The Standard of Standards

Digital Sovereignty and Fair Competition Through Cross-Sector Interoperability

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Bertelsmann Stiftung

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Executive summary

Standards in the digital realm are more than technical specifications – they serve as market infrastructure with normative force. Consider the Internet: foundational standards such as the Transmission Control Protocol/Internet Protocol (TCP/IP), Simple Mail Transfer Protocol (SMTP) and Hypertext Transfer Protocol (HTTP) govern how computers exchange data, how email is sent and how webpages are transmitted. The openness of these standards have created the foundation for global markets worth trillions of euros.

But the openness of these core technologies has not carried over to the application layer – the world of applications we use every day for a range of purposes. As a result, the application layer is often marked by limited competition, fragile digital sovereignty and monopolies reinforced by network effects and winner-takes-all dynamics. The ordoliberal principles that made TCP/IP and other standards possible – competition, interchangeable components and decentralized control – largely no longer apply to today's platforms and applications.

Creating an ordoliberal digital space requires next-generation standards – interoperability standards that reach all the way into the application layer. The European Interoperability Framework (EIF) shows that true interoperability must span four layers: legal, organizational, semantic and technical. Successful interoperability standards such as the Global System for Mobile Communication (GSM) in mobile networks or the European Health Data Space (EHDS) demonstrate that only when all four layers are addressed systematically can functioning, cross-sector ecosystems emerge.

Today, sectors such as health care, energy and mobility are each working on their own interoperability standards. Yet standardization efforts based on different methodologies inevitably produce sector-specific architectures and governance models that are nearly impossible to harmonize after the fact. This "methodology lock-in" obstructs cross-sector collaboration.

Solving this challenge requires a unified, sector-neutral and technology-neutral methodology. This study therefore proposes a Standard of Standards. It lays out a structured process – from jointly defining a use case across all four EIF interoperability layers to automated quality assurance.

Establishing this Standard of Standards will require a forum to oversee the methodology, update it continuously and provide essential resources for standard development and quality management as digital public goods. An ordoliberal governance framework must ensure openness, adherence to FRAND[1] principles and broad accessibility for all stakeholders, including small and mid-sized enterprises and civil society.

1 Fair, reasonable and non-discriminatory.

Glossary

Application layer
Networked software and applications that users interact with or that perform tasks for companies, organizations and institutions. In the context of TCP/IP, the application layer includes web browsers, email clients, cloud applications and many other services and protocols that build on the layers beneath it.

Digital sovereignty
Digital sovereignty means that individuals, companies and institutions possess the capabilities and means to exercise their role in the digital work independently, autonomously and securely in the digital world.[2]

Digital public good
Digital resources – including software, standards, data, AI models and content – that are designed as public goods: open source, freely accessible and licensed in ways that allow unrestricted use, adaptation and redistribution.

End-to-end principle/End-to-end communication
An architectural principle in which any systems connected to a network can communicate directly with one another without requiring central intermediaries. On the Internet, for example, any device with an IP address can in principle communicate with any other device.

Conformance testing/Automated testing
Automated software testing used to verify compliance with a specification.

2 The definition is adapted from CIO Bund 2020.

Interoperability
The ability of organizations to interact with one another to achieve shared, mutually beneficial goals. This occurs through the exchange of information and knowledge in the supporting business processes – in other words, through data exchange between their information and communication systems.

Interoperability standard
A standard that enables interoperability for one or more use cases. Interoperability standards reference or integrate all four layers of the European Interoperability Framework (EIF).

Interoperability-by-Design (IbD)
A systematic approach in which interoperability is built into the design, architecture and governance of digital systems from the outset – taking into account all four layers of the European Interoperability Framework (EIF).

Standard
A binding or widely accepted specification that defines requirements, guidelines or characteristics for software, hardware, products or systems. Standards may be established formally (through recognized standardization bodies such as ISO, CEN, ETSI, W3C or IETF), informally (through industry consortia and forums) or as de facto standards (through market adoption).

Standard in the EIF
A standard used within or across sectors on one or more layers of the European Interoperability Framework – legal, organizational, semantic or technical.

Technical interoperability

The ability of technical systems, interfaces, protocols and data formats to communicate and exchange data seamlessly without custom adjustments.

Use case

An application scenario. In the context of this study, an end-to-end scenario in which two or more individuals or organizations communicate and use the exchanged information to achieve a clearly defined purpose.

Acronyms

3GPP	3rd Generation Partnership Project
API	Application Programming Interface
AWS	Amazon Web Services
B2B	Business-to-Business (business relationships between companies)
B2C	Business-to-Consumer (sale of products and services directly to end consumers)
CEN	Comité Européen de Normalisation (European Committee for Standardization)
CEPT	Conférence Européenne des Administrations des Postes et des Télécommunications (European Conference of Postal and Telecommunications Administrations)
CSRD	Corporate Social Responsibility Directive
DG Connect	Directorate-General for Digital and Technology Networking
DG SANTE	Directorate-General for Health and Food Safety of the European Commission
DICOM	Digital Imaging and Communications in Medicine (international standard for the storage, transmission and exchange of medical images and associated data)
DPP	Digital Product Passport
eIDAS	Electronic IDentification, Authentication and trust Services (EU regulation that defines the legal framework for electronic identification and trust services in the EU)
EIF	European Interoperability Framework
EHDS	European Health Data Space
EHR	Electronic Health Records
ETSI	European Telecommunications Standards Institute
FHIR	Fast Healthcare Interoperability Resources
FRAND	Fair, reasonable and non-discriminatory
HL7	Health Level 7
HTTP	Hypertext Transfer Protocol
GSM	Global System for Mobile Communications
IAM	Identity and Access Management
IbD	Interoperability-by-design
IEEE	Institute of Electrical and Electronics Engineers

IETF	Internet Engineering Task Force (international organization for the development of standards for the Internet)
IHE	Integrating the Healthcare Enterprise
IP	Internet Protocol
ISO	International Organization for Standardization
ITU	International Telecommunication Union
SME	Small-and-medium sized enterprises
MVNO	Mobile Virtual Network Operator
OIDC	OpenID Connect (authentication protocol based on OAuth 2.0)
RSS	Really Simple Syndication (simple news distribution)
SaaS	Software-as-a-Service
SDO	Standard Development Organization
SEC	Securities and Exchange Commission
SMS	Short Message Service
SMTP	Simple Mail Transfer Protocol
SNOMED CT	Systematized Nomenclature of Medicine Clinical Terms
TCP/IP	Transmission Control Protocol/Internet Protocol
W3C	World Wide Web Consortium

Preface

The topic of digital sovereignty has been high on the political agenda not only since the German-French Summit on Digital Sovereignty in Berlin in November 2025. At this summit, representatives from politics and business discussed Europe's position in global technology competition. The focus was on artificial intelligence and home-grown European solutions – undoubtedly central issues. One crucial aspect, however, remained largely in the background of this debate: the role of standards.

Standards form the foundation of the digital economy. Their importance can be compared to standards in the traditional industrial world, such as the DIN paper format. Basic internet standards illustrate this vividly: the Transmission Control Protocol/Internet Protocol (TCP/IP) is the core protocol on which the entire internet is built and which enables markets on a trillion-euro scale; the Simple Mail Transfer Protocol (SMTP) allows billions of emails to be sent every day. The decisive factor here is interoperability – that is, the ability of different systems to communicate with one another. Open standards such as TCP/IP create precisely the scalability and efficiency that make the success of the digital space possible in the first place.

