Technological Forecasting & Social Change 221 (2025) 124340

Contents lists available at ScienceDirect

Technological Forecasting & Social Change

journal homepage: www.elsevier.com/locate/techfore

Supporting the digital transformation journey through monitoring systems in healthcare. A comparative analysis of European empirical approaches through an adaptation of the IPOO framework

Alessandro Vinci [a,*], Andrea Vandelli [a], Alessia Caputo [a], Milena Vainieri [a]

[a] *Management and Healthcare Laboratory (MeS), Institute of Management, Sant'Anna School of Advanced Studies, Pisa, PI, Italy*

A R T I C L E I N F O

Keywords:
Digital transformation
Performance measurement
Digital health
Healthcare management
Health system performance assessment
KPIs
IPOO

A B S T R A C T

This study explores how digital transformation (DT) is operationalized and measured within Health System Performance Assessments (HSPAs) across European Union (EU) countries. By conducting a documentary analysis of national HSPAs through the READ approach, we identified 11 EU countries that include digital health metrics and extracted a total of 93 Key Performance Indicators (KPIs). These indicators were systematically categorized using the Input-Process-Output-Outcome (IPOO) framework and clustered into four deductively derived domains and corresponding sub-domains. Building on this empirical foundation, we propose a novel conceptual framework that integrates theoretical and practical dimensions of DT monitoring. The framework assigns representative KPIs to each IPOO phase and highlights critical but currently under-monitored areas. Despite notable progress in areas such as electronic health records, telemedicine, and digital service usage, the findings reveal persistent challenges. Furthermore, significant variability exists across countries in the adoption and computability of DT indicators. By providing a structured model and a comprehensive pool of indicators, this study contributes to both academic literature and practical policymaking. It supports efforts to guide DT measurement across healthcare systems while maintaining the flexibility needed to adapt to diverse national contexts. Future research should explore the evolving integration of DT metrics and continue to address gaps that hinder effective performance monitoring and policy development in healthcare digitalization.

1. Introduction

Digital Transformation (DT) is “a process that aims to improve an entity by triggering significant changes to its properties through combinations of information, computing, communication, and connectivity technologies” (Vial, 2019). Therefore, service digitalization can be seen as creating public value (Bryson et al., 2014; Schiavone et al., 2021). In addition, it fosters better functionality of traditional services and can provide better transparency (Cucciniello et al., 2017; Graham et al., 2016; Porumbescu et al., 2022), resulting in increased accountability on the part of public administration and citizen involvement (Gil-Garcia et al., 2018). At the same time, DT has a significant impact on efficiency by streamlining procedures for accessing information (Marques and Ferreira, 2020). Over the past few decades, the emergence of digitalization has transformed public services into a prominent topic on the agenda (Fakhoury and Aubert, 2015; Paskaleva and Cooper, 2018; Venkatesh et al., 2003). The pandemic has led the public sector to speed up DT to ensure citizens receive the services through non-physical means. Even if these effects can be observed in different scenarios, the healthcare sector represents a privileged subject of study, where the pandemic forced a reevaluation of the “new normal” paradigm, prompting the need to adopt measures to mitigate future shocks (Amankwah-Amoah et al., 2021; Cobianchi et al., 2020; Ndayishimiye et al., 2023; Tortorella et al., 2022). Recent literature has examined the profound shift in healthcare driven by DT, highlighting both advancements and ongoing challenges.

One of the most significant changes has been the expansion of certain types of digital health services to provide remote care. Indeed, healthcare is one of the most affected sectors by digital technologies during the pandemic (Dal Mas et al., 2020). This is the case for telemedicine and eHealth platforms. Some studies underscored how telemedicine rapidly evolved into an essential tool for clinical services, to ensure continuity of care during lockdowns (Bokolo, 2021), highlighting the unprecedented adoption of telehealth in primary and outpatient care, which would

* Corresponding author: Piazza Martiri della Libertà 33, 56127, Pisa, PI, Italy.
E-mail address: alessandro.vinci@santannapisa.it (A. Vinci).

https://doi.org/10.1016/j.techfore.2025.124340
Received 18 July 2024; Received in revised form 22 July 2025; Accepted 28 August 2025
Available online 12 September 2025

have been unthinkable before the pandemic due to regulatory and infrastructural inertia (Peek et al., 2020). Also, the rapid growth of new digital tools, like Artificial Intelligence (AI), has enhanced the DT of healthcare. Pandemic surveillance, disease prediction, and automated decision-making helped predict the spread of COVID-19 (Budd et al., 2020). A study on the use of different digital tools in clinical decision support systems emphasized how this has further optimized patient management and improved healthcare workflows (Getachew et al., 2023).

