accrued by DPI

Trust in the data

DPI is only as good as the data it runs on. If the underlying data is low quality, outdated or incomplete, it can introduce errors, compounding exclusions and inefficiencies that undermine both public trust and economic value. Take digital identity systems, for example. If records are inconsistent, people can lose access to essential services — whether that's welfare benefits, financial services or voting rights. These biases can reinforce inequalities — as seen in cases where data quality has led to several cases of individuals being locked out of the entitlement systems entirely (eNCA and Motsoaledi, 2023). Aadhaar's experience in India shows how errors in biometric matching and data inconsistencies led to wrongful exclusions, sometimes with serious consequences. One study of Aadhaar found a 'rise to a spectrum of resolution in which the rights and entitlements of "high-resolution citizens" are expanded, while those of "low-resolution citizens" are curtailed' (Singh and Jackson, 2021). The situation may be further complicated when the DPI system does not fully replace previous systems, allowing for coexisting inconsistencies. In Nigeria, the overlap between the NIN, BVN and TIN systems has created inefficiencies and made it harder for individuals to verify their identity (Macdonald, 2024).

Beyond access issues, **poor data quality also weakens the economic potential of data as a high-valuable input.** If datasets are unreliable, they can't effectively support AI-driven services, predictive analytics or automated decision-making.

Many have also highlighted that there are specific sets of considerations and potential compounding effects for vulnerable populations, including due to the growing use of algorithms in critical decision-making around entitlements and services (Sambhav et al, 2024; Tapasya et al, 2024). This 'algorithmic imprint' seems to persist even when algorithms were deemed inappropriate and removed (Ehsan et al, 2022).

For DPI to deliver on its promise, governments must treat data quality as a core policy priority — not an afterthought. This means investing in continuous data validation, ensuring strong correction mechanisms and building clear accountability structures. Without these safeguards, DPI risks becoming yet another layer of exclusion rather than a tool for economic and social inclusion.

Inclusive adoption and scale

Even with high-quality data, DPI is meaningless if large parts of the population can't access it. If people lack digital literacy, a stable internet connection or even the required identification documents, they risk being locked out — making DPI another barrier, rather than an enabler. Digital divides don't just happen — they get reinforced. Geographic, income-based and gender disparities in adoption mean that the people who could benefit most from DPI are often the ones least likely to use it. The World Bank's

ID4D dataset shows that in some countries, rural populations, women and low-income groups are much less likely to have a foundational digital ID (World Bank, 2021). For example, women in low-income countries (LICs) are eight percentage points less likely to have an ID than men.

Bangladesh's Phygital Experience

One way to bridge the access gap is through hybrid models — integrating digital services with physical access points. A2i, Bangladesh's National Innovation Agency, established over 9000 union digital centres (UDCs) nationwide in an effort to include a physical 'access layer' on top of the digital public infrastructures. The idea was that local entrepreneurs could run outsourced government services shops at a maximum range of 4km from any individual in the country. Studies so far show mixed results. While UDCs can empower rural communities, minimising information gaps, reducing time-cost-visit and providing service delivery at affordable prices, there are still issues of lack of engagement from marginalised groups, lack of awareness and conflict of job responsibility with the local government secretaries, and weak network connection (see Abedin et al, 2021; Amin and Shumshunnahar, 2023).

Ensuring inclusive adoption means thinking beyond digital-first approaches. DPI needs on-the-ground infrastructure, targeted digital literacy efforts and strong feedback loops to track usage across different demographics. If governments want DPI to actually serve the whole population, they need to proactively identify who's being left behind — and design ways to fix it.

Complementary DPI

Assessing the impacts of DPI in a particular context requires evaluating the combinatorial effects of combining more than one foundational DPI. One of the characteristics of infrastructure (Section 2) is its **compounding effects of complementary infrastructures**. Therefore, a country with a digital ID combined with a data exchange system, like Estonia, is more likely to have increased scaling and dynamic effects than one which only has one or the other.