However, this structural openness of the internet has not carried over to the application layer – the world of software and platforms that we use every day. Here, closed ecosystems dominate. Large technology companies do indeed build on open internet standards, but the services they offer on this basis are, for the most part, neither standardised nor interoperable. The consequences for digital sovereignty are considerable: where only proprietary interfaces exist, structural dependencies and single points of failure arise. A lack of interoperability leads to lock-in effects, restricts users' ability to switch providers and distorts competition.

Against this backdrop, the present publication seeks to help bring the importance of digital standards more prominently into the political discourse. The study analyses the central role of interoperability in the emergence of large markets in the digital space, shows why it is so crucial at the application layer – and yet often lacking – and explains how interoperability can reduce lock-in effects, strengthen resilience and promote fair competition. In addition, the study makes a concrete policy proposal for achieving cross-sector interoperability in the future: a "Standard of Standards" as a unified methodology for the development of interoperability standards.

We would like to thank Martin Pompéry and Hansjörg Baur for authoring the study and for the excellent collaboration.

The publication is aimed at political decision-makers as well as those responsible in public administration, standardisation bodies and industry. As you engage with the analysis and recommendations, we invite you to consider how these ideas can inform your own decision-making.

We welcome feedback and ideas on this publication and, above all, look forward to continuing the exchange on how cross-sector interoperability can strengthen digital sovereignty and fairer competition.

Dr. Felix Sieker
Project Manager | Programm Digitalisierung & Gemeinwohl | Bertelsmann Stiftung

1 | Introduction

Digital transformation is reshaping the foundations of modern life – how societies function, how people interact and how companies operate, compete and collaborate. Technical standards in the digital sphere are not marginal details; they set the norms and rules that govern this environment. They determine how systems are built, how data flows and how communication happens. In this landscape, interoperability plays a defining role. It captures both the aim and the ability of diverse systems to rely on shared standards to communicate and exchange data effectively at the application level. Standards are the bedrock of this interoperability.

The Internet's success rests on technical standards that allow heterogeneous systems to interoperate. This technical interoperability has enabled digital markets worth trillions of euros. But the past two decades make clear that the openness embedded in the network layer has not extended to the application layer. Instead of interoperable applications, increasingly closed platform ecosystems have taken root – ecosystems that generate lock-in effects, constrain digital sovereignty and weaken competitive dynamics.

Against this backdrop, this study examines how interoperability standards can be governed in ways that curb lock-in, open up markets and strengthen digital sovereignty.

Problem statement

Standards for the digital realm typically focus on technical specifications and requirements, while organizational and legal dimensions often remain unaddressed. As a result, a range of sector-specific initiatives – spanning public administration, health care, energy and mobility – are currently working to develop interoperability standards that incorporate these broader dimensions.

Although these initiatives pursue similar objectives, they often rely on different methodologies and operate without overarching coordination. This leads to several challenges:

1. **Methodological fragmentation:** Each community must renegotiate fundamental interoperability concerns – from defining semantic models to clarifying legal frameworks.

2. **Lack of cross-sector interoperability:** Standards developed through non-aligned methodologies are difficult to harmonize after the fact, complicating digital collaboration across sectors.

3. **Insufficient attention to regulatory principles:** Technical interoperability alone does not guarantee competition or digital sovereignty.

The Standard of Standards as a unified methodology for interoperability

This study develops concrete policy recommendations for European and global standardization governance. The analysis rests on three core propositions:

1. **Standards function like law in the digital realm:** Principles such as digital sovereignty and competition must be embedded from the outset – in the design of standards, in the governance of standardization processes and in the target architecture and governance of digital systems.

2. **Technical standardization alone is insufficient:** Achieving interoperability at the application layer – the world of software applications we use every day – requires a holistic methodology that integrates not only technical specifications but also legal, organizational and semantic dimensions.

3. **Methodological consistency is necessary:** Only a shared methodology can ensure lasting interoperability across sectors and jurisdictions.

Building on these propositions, the study proposes a Standard of Standards: a unified methodology for developing interoperability standards that systematically addresses all four layers of the European Interoperability Framework – legal, organizational, semantic and technical.

Structure of the study

Chapter 2 begins with a historical review that examines how standards have shaped markets and strengthened sovereignty, using the Internet as a case in point. It shows that technical design choices carry far-reaching economic consequences and draws regulatory lessons from this history.

Chapter 3 introduces the European Interoperability Framework (EIF) and uses it to derive requirements for the governance of interoperability standards. It underscores that standards must always be developed in relation to concrete use cases and across all four interoperability layers.

Given the need for coordination across sectors, Chapter 4 develops the concept of a Standard of Standards as a unified methodology for standardization processes. It defines selection criteria and highlights the importance of an ordoliberal framework that safeguards competition and digital sovereignty.

Building on this conceptual groundwork, Chapter 5 presents two case studies: mobile communications standardization through GSM and the European Health Data Space (EHDS). Assessing these interoperability communities through the criteria developed earlier shows how they can serve as blueprints for an ordoliberal digital environment.

Chapter 6 translates these findings into concrete policy recommendations for governments, standardization bodies and industry.

Finally, Chapter 7 offers an outlook on the evolution toward a third generation of interoperability – the interoperability-by-design network.

2 | Standards and ordoliberal digital spaces

The modern Internet would be unthinkable without standards. When we send an email, we rely on the Simple Mail Transfer Protocol (SMTP), a standard introduced in 1981. When we open a website in a browser, we use the Hypertext Transfer Protocol (HTTP) to enable the necessary data exchange. Both protocols define the precise mechanics of data transmission and establish a shared language that allows computers to communicate reliably.

Both protocols build on the same foundational standard: the Transmission Control Protocol/Internet Protocol (TCP/IP). Published in 1981[3] – at a time when the precursor to the Internet consisted of only a few hundred computers[4] – TCP/IP emerged when it was still unclear which technical architecture would ultimately underpin the Internet. A wide range of end devices, communication tools, operating systems and application programs coexisted.

The designers of TCP/IP therefore sought a way to ensure communication despite this diversity and uncertainty. This search led to the groundbreaking idea of defining a communication principle that treated variation in hardware and software not as an obstacle but as the norm. The TCP/IP principle is organized into several layers (see Table 1).

What makes this concept distinctive is its division of tasks and modular design: Each layer serves exactly one function. The concrete implementation of any layer – in hardware or software – can vary freely. As long as the specifications are met, communication remains possible.

3 RFC 793 (Postel 1981a), RFC 791 (ISI, USC and Postel 1981) and RFC 792 (Postel 1981b).

4 Living Internet 1981.

Table 1 **| The four-layer TCP/IP model**

Layer	Standards:	Function/Role	Interoperability example:* Browsing the Internet
Application	HTTP, SMTP and others	Application-specific data exchange	Different browsers render websites in a consistent way
• Transport	Transmission Control Protocol (TCP)	Ensures reliable data transmission	Successful data exchange across different operating systems
• Internet	Internet protocol (IP)	Transfers individual data "packets"	Heterogeneous computer systems at different locations communicate using different Communication technologies (e.g., 5G, Wi-Fi)
• Network access	Ethernet and others	Physical data transmission	

* The example is illustrative and therefore highly simplified from a technical perspective.
Source: Authors' own illustration

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The network access layer illustrates this well. In the early days of the Internet, communication within an office complex often relied on Token Ring or Ethernet technologies. Communication between remote sites or data centers, by contrast, still depended on the telephone network. TCP/IP ensured that data could move between these fundamentally different systems – a capability we now call interoperability.[5]

The Internet continues to rely on this technical interoperability. It allows different browsers (application layer – for example, Chrome, Edge, Safari) running on different operating systems (Windows, macOS, Linux, Android, iOS) and different devices (desktops, laptops, smartphones) using different connectivity technologies (DSL, fiber or 5G mobile networks) to communicate seamlessly and consistently.