However, this transformation has not been without challenges. Digital health literacy among healthcare providers and patients remains a critical issue. Some studies found that only a limited part of healthcare professionals had adequate digital health literacy, which hindered their ability to share COVID-19-related information effectively, calling for targeted training programs and improved digital access to enhance healthcare providers' competence in using eHealth tools (Chereka et al., 2022). Equity in digital health access is another major concern. The most fragile segments of the population may bear the weight of this transformation, with the risk of these individuals being left out of digital health communications, limiting their ability to receive timely health information and services (Specht et al., 2022). Moreover, concerns about privacy, data sharing, and ethical considerations in digital health interventions need to be addressed for sustainable digital transformation (Budd et al., 2020).

In a broader perspective, research highlights the importance of integrating digital solutions into routine healthcare practices. This integration emphasizes that DT in healthcare can improve societal resilience, serving not only as a response to pandemics but also as a long-term strategy to tackle challenges related to healthcare accessibility (Baudier et al., 2023).

Considering the promising yet complex environment surrounding the ongoing paradigm shift in healthcare, it is essential to adopt an integrated perspective on DT. This approach is necessary to systematize and organize both the knowledge and practical implications associated with it, and to produce public value (Schiavone et al., 2021; Zyzak et al., 2024).

Only a few studies attempted to provide a structured framework for understanding DT in healthcare. Binci et al. (2021) propose a framework focused on the adoption of remote monitoring. Their framework identifies key socio-technical variables that facilitate digital innovation adoption by practitioners and highlights essential considerations for evaluating remote monitoring as a precondition for investment decisions. From another perspective, the study by Dal Mas et al. (2023) presents a holistic framework of the main dimensions of DT in healthcare, mapping the key enabling technologies, adoption processes, expected benefits, and stakeholder involvement. This framework provides a valuable synthesis of existing research, systematizing the current state of the art while outlining future research directions in the mentioned domains.

These frameworks provide valuable insights, but their specific focus leads to limitations. The first study centres on remote monitoring, addressing only one aspect of DT rather than the broader transformation, while the second presents a literature-based framework that conceptualizes DT but lacks a structured approach for practical application. Additionally, both prioritize qualitative insights without incorporating quantitative measures to systematically assess DT's impact. Advancing DT in healthcare requires a more comprehensive framework, with the integration of quantitative assessments to support practical implementation and informed decision-making, offering the possibility of measuring DT in healthcare. The research on DT of healthcare stresses the importance of directing efforts towards evaluating digital health technologies, particularly in terms of their impact on health outcomes and customer experience, highlighting the necessity for measuring the performance of e-health initiatives and their implementation and meaningful use for health organizations (Kraus et al., 2021a). Moreover, research calls for developing and implementing structured measurement frameworks reflecting the influence of digitalization on public administration and stakeholders (Brenner et al., 2023; Dobrolyubova, 2021).

Some efforts to measure DT in the public sector are identifiable from international practice, with one notable structured example. The Digital Economy and Society Index (DESI) is a comprehensive index designed to assess the digital competitiveness of European Union countries and monitor their overall digital performance (European Commission, 2022). DESI index offers a valuable and insightful starting point, but leaves room for investigation since this index is general and does not refer specifically to the healthcare sector. Health systems are indeed complex and challenging to understand and manage due to governance fragmentation, uncertainty, pluralism, and a multidisciplinary environment (Lemieux-Charles et al., 2003; Paoli et al., 2019; Plsek and Greenhalgh, 2001), and often adopt a multilevel organizational structure to optimize service delivery and resource allocation (Barlow, 2017; D. S. Kringos et al., 2015; Saltman et al., 2011).

To tackle this complexity and address the existing gaps in the literature, the objective of this paper is to propose a conceptual framework for measuring DT within the healthcare sector, employing both deductive and inductive strategies. Furthermore, the study is enhanced by the inclusion of empirical examples of metrics that can be utilized to evaluate the progression of DT. This study aims to contribute to both theoretical advancements and practical applications in the field of digital health transformation. From a theoretical perspective, it offers new insights into how digitalization in healthcare can be systematically monitored and assessed. This study can provide a structured approach to evaluating digital health progress, making it a key reference for scholars and researchers seeking to understand the critical dimensions of DT in healthcare systems. Beyond descriptive analysis, this study proposes a conceptual framework that integrates theoretical foundations with practical applicability, making it a valuable tool for policymakers, healthcare professionals, and public health authorities. The proposed framework serves as a structured guide for tracking, assessing, and refining digital health transformation strategies, helping decision-makers design evidence-based policies and performance monitoring systems that align with the evolving landscape of healthcare digitalization.

This article is structured as follows. In this section, we provided the background information, identified the gaps in the literature, and proposed our objective. The following section analyses the theoretical background of DT, focusing on major topics that emerge from the literature, as these form the theoretical foundation for our study. We then present our methodology, including the approach employed to interpret, understand, and present our results and the research design. In the discussion section, we introduce our conceptual framework for tracking and monitoring the DT journey in healthcare and highlight key areas that require further development. Finally, we conclude with a summary of our findings, along with the implications and limitations of the study.

2. Theoretical background

DT encompasses an