To fully realise DPI's benefits, governments should adopt a systems-thinking approach. Policymakers should evaluate, from the offset, whether there are already other shared components initiatives in the country that can be leveraged to gain speed, scale and cross-sector innovation.

Country size

The analyses in the previous sections made it clear that the potential for DPI's impact is significant. However, the spillover effects are likely more significant for countries with a larger population. This is because **infrastructural characteristics imply decreasing marginal costs as more users and use cases leverage the infrastructure**. For example, the return on investment of a highway that links only two cities in a low-populated area is lower than one that connects various locations and has higher traffic. The same applies to digital. The economic benefits of building a digital ID in India, where government officials claim that Aadhaar costs below $1.50 per person (GSMA, 2017), are likely much higher than in a smaller country, where the marginal costs of an ID system tend to be higher.

For smaller countries, maximising DPI's value requires strategic design choices — such as leveraging regional collaborations or open-source architectures (such as DPI as a packaged solution or DaaS). There is also a stronger need for governments to assess not only the feasibility of DPI investments in isolation, but also partnership models that can enhance scalability and sustainability.

Local accountability

DPI may lead to over-centralisation, reducing local accountability. While it can enhance efficiency and streamline public services, there is a risk that it could centralise decision-making to the point where local officials lose the ability and accountability to address community-specific needs. For example, if the data is not accurate, or if the user needs support and there are no easily accessible and inclusive contact points for grievance redressal, on an individual level, the DPI system may be decreasing the value for a few people, even if the society-wide benefits prevail. An anecdotal experience in India[3] illustrates the potential struggles of a citizen who lost their Aadhaar card and struggled to find a local solution. In several countries it has been up to civil

3 Dheeraj Kumar, @roadscholarz, 25 July 2024 (1/6): Hello @UIDAI, please read this thread and act on it. Sangeeta Kumari lost her Aadhaar number and is unable to retrieve it. First she was told to re-enrol and when that failed, the UIDAI Helpline told her 'find out your date of birth'! [Tweet]. Twitter: https://x.com/roadscholarz/status/1816315227866124422

society and the courts to raise issues on behalf of individuals who have lost access to services due to issues with digitised government services.[4]

To mitigate these risks, DPI should be complemented with effective grievance redressal mechanisms and accountable local governance structures that ensure local officials remain responsive and adaptable to the unique challenges of their communities. Balancing the benefits of centralisation with the need for localised, accountable governance is crucial.

5.2 Key trade-offs in steering DPI

How to balance sovereignty and strategic dependencies?

One of the main justifications for investing in digital public infrastructures, as opposed to private digital infrastructures, has been the desire for increased sovereignty. In most cases, sovereignty has been understood as ownership of the infrastructure, which may enable it to be more resilient against external tampering, rent extraction by private actors and over-dependence on a small number of actors that can risk instability at the infrastructure level. However, at least **two trade-offs** can be taken into account. First, while a national or public-interest-led infrastructure may increase sovereignty, **the implications for quality depend on local capacity.** Lack of competition with international companies could lead to poor service if national providers do not offer high-standard services. The second consideration is a country's reliance on foreign and private companies for cloud, security and hardware provision. While DPI may enable sovereignty at the software layer, **a country may fall under a sovereignty illusion if it is locked into service provision by international players or there is market concentration on lower levels of the technology stack.**

To lower the risks, policymakers must consider whether they are adhering to private, largely used international or their own standards. Rules for procuring software and services on top of the shared DPI layer can also be reviewed to prevent vendor lock-in. Finally, governments should

4 See, for example, the cases of Kenya, India, Uganda, South Africa and Jamaica.

assess sovereignty not just as ownership of infrastructure, but as long-term control over its operations, standards and dependencies — ensuring resilience without sacrificing quality or innovation.

Which effects on competition to prioritise?