A central feature of TCP/IP is the end-to-end principle – also known as end-to-end communication.[6] This principle holds that every computer connected to the Internet can communicate directly with any other. What appears to be a mere technical detail carries profound economic implications, as the next section demonstrates.

How standards enable markets

Standards are more than technical specifications – they constitute essential market infrastructure.

They can foster or stifle competition, open or close markets and encourage or impede innovation.

In the digital realm, standards exert a quasi-regulatory force,[7] shaping market structures much as law does. Designing these standards is therefore a core task of economic governance.

5 More precisely: technical interoperability, as discussed in Chapter 3.

6 Saltzer, Reed and Clark 1984.

7 "Code is law"; see Lessig 1999.

The following discussion illustrates how technical standards influence market formation, using the design decisions behind TCP/IP as an example.

Interoperability as a precondition for competition and innovation

One of TCP/IP's most consequential design choices was shifting greater functionality into the two middle layers – the Internet and transport layers (see Table 1). This generated three effects:

1. **Cheaper hardware:** Functions necessary for reliable data exchange became software-based rather than hardware-based (in the network access layer). This dramatically lowered hardware requirements. Where complex and expensive communication systems had once been necessary, simpler and more affordable devices now sufficed[8] – catalyzing the emergence of a broader network-equipment market.

2. **More competition:** Interoperability makes components interchangeable – in this case, hardware components. Buyers can choose among multiple vendors, and vendor lock-in becomes harder to enforce, strengthening competitive dynamics.

3. **Greater innovation:** Interoperability allows innovative and specialized network equipment to integrate easily into existing systems. Such innovation often comes from new entrants. Lower barriers to entry support more open innovation ecosystems populated by highly specialized producers.

End-to-End communication as the foundation of digital markets

A second, equally important aspect of TCP/IP is the principle of end-to-end communication. Once a computer system is connected to the Internet, it can communicate freely with any other connected system.

8 In particular Ethernet technology, which was technically inferior to competing approaches but significantly more cost-effective.

The end-to-end principle[9] is not a technical footnote but a fundamental design choice that shapes market architecture. The freedom to communicate over the Internet creates the freedom to conduct business over the Internet. A company in Berlin can transact directly with a customer in Shenzhen without intermediaries. A startup in Aschaffenburg[10] can market its innovative services worldwide.

End-to-end communication has been – and continues to be – a core driver of large-scale software markets. Because end devices can communicate with one another without restriction, the physical "location" of providers and users no longer matters. This decoupling of service delivery from geography, combined with the resulting economies of scale, has fueled significant growth.[11] The cloud computing market, for example, has expanded from its early days in 2002[12] to more than $600 billion today[13] – just one illustration among many.

9 Saltzer, Reed and Clark 1984.

10 A mid sized city in Germany.

11 Katz and Shapiro 1985; OECD 2022.

12 Assuming the official launch of Amazon Web Services (AWS) in 2002 as the baseline.

13 Back End News 2024.

At the same time, the end-to-end principle exposes a regulatory dilemma: it also enables network effects and winner-takes-all dynamics that can lead to monopoly formation.[14] We return to this issue in Section 2.3.

Markets enabled by open standards: An economic overview

Four decades after the publication of TCP/IP, its economic impact can be quantified. Table 2 highlights selected digital markets that emerged as a direct result of the Internet's capabilities.

The four selected markets together represent a volume of nearly €27 trillion as of 2023.

Although TCP/IP is not sufficient on its own, the design decisions outlined above were necessary for the emergence – and especially the rapid growth – of markets and economic value creation on the Internet. This economic record underscores the regulatory relevance of how standards in the digital realm are shaped. Those who set standards determine access, dependencies and room for maneuver – and therefore also influence core questions of digital sovereignty.

14 Katz and Shapiro 1985.

Table 2 | **Internet-enabled markets**

Market	Size (2023)	Link to TCP/IP
E-Commerce (B2B & B2C)	€25.93 trillion*	Direct commercial relationships without intermediaries enabled by end-to-end communication
Cloud computing and Software-as-a-Service (SaaS)	€669 billion**	Innovation and location-independent service delivery enabled by end-to-end communication
Network equipment	€147 billion***	Competition driven by the interchangeability of hardware components; economies of scale enabled by standardization
Video-on-demand	€104 billion****	Global reach without reliance on local distribution channels or intermediaries

* Grand View Research 2024a.
** Back End News 2024.
*** Grand View Research 2024b.
**** Polaris Market Research 2024.

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Digital sovereignty as an economic and political priority

Digital sovereignty has become a central concept in political and economic debates – yet its meaning is multifaceted and often diffuse. This section focuses on those dimensions of digital sovereignty that are directly linked to standards. To make this relationship more concrete, we examine digital sovereignty from three perspectives: availability, confidentiality and choice.[15]

Availability: Resilience through interoperability and data portability

The availability of digital services depends heavily on the ability to substitute components and providers. Standards create a critical business prerequisite: when software and devices are interoperable, unavailable components can be replaced with alternative solutions without rebuilding an entire infrastructure or system from scratch.

Interoperability also enables data portability by allowing data to be moved and exchanged automatically across different systems. This reduces dependencies and lock-in effects, which often characterize proprietary platforms and systems.

Confidentiality: Standards as the basis for privacy and distributed ecosystems

Open standards enable transparency: When encryption methods, security standards or data formats are openly documented, security researchers can identify vulnerabilities and users can assess actual levels of protection. Proprietary or closed systems, by contrast, rely on "security through obscurity" – trust without the ability to verify.

Open standards can also support decentralized data storage.[16] On the basis of interoperability, ecosystems can emerge in which users retain control over their data without sacrificing functionality compared with proprietary or centralized systems.

Choice: Competition enabled by open standards

The third dimension concerns the ability to choose freely among providers, technologies and operating models. A lack of interoperability, by contrast, creates lock-in effects – as today's messaging apps demonstrate. Users cannot switch between WhatsApp, Signal or Telegram without losing access to their contacts. Such technological lock-in limits individual choice and stifles competition and innovation.

Standards, in turn, allow products and services to be substituted. They create markets in which different providers can compete without requiring users to abandon their existing networks or data.

Taken together, these examples illustrate the significant impact ofmissing standards and missing interoperability – both on digital sovereignty and on the structure of digital markets. This effect is especially pronounced in areas with strong lock-in or network effects.[17] These include not only messaging services and social networks, but also e-commerce platforms, supply-chain management systems and much more.

In these domains, the limits of purely technical standards also become apparent: **the openness and technical interoperability of the network layer (TCP/IP) do not automatically extend to the application layer.**[18] Even where competition exists at the network layer, the absence of standards and interoperability at the application layer produces network effects and first-mover advantages.[19] This discrepancy between the two layers is a central challenge in today's digital environment.

15 Adapted from Swiss Data Alliance 2024

16 The social media networks Mastodon and Bluesky are good examples. For podcasts, decentralized distribution via the HTTP protocol in combination with open file formats (web feeds or RSS feeds) is well established.