DPI can influence competition in several ways. On the one hand, DPI can lower entry barriers for new firms in downstream markets by providing services like identity verification and digital payments on which other products and services can be built cost-effectively. In some cases, government provision of these enabling services at low or no cost can help level the playing field. DPI could even be the catalyst for new services that could ultimately grow into formidable competitors for incumbent firms in other markets. In many places, for instance, digital payment players ultimately expanded their offerings and have become complements or even substitutes to incumbent financial service providers (see example below). Some services may operate best under natural monopoly conditions in order to enable markets at other layers of the stack. However, governments will need to consider what guardrails should be put in place to ensure that the vision of market enablement at those layers is realised and to prevent excessive rent extraction.

Brazil's digital payments PIX is associated with increased competition in the deposit market

A study found a significant and persistent decline in deposit market concentration in Brazil after the introduction of PIX, primarily because households opened relatively more deposit accounts at smaller banks than at larger banks. The study also shows that small banks gained significant deposit market power relative to large banks due to the PIX launch (Sarkisyan, 2024).

On the other hand, DPI does not level all playing fields – warranting careful consideration of not just *what* value is created, but also *for whom* the value is created. On the DPI layer itself, natural monopoly characteristics are likely to exist. When a single entity or a consortium of entities controls critical digital infrastructure (or the standards around it), they can set the terms of access and usage, potentially stifling competition. This risk is particularly pronounced if parts of the implementation are proprietary (biometric hardware, for example) or if there are high switching costs for users and service providers (such as cloud services). **Competition should also be considered in the layers below (enabling infrastructure) and above (applications and services with access to the DPI).** While DPI may enable innovation and new business models to emerge, historical examples and current market trends suggest that DPI projects may contribute to natural monopolies or oligopolistic structures, particularly in the case of fast-movers (see examples below). This may be the case with or without DPI; outcomes depend on a whole-of-government approach, including collaboration with competition and data protection authorities, for instance.

Some companies gained significant market share with India's DPI

India's Aadhaar, particularly the eKYC capability built on top of it, enabled the disruptive new business model for the mobile network operator Reliance JIO, rapidly gaining market share in the telecom market (Alonso et al, 2023). Likewise, UPI created a new duopoly for payment intermediaries (PhonePe and Google Pay) on top of the infrastructure. At the same time, these companies and their business models have been associated with an increase in DPI adoption. Therefore, balancing private and societal interests, and possible market concentration effects, are trade-offs to be considered for evaluating DPI's value to individuals, industry and society.

Shifting competition through interoperability may also affect markets in unintended ways. While there are not enough studies on DPI and competition, an example in the mobile money market in African countries may provide useful insights (Brunnermeier et al, 2023). The study found that while large-scale interoperability policy lowered mobile money fees, it also lowered the profitability of private players, leading to reduced investments in network coverage and mobile towers, especially in rural and poor districts. Therefore, interoperability also resulted in a decline in various survey metrics of financial inclusion.

Many governments have yet to fully address the practical implications of the DPI systems for competition. Ultimately, DPI's competitive impact is shaped not just by its design, but by how governments regulate market dynamics. Thoughtful policy choices can ensure that value creation benefits a broad ecosystem rather than entrenching a few dominant players. Competition policies are likely to be needed along with DPI implementation.

How to balance the relational value versus efficiencies?

As described in previous sections, DPI reduces transaction costs, increasing savings. By reducing human intermediaries at scale, it may also lower corruption levels. However, **in some societies, and geographical and demographical contexts, the relational aspect may be more valued than the efficiency gains.** This observation aligns with the findings of Ratner et al (2022), who examine how 'digital data infrastructures' can both organise and disorganise social relations and Knox (2021), who examines how digital infrastructures have shaped social relationships. It also aligns with Rees et al (2022), who emphasise that while digital networks can enhance social connectedness, they cannot fully replace the necessity of physical interactions, particularly in community-oriented spaces. The interplay between digital and physical infrastructures thus highlights the importance of considering how digital tools can either bridge or widen existing social divides.