17 Katz and Shapiro 1985; European Commission 2022b: Recital 64.

18 See Table 1.

19 European Commission 2023b: Recitals 1, 2, 79.

Regulatory lessons

The historical experience that openness and interoperability at the Internet's foundational infrastructure layer do not automatically extend to the application layer yields several regulatory lessons:

Standards directly shape sovereignty in the digital realm.
Missing standards or insufficient interoperability create the risk of sovereignty loss in the digital space. This becomes especially apparent at the application layer, where network effects often lead to monopolies and winner-takes-all dynamics.

Decisions for or against standardization and interoperability – as well as how they are designed – are therefore not merely technical choices; they are fundamental decisions about economic governance and digital sovereignty.

Enabling competition, market openness and sovereignty requires more than technical standardization.
The technical interoperability and openness of standards like TCP/IP do not automatically translate to the application layer. Ensuring competition, interoperability and sovereignty requires a broader, actively shaped standardization process that extends beyond purely technical considerations.

Network effects require regulatory safeguards.
The end-to-end principle enables network effects that can foster innovation but also promote monopoly formation. The regulatory response is mandatory interoperability at the application layer – a mechanism to safeguard competition and reduce constraints on digital sovereignty.

Digital sovereignty is achievable only through meaningful choice.
Sovereignty in the digital realm depends on freedom of choice: individuals, companies and institutions must be able to switch between providers and systems without losing access to data, core functionalities or networks. This level of freedom is attainable only through interoperability standards.

3 | From technical standards to interoperability standards

The historical review shows that while technical standards such as TCP/IP can create digital markets and enable digital sovereignty, openness and interoperability at the technical level do not automatically extend to the application layer. The resulting question – how interoperability can be achieved at the application layer – is examined below through the lens of the European Interoperability Framework (EIF).

EIF European Interoperability Framework

In 2017, the European Commission introduced the EIF,[20] a systematic approach designed to achieve interoperability at the application layer and, in turn, to support deeper collaboration among organizations through digital services. The primary aim is to integrate EU member states, their public administrations and the digital services that underpin essential public functions.

The Commission describes this objective as follows:

> As stipulated in the Treaties of the European Union (EU), the EU's internal market guarantees four 'freedoms' - the free movement of goods, capital, services and people between the 28 Member States. **These freedoms are assured by common policies supported by interconnected, interoperable networks and systems.**[21]

20 European Commission, New European Interoperability Framework (2017).

21 European Commission 2017b: Annex 2, page 4. In the German version of Annex 2, the adjective "interoperable" is unfortunately missing here. Emphasis added.

What is striking about the EIF, as the quotation underscores, is its explicit linkage of legal frameworks with technical elements such as interoperable systems and networks. The framework recognizes that interoperability cannot be achieved through technical specifications alone; it requires a holistic approach. This approach is reflected in a four-layer model of interoperability (see Figure 1).

The EIF four-layer model of interoperability

At the core of the EIF is a four-layer framework that understands interoperability as a multidimensional concept. Each layer addresses a distinct aspect of collaboration between digital systems and organizations:

Legal interoperability provides the foundation, ensuring that organizations and individuals can cooperate effectively across national legal systems. This includes harmonizing legal norms that govern data exchange and digital collaboration.

Organizational interoperability concerns the alignment of business processes, responsibilities and expectations across organizations. It ensures that differences in organizational cultures, workflows and governance structures do not become barriers to cooperation.

Figure 1 | **European Interoperability Framework – Four-level model of interoperability**

* European Commission 2025b.

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Semantic interoperability ensures that exchanged data is interpreted consistently by all parties. It includes the standardization of data models, ontologies and semantic relationships so that the same information carries the same meaning across systems.

Technical interoperability enables the actual exchange of data between computer systems. It encompasses protocols, interfaces and technical standards that make communication possible. This is the layer where standards such as TCP/IP are situated.

These four layers are not independent; rather, they form an integrated whole.

Illustration:

Example 1: An Italian tradesperson seeks to register a business in Germany

Legal interoperability: Germany has specific regulations, including distinctions regarding false self-employment and the requirement for authorization by the chamber of crafts.

Organizational interoperability: In Germany, establishing a business requires filings with several bodies, including the local trade office, the chamber of crafts, the statutory accident insurance association and the tax authorities.

Semantic interoperability: Italian professional qualifications cannot be mapped automatically to German occupational titles or master craftsman certifications.

Technical interoperability: The tradesperson cannot use their Italian digital ID within the German systems operated by chambers of crafts and accident insurance associations.

Example 1 demonstrates why all four layers of the EIF model must be considered simultaneously. Semantic interoperability is of limited use if organizational processes are not aligned. Even fully harmonized organizational and semantic standards will fail if the legal framework is missing, for example when exchanged data does not meet national compliance requirements.

Whether used as an analytical tool or as a design framework, the EIF model offers high practical relevance. It helps identify interoperability gaps and supports the selection and evaluation of standards needed to achieve interoperability. In addition, the EIF model can serve as a blueprint for designing interoperability standards themselves.

Infobox 1 | **Technical standards vs. interoperability standards**

Technical standards such as TCP/IP define specific technical dimensions of the digital realm: protocols for data exchange between computer systems, data formats and interfaces. These standards typically address the technical and, in some cases, the semantic layer of the EIF.

Interoperability standards go further by integrating all four EIF layers:
They address the legal layer by harmonizing legal norms and compliance requirements; the organizational layer by defining business processes, responsibilities and workflows; the semantic layer by establishing shared data models and common meaning structures; and the technical layer by standardizing protocols, interfaces and data formats.

The EIF as a framework for interoperability standards

The EIF treats interoperability as a multidimensional concept. Standardization processes that aim to achieve interoperability at the application layer must therefore be designed with this multidimensionality in mind. The goal is to develop sustainable interoperability standards that span and integrate all four layers of the EIF model – going far beyond the technical standards discussed earlier.

The EIF model also provides a framework for analyzing existing interoperability standards and developing new ones. This can be illustrated through the example of the Digital Product Passport (DPP) for batteries.

Example 2: Digital Battery Passport

Beginning in February 2027, the Digital Battery Passport will become mandatory across the EU.[22] The regulation aims to improve comparability, CO2transparency and the recycling and reuse of batteries. Accordingly, the passport will need to include mandatory information on material composition, carbon footprint and other attributes.[23] The regulation requires all actors in the battery value chain – suppliers, manufacturers and retailers – to make the relevant information available. Meeting these requirements demands extensive standardization processes across all four interoperability layers (see Table 3).

22 European Commission 2023a: Article 77.

23 Ibid: Articles 7 and 8.

Table 3 | **Digital Battery Passport – exemplary interoperability analysis based on the EIF four-layer model**

Provision of the Digital Product Passport (DPP) for batteries across the value chain

	What does the standard define?	Impact of missing standards and interoperability
Legal interoperability	Verified compliance with EU norms and Chinese battery regulations	Higher costs and legal uncertainty across the entire value chain; market entry barriers, especially for small and mid-sized enterprises.
Organizational interoperability	Standardized data access management for stakeholders (owners, producers, recycling firms, etc.); template contracts governing data use and access	Higher costs for all participants and reduced data availability; lock-in effects for market actors; negative secondary effects such as lost economies of scale and lower recycling rates.
Semantic interoperability	Scope of voluntary and mandatory product information; calculation of CO2emissions; learly defined recycling information	Market entry barriers, particularly due to higher development and compliance costs.
Technical interoperability	Data exchange between computer systems	Market entry barriers; generally higher costs due to manual processes, reduced data availability and related inefficiencies.

Source: Authors' elaboration | BertelsmannStiftung

The DPP example illustrates that an interoperability standard cannot be derived from examining individual data formats or legal rules in isolation. Instead, it requires a multidimensional analysis of a concrete use case – one that incorporates all relevant technical and non-technical standards, regulations and requirements across all four interoperability layers.

Such a complex process demands effective and comprehensive governance. Whenever elements of the EIF model – or entire layers – are overlooked, market participants must compensate with custom solutions. This typically results in higher costs, fragmented approaches and, ultimately, limited interoperability at the application layer.

Requirements for the governance and structure of interoperability standards

The EIF model, with its four interdependent interoperability layers, underscores the importance of managing use cases with clear, outcome-oriented objectives. Concrete, well-defined use cases make interoperability measurable – and therefore achievable – throughout the standardization process.

Use cases enable gap analyses that assess whether existing standards, norms and legal frameworks are suitable and can be reused. This is essential for reducing effort and ensuring interoperability.

Where adequate standards do not yet exist, or where existing ones need refinement, the use-case perspective can guide the standards' design and development phases. Even if a new standard covers only part of the four interoperability layers, its design must reflect the requirements of all layers, as they directly shape the feasibility of the solution.

From the EIF model, three core governance requirements for interoperability standards follow:

1. Governance must ensure that all relevant interoperability dimensions are addressed systematically during standard development. This includes the active involvement of relevant stakeholders in the standardization process.

2. Standardization processes must be able to translate use cases into interoperability standards that cover all four layers – legal, organizational, semantic and technical.

3. Partial or standalone standards used to achieve interoperability cannot be considered in isolation. They must always be assessed and integrated within the context of concrete use cases and across all four interoperability layers.

What happens, however, when different sectors do not use comparable methodologies to achieve interoperability? How can we avoid a situation in which every community reinvents the basic principles of interoperability from scratch?

The following chapter develops the answer to these questions with the concept of a unified standardization methodology: a Standard of Standards.

4 | The Standard of Standards as a unified methodology for developing interoperability

Experience from numerous initiatives – including the rollout of electronic health records and the development of sectoral smart-grid infrastructures – has shown that interoperability built on divergent methodological foundations is nearly impossible to harmonize after the fact. Technical translators or interfaces may be able to connect individual data flows, but they typically fail in the face of deep semantic, organizational and legal incompatibilities.[24] The result has been high integration costs, functional losses and a lack of trust among actors and systems. We refer to such implementations as the **first generation of interoperability**.

Differences in sectoral and national structures – and, by extension, the use of different methodologies – inevitably produce incompatibilities at the architectural and governance levels. Divergent approaches to defining semantics, managing processes or certifying compliance create a “methodology lock-in” that, much like a technology lock-in, constrains the scalability and long-term viability of interoperability.

Advancing to the **second generation of interoperability** therefore requires a unified methodology – one that makes sectoral and national differences manageable in a standardized way and supports cross-sector and cross-border cooperation from the outset.

To this end, we propose a unified methodology: the Standard of Standards for interoperability.

24 A vivid example is the cross-border exchange of health data within the EU; see European Commission 2022a.

The Standard of Standards as a technology- and sector-neutral framework

We use the term “Standard of Standards” to describe a unified methodology that systematically defines and governs the entire process of developing interoperability standards. The Standard of Standards specifies how interoperability can be achieved, tested and continuously improved. It provides an overarching framework that ensures diverse actors, industries and governance structures follow the same methodological principles – regardless of their legal, organizational, semantic or technical starting points.

We define the Standard of Standards as a technology- and sector-neutral framework that secures interoperability across all four layers of the EIF.[25] It enables the development of sector-specific and national standards along a shared logic, ensuring compatibility from the outset. Whether in public administration, health care, the energy sector or mobility, each use case is modeled, tested and certified according to the same methodological principles.

The Standard of Standards spans the interfaces between governance, methodology and technology, ensuring that interoperability is not treated as an integration task to be solved after the fact but as a built-in property of any digital system. This marks the second generation of interoperability – the foundation for an open, scalable and trusted ecosystem in which innovation and standardization reinforce rather than constrain one another.

25 European Commission 2017a.

Selection criteria for the methodology underpinning the Standard of Standards

Selecting an appropriate methodology for the Standard of Standards must meet a range of requirements. Any existing methodology considered for adoption must demonstrate technological agility, organizational feasibility, governance robustness and cross-sector applicability. For the European legal and regulatory environment, we propose evaluating and selecting such a methodology on the basis of five criteria.

Global, or at least European, community support and robust governance

The methodology must already be backed by a broad and established global – or at minimum, European – community. It must also be capable of ensuring incorruptible governance. For this reason, the methodology should be actively supported and safeguarded by EU institutions and national governments.

Use case stability and technology independence

At the core of the Standard of Standards lies a shared use case. Interoperability communities involved in standardization across the four EIF layers should be invited to participate in defining this use case.

The definition at the legal level is primarily shaped by governments, regulators and standardization organizations. Successful implementation, however, requires essential contributions from IT architects (e.g., reference architectures) and system vendors (e.g., technical standards) for the technical and semantic layers, as well as input from data and subject-matter experts within each sector for the semantic and organizational layers. Only through this collaborative dialogue, which must also incorporate the needs of end users such as small and mid-sized enterprises, as well as civil society, can true end-to-end interoperability be ensured in practice.

The use case forms the foundation for all subsequent standardization activities. From semantic modeling to the data transport layer, every required standardization activity across the various layers must align with this jointly defined use case. At the methodological level, defining a use case (e.g., "standardized cross-border exchange of health data") directly determines the ontologies to be applied (semantics), the mandatory workflows (organization) and the technical protocols, with each supported by their respective standardization communities and organizations.

The choice of use cases is the most critical decision, as it determines the scope and complexity of all subsequent standards across the EIF layers. By addressing all four layers – legal, organizational, semantic and technical – during the definition phase, the resulting interoperability standards are ensured to be not only technically feasible and semantically consistent but also legally compliant and organizationally implementable from the outset.

Furthermore, the methodology must remain strictly independent of any underlying technologies. Much like a mobile phone call, which functions seamlessly across multiple generations of network technologies from 2G to 5G, the methodology must preserve a use case across many technological cycles, even as the underlying components – such as technical standards – evolve. This guarantees long-term sustainability and investment security.

Sectoral validation and global adoption

The methodology must already have demonstrated its practical viability. In concrete terms, it must have been successfully applied in at least one complex sector to establish interoperability standards aligned with the EIF's four-layer model. This sectoral validation – combined with global adoption – provides essential evidence of the methodology's robustness and its ability to address demanding challenges, particularly in identity management, data protection and security.

Cross-sector applicability

Building on proven success in a complex sector, the methodology must also demonstrate that it can be applied across sectors. It has to be transferable efficiently and reliably to new domains. This cross-sector validation is critical to preventing "methodology lock-in" and to enabling collaboration across industries. Whether the use case concerns health care, public administration or the energy sector, the methodology must provide a shared foundation for developing interoperability standards.

Mandatory testing

Mandatory, automated conformance testing is essential for ensuring quality on the path to interoperability. It forms the foundation for compliance, trust and operational reliability.

For this reason, the methodology behind the Standard of Standards must require the definition of rigorous testing protocols. Only then can we ensure that jointly defined use cases and the resulting interoperability standards are implemented correctly and reproducibly in real-world environments.

Equally indispensable is transparency around the conformance tests performed – tests that verify whether software correctly implements the designated use case and achieves interoperability. Transparency is the basis for trust: users need assurance that software has been validated for compliance, and manufacturers introducing new products or services must know that other market actors are adhering to the same interoperability standards. Such shared trust is the prerequisite for a dynamic, competitive market.