Therefore, governments must proactively consider alternative and easy-to-access mechanisms for in-person grievance redressal, particularly in contexts where internet penetration and digital literacy are low.

6. From framework to action

Digital public infrastructure is not just about technology — it is about how societies choose to design their digital future. Yet, as with physical infrastructure, measuring its economic and societal value remains a challenge. While its benefits are widely assumed, they are often difficult to quantify, making evidence-based investment and governance decisions more complex.

This paper offers a starting point for governments to understand how DPI functions as infrastructure, which design choices maximise its economic value and how to measure its direct, dynamic and market-shaping effects. By embedding these measurement principles into investment frameworks, governance models and regulatory approaches, policymakers can ensure that DPI delivers sustainable, inclusive and measurable public value. However, realising this potential requires a proactive approach — not just in designing DPI, but in defining who benefits, how success is measured and what mechanisms ensure accountability. This requires deliberate strategic choices — not just about governance and investment, but about competition, accountability and long-term resilience.

Several **critical questions remain:**

- Governance and strategy: If DPI can unlock significant economic value, what role should ministries of finance and treasuries play in steering DPI adoption and investments?
- Funding and incentives: Can funders and donors establish investment conditionalities to encourage the widespread, responsible adoption of DPI?
- Maximizing impact: Are current DPI implementations capturing their full potential value? What governance and design choices could be adjusted to unlock more?
- Metrics and accountability: Are DPI implementers tracking the right indicators for DPI's impact? Who is responsible for ensuring alignment with public value?

At its core, DPI's impact will depend not just on what is built, but how it is governed and who benefits. While its potential for value creation is vast, the wrong design choices could just as easily entrench inefficiencies, reinforce monopolies or exclude marginalised communities. The real test for DPI is not whether it is implemented, but whether it actively expands economic opportunity, enhances inclusion and delivers measurable public value.

DPI Design Characteristics		
Minimal and reusable building blocks	**Data as a high-value input**	**Public oversight and governance**
Allows for cost-effective and adaptable digital solutions that support multiple services	*Weak or no relationship*	Makes DPI a core responsibility of the state and ensures essential functions are prioritised
Supports modular expansion without costly system overhauls and increases long-term sustainability by allowing targeted upgrades rather than full system overhauls	Maintaining long-term reliability and economic value requires sustained investment in data quality, verification and governance	Requires an investor with a sufficiently low discount or hurdle rate and potential de-risking of private investment. Also needs governance to ensure data accuracy, prevent bias and uphold responsible stewardship
Supports shared infrastructure across different industries	Data is non-rival, but privacy, security and governance concerns must be managed	Requires sustainable funding models to mitigate free rider issues and ensure long-term maintenance, security and upgrades
Allows more players to build services on top of DPI with lower costs and supports rapid scaling of digital services across new sectors	Expands coverage and access to trusted data sources	Ensures public accessibility through cross-subsidies and regulatory oversight, even when privately operated
Allows shared digital infrastructure to be used in multiple applications	Structures data so it can serve as a reusable economic resource	*Weak or no relationship*
Reduces costs for future DPI-based services	Improves downstream services through data-driven insights and automation	Requires oversight to ensure broad public benefit and prevent rent extraction
Supports ecosystem-wide innovations through reusability	Enhances real-time and evidence-based decision-making capabilities and strengthens economic forecasting	Requires adaptive governance to manage evolving risks and ensures public accountability to prevent negative externalities
Encourages innovation in complementary sectors	Allows data to serve as a bridge across multiple systems	Does not inherently influence interdependence, but can establish policies to manage integration
Reusable building blocks risk **entrenching monopolies** if dominated by a few vendors	Low quality data or poor data governance can **reinforce bias and exclusion**	Weak oversight increases risks of **regulatory capture** by dominant firms

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