Meeting these criteria ensures that the selected methodology is sufficiently robust to serve as the foundation for the Standard of Standards – and to support true end-to-end interoperability.

The ordoliberal framework: Safeguarding competition and market structure

Even the most technically refined methodology for achieving interoperability carries the risk that mastery of that methodology – or restricted access to it – could allow a single actor to gain a dominant market position. To prevent this, the Standard of Standards must be embedded in an ordoliberal framework.

First, the Standard of Standards itself must be implemented as an open standard: vendor-neutral, universally accessible, free of charge and available under fair, reasonable and non-discriminatory conditions.[26]

Second, the governance of conformance testing is crucial. This includes the existence, evolution and accessibility of test suites and the supporting infrastructure. Access to and use of these tests and infrastructures must be clearly defined, and the conformance process as a whole must not create barriers to entry. Ideally, the tests and related infrastructure should be made available as digital public goods.[27]

Third, governance structures must regulate how use-case definitions are created, managed and validated. This includes determining who is eligible to participate and how consensus is reached. Governance models used by standardization bodies offer potential templates.

This also extends to agenda-setting – the process of selecting and prioritizing use cases. In many standardization communities,[28] division of labor has proven effective, with domain experts, particularly non-technical experts, playing a central role in identifying use cases.

Because the Standard of Standards is intended for cross-sector use, its ordoliberal framework and its standardization governance must reflect that broad scope. Particular emphasis should be placed on ensuring access for stakeholder groups that have traditionally been under-represented in technical standardization, including small-and-medium-sized enterprises and civil society actors.

26 FRAND – fair, reasonable and non-discriminatory.

27 For the definition, see DPGA 2025.

28 For example, IHE International (2025); WBCSD (2025); iLEAP (2025).

Conclusion

The Standard of Standards defines a unified methodology for achieving digital interoperability. Its defining feature is its sector-neutral and technology-neutral design, a necessary foundation for achieving scalable and sustainable interoperability. It establishes the processes that must be embedded within an ordoliberal governance framework.

At the core of the Standard of Standards are focused use cases that span all four layers of the European Interoperability Framework (legal, organizational, semantic and technical). Mandatory automated conformance testing provides a technical basis for trust, which is essential for the reliable deployment of compliant software.

Agreeing on a shared methodology for standardization also creates the conditions for legal interoperability across jurisdictions – a principle that will be indispensable as digital systems become increasingly interconnected across Europe and beyond.

5 | Brief analysis of two successful interoperability communities

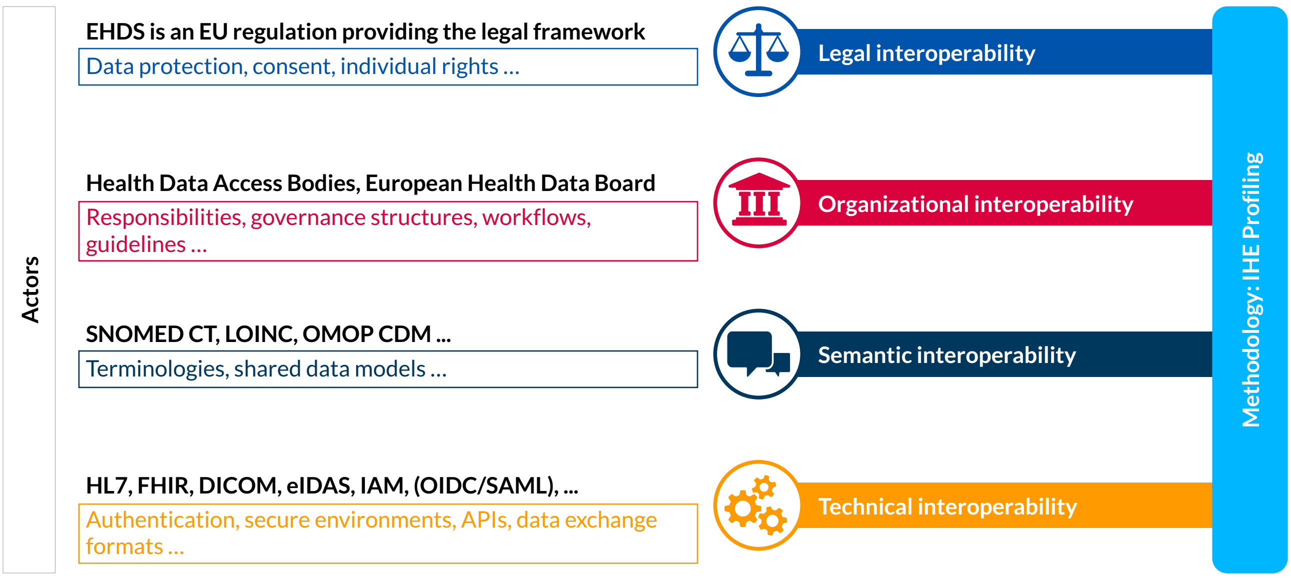
Building on the concept of a Standard of Standards, this section examines two European communities that have successfully established interoperability across all four layers of the EIF. The focus is on the methodologies these communities employ – specifically in relation to the selection criteria defined in Chapter 4. In both cases, we already see a strong reliance on shared use cases, mandatory testing and robust governance structures. The section concludes by outlining initial approaches for applying a community's methodology across sectors.

EHDS: European Health Data Space

Description

The EHDS regulation is designed to establish a common framework for the use and exchange of electronic health data across the European Union. Its goal is twofold: first, to improve individuals' access to and control over their personal electronic health data; and second, to enable the reuse of certain data for purposes of public interest, policymaking and scientific research. The regulation also creates a harmonized

Figure 2 | **The four levels of the EIF illustrated by the European Health Data Space (EHDS)**



Source: European Commission

BertelsmannStiftung

	Community	Use-case orientation	Sectoral validation	Cross-sector applicability	Mandatory testing
EHDS/IHE	+++	+++	+++	++	+++

legal and technical framework for electronic health record (EHR) systems, promoting interoperability, innovation and the smooth functioning of the single market.[29]

EHDS in the context of the European Interoperability Framework

Assessment based on the selection criteria in Chapter 4:

Global – or at least European – community and robust governance: Overall coordination of the EHDS lies with the European Commission, particularly DG SANTE and DG CONNECT. The semantic and technical foundations of the EHDS draw on the work of leading global communities and standards such as HL7 (Health Level Seven),[30] FHIR (Fast Healthcare Interoperability Resources),[31] SNOMED CT (Systematized Nomenclature of Medicine)[32] and IHE (Integrating the Healthcare Enterprise).[33]

Use case stability and technology independence: Interoperability is built on IHE profiling,[34] a use-case-driven methodology consistent with the EIF. It is supported by extensive documentation and is in the process of seeking ISO standardization. The methodology is technologically neutral.

Sectoral validation and global adoption: Although the EHDS is an EU regulation, its approach can be adopted beyond the EU, provided countries or organizations obtain the appropriate EHDS certification.

29 European Commission 2025a.

30 https://www.hl7.org/.

31 https://www.fhir.org/.

32 https://www.snomed.org/.

33 https://www.ihe.net/.

34 https://www.ihe.net/resources/profiles/.

Cross-sector applicability: he transferability of the IHE methodology used in the EHDS has already been demonstrated in the energy[35] and mobility[36] sectors.

Mandatory testing focus: IHE's testing methods – including Connectathon and Projectathon – are supported by an open-source platform and ensure neutral monitoring of test outcomes through robust governance structures.[37]

Summary: EHDS

Technically, the interoperability of the European Health Data Space is built on use-case–based IHE profiling and its integration of global standards developed by leading technical and semantic communities such as HL7, FHIR and SNOMED CT. The underlying methodology is fully compatible with the European Interoperability Framework.

The four EIF layers are reflected, for example, in the EHDS regulation (legal), the data-retrieval process defined through IHE profiles (organizational), the shared medical terminology SNOMED CT (semantic) and secure technical data formats and protocols such as HL7/FHIR (technical).

Key principles include transparency and openness: interoperability standards must not be proprietary or subject to exclusive ownership, a prerequisite for competition and broad adoption. Automated testing tools developed within the IHE community ensure reliable implementation of the standards. Through pilot projects, the EHDS approach is emerging as a potential blueprint for cross-sector interoperability across the European Union.

35 https://www.smartgrids.at/interoperabilitaet/ies-initiative/.

36 https://www.bahnindustrie.at/download/303/Whitepaper_Interoperability_V1.0.pdf.

37 https://www.ihe-europe.net/testing-IHE/connectathon.

GSM: Global System for Mobile Communications

Description

GSM was launched in the 1980s as a pan-European open mobile communications standard initiated by the Conférence Européenne des Administrations des Postes et des Télécommunications (CEPT). It later became the foundation that ETSI (European Telecommunications Standards Institute)[38] and the 3rd Generation Partnership Project (3GPP)[39] extended into subsequent generations – 3G, 4G and 5G.

From the outset, the GSM ecosystem comprised far more than radio interfaces. It required rules for spectrum allocation, roaming agreements and billing practices; protocols for interconnecting networks; and operational and business processes – including for providers without their own networks (mobile virtual network operators, or MVNOs). The interoperable collaboration among GSM stakeholders spans all four layers of the EIF.[40]

GSM in the context of the European Interoperability Framework

With reference to the selection criteria defined in Chapter 4, several points stand out:

Global – or at least European – community and robust governance: Governance of GSM was initially handled by CEPT, and later by ETSI and 3GPP. The original community emerged in Europe and subsequently expanded to a global scale.

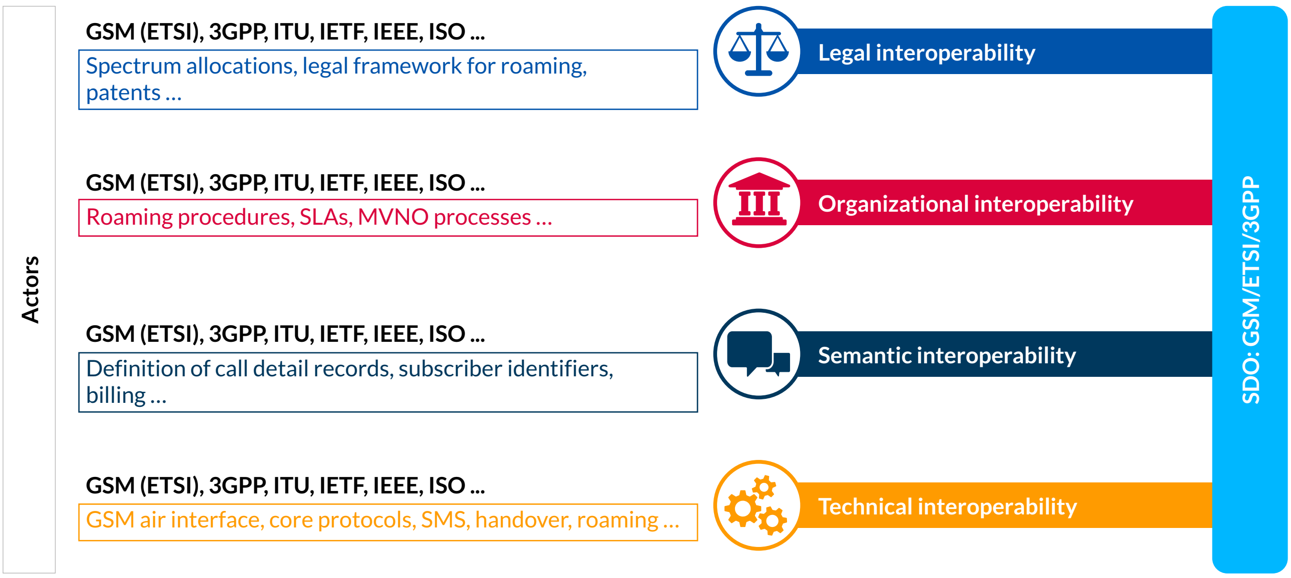
Use case stability and technology independence: The FRAND (fair, reasonable and non-discriminatory) licensing obligation ensures that all market participants have equitable access to the standardized technology and prevents technology lock-in. GSM in-

38 https://www.etsi.org/.

39 https://www.3gpp.org/.

40 https://www.gsma.com/about-us/who-we-are/our-history/.

Figure 3 | **The four levels of the EIF illustrated by the Global System for Mobile Communications (GSM)**



Source: European Commission

BertelsmannStiftung

	Community	Use-case orientation	Sectoral validation	International applicability	Mandatory testing
GSM/3GPP	+++	+++	+++	+++	+++

troduced a comprehensive and formally documented methodology for standard development and specification, ensuring consistency and long-term viability.

Sectoral validation and global adoption: The GSM standardization effort has been supported – and is still supported – by a global community, later formalized within 3GPP. This structure guarantees continuous evolution and maintains interoperability across generations of mobile technology.

Cross-sector and international applicability: Through standardized technical and organizational roaming protocols, GSM made cross-border interoperability across national and commercial mobile networks a core feature from the outset.

Focus on mandatory testing: The GSM ecosystem incorporated specified conformance tests that made it possible to systematically and automatically verify whether devices and networks complied with the standard. This ensured that third-party manufacturers and service providers could enter the GSM marketplace.

Summary: GSM

The GSM standard (Global System for Mobile Communications) is widely regarded as the first large-scale, globally successful model of multilayer interoperability developed in Europe and adopted worldwide.

Its success rested on far more than technical specifications. GSM established a coherent ecosystem that anticipated and integrated all four layers of the EIF:

- legal interoperability through harmonized licensing regimes and spectrum allocations across member states;
- organizational interoperability through clear roaming agreements among network operators;
- semantic interoperability through standardized message and data structures (for example SMS and subscriber data); and
- technical interoperability through the radio access specifications and transmission protocols themselves.

This holistic architecture was carried forward by the 3GPP standardization model (3rd Generation Partnership Project) and has been continuously maintained through successive generations – including 5G and the forthcoming 6G – underscoring the sustainability and resilience of this interoperability approach.

Blueprints for an ordoliberal digital space

The analysis of successful infrastructure models such as GSM, alongside forward-looking EU regulations such as the European Health Data Space (EHDS), demonstrates that functioning digital ecosystems can be built in Europe.

Both cases illustrate open, ordoliberal-protected communication infrastructures whose success rests not only on technical specifications but on a comprehensive methodology that integrates all four layers of the EIF – legal, organizational, semantic and technical. In both examples, Europe ensured early-stage protection and scale through sound governance – ETSI/3GPP in the case of GSM, and EHDS/IHE for health data – until a global community could assume stewardship and ensure the continuous evolution and implementation of the standards.

To achieve true end-to-end interoperability across sectors – and avoid a fragmented landscape defined by methodological lock-ins – a consistent and proven approach must be applied. This underscores the need for a sector-neutral Standard of Standards: a unified, field-tested methodology that serves as a binding blueprint across domains. Only through such a framework can Europe prevent the fragmentation of digital spaces and, through mandatory automated testing, establish a reliable technical foundation for innovation, competition and digital sovereignty.

6 | Recommendations

The analysis of GSM and the European Health Data Space demonstrates that end-to-end interoperability is not only technically feasible but can be successfully scaled through a comprehensive and coherent methodology. The central remaining challenge is to establish this Standard of Standards as a binding, sector-neutral framework. To that end, we offer two strategic recommendations: first, on the structural requirements of such a framework (Recommendations 1 and 2), and second, on the values that should underpin a constitutional foundation[41] for the digital space (Recommendation 2).

Recommendation 1: Establish a Standard of Standards as the methodology for developing interoperability standards at national, European and global levels

Recommendation: All relevant stakeholders – including national governments, the European Union and key industry bodies and standardization organizations – should commit to a shared methodology for developing and implementing interoperability. This framework, the Standard of Standards, should ensure interoperability within sectors, across sectors and across borders, covering all four layers of the European Interoperability Framework: legal, organizational, semantic and technical.

Rationale: The absence of a shared methodology, or the use of incompatible approaches, leads to methodological lock-ins that impede or prevent interoperability. A unified approach is therefore essential to enable cross-sector and cross-border interoperability.

Recommendation 2: Establish a governance forum for the Standard of Standards and its technical advancement

Recommendation: Methodological consistency requires a dedicated community, that is, a forum that serves as the central governance body. This forum should function as the primary institution responsible for developing, implementing and overseeing the methodology used to create interoperability standards. It would monitor governance practices and ensure the consistent application of the Standard of Standards across sectors and interoperability initiatives.

The forum would also be responsible for advancing the technical tools that support the methodology, such as test-automation frameworks, and for guiding the broader evolution of the Standard of Standards toward an interoperability-by-design network. It is essential that, all relevant stakeholders are represented within the forum's governance structures.

Rationale: Sustained and effective interoperability requires a central governance entity that does not merely define the Standard of Standards, but also steers its continuous development. Such a forum would coordinate governance across all relevant initiatives and ensure that the resulting interoperability

41 Lessig 1999: 5 ff.

standards remain consistent and compatible, regardless of sector or jurisdiction. In addition, the forum must select and maintain the technical infrastructure needed to implement the standards, including test methods and tools, thereby creating the foundation for long-term, stable interoperability. Ensuring access for small and mid-sized enterprises is particularly important. The forum should therefore guarantee an inclusive standardization process that allows all actors to participate meaningfully in the development and refinement of interoperability standards.

Over the medium term, this approach would establish the governance structures, ecosystem and technical foundations required for an **interoperability-by-design** network.

Recommendations for a phased implementation

As a first concrete step, a coordinated search and assessment process should be launched at the European and global levels to systematically evaluate existing interoperability communities against the selection criteria defined under the Standard of Standards. The aim of this process should be to identify which communities – based on their governance structures, methodological approaches and potential for cross-sector alignment – are suited to serve as the anchor or nucleus of a future governance forum. In parallel, the process should examine which sector-specific communities already possess proven interoperability mechanisms that could be expanded into cross-sector forums. Mapping the existing governance and standardization landscape in this way creates the foundation for identifying synergies, avoiding duplicative structures and strategically engaging those actors who are positioned to help steer the transition toward European and global end-to-end interoperability.

7 | Outlook

From a unified methodology to an interoperability-by-design network

Interoperability has evolved across several stages over the past decades. The first generation – ad hoc interoperability – relied on reactive integrations between systems, resulting in a patchwork of proprietary solutions and high maintenance burdens.

The second generation, defined by sector-neutral and structured interoperability, represents a significant advance: interoperability is now recognized as a strategic systems objective. Yet the process of developing interoperability standards remains largely manual, complex and resource-intensive.

Third generation of interoperability: interoperability-by-design

Against this backdrop, the following outlook illustrates why the full potential of interoperable digital ecosystems can only be realized by extending the Standard of Standards into an Interoperability-by-Design network (IbD network).

The Standard of Standards, with its unified methodology grounded in the EIF model and a standardized use case, provides the essential foundation. It is designed to overcome sectoral fragmentation while enabling coordination across diverse interoperability communities. Yet this foundation alone is not sufficient for interoperability to fully unfold its impact. What is still missing is a shift away from today's largely manual and resource-intensive processes for developing interoperable solutions – toward an automated interoperability infrastructure.

Infobox 2 | **Three generations of interoperability**

First generation: ad hoc-interoperability	Interoperability is treated reactively, typically to connect specific IT systems. This phase is characterized by the absence of structured governance, a proliferation of proprietary solutions with custom interface agreements and high maintenance costs.
Second generation: structured interoperability	Interoperability is understood strategically as a system-level objective aimed at achieving end-to-end integration across all four layers – legal, organizational, semantic and technical. This generation is marked by the introduction of formal processes, shared standards, systematic documentation of use cases, conformance testing and reusable components.
Third generation: interoperability-by-design (IbD)	Interoperability is systematically and automatically embedded into system design, architecture and governance. The goal is end-to-end interoperability across all layers – technical, semantic, organizational and legal – through model-driven specifications and real-time verification.

For this reason, an IbD network should be viewed as the third generation of interoperability. While the Standard of Standards defines a methodology, an IbD network would represent the next technological and organizational evolution by systematizing and automating its application. Instead of relying primarily on downstream conformance testing, as in the second generation, an IbD network could support model-driven specifications of use cases, real-time verification and automated integration testing. All users would be able to incorporate use cases into their local systems without any need for programming expertise. This would lower development costs and ensure end-to-end interoperability across all layers from the outset.

The governance structure created for the Standard of Standards should therefore be designed with the long-term evolution toward this third generation in mind. Ultimately, such an IbD network would enable citizens and businesses – including in particular small and mid-sized enterprises – to use digital services seamlessly, securely and autonomously across sectoral and national boundaries, thereby strengthening digital sovereignty.

Making standardization processes more democratic with AI

Artificial intelligence is opening new possibilities for the development of interoperability standards. The aim is not to automate standard-setting entirely, but to make the process more efficient, transparent and inclusive. Historically, standard-setting environments have been shaped by high barriers to entry, specialized expertise, resource constraints and exclusive formats. These conditions have favored the structural dominance of a small number of actors and have contributed to the underrepresentation of many groups, including small and mid-sized enterprises and civil society. As a result, many stakeholders remain excluded from shaping standards that directly affect them, both normatively and practically.[42]

42 Baron et al. 2019.

AI can help democratize standardization processes by making deliberative procedures scalable both in breadth and in depth. (1) Scalable in breadth: More diverse actors can participate when access barriers are reduced – for example, through automatic summarization, translation or clarification of technical terminology. At the same time, AI enables more efficient and effective deliberation in large groups. Early research suggests that language models can help moderate contentious discussions and support groups in articulating shared positions.[43] This makes it possible to scale deliberation processes significantly. (2) Scalable in depth: AI-supported tools can also enhance the internal quality of standardization processes. Language models can help structure discussions, organize arguments and evidence, cluster contributions and highlight lines of disagreement.[44]

That said, standard-setting remains a political negotiation process; AI cannot replace that. But it can make the technical side of the process more inclusive, opening up participation to a broader set of stakeholders who have historically been left out.

43 Tessler et al. 2024

44 Small et al. 2023.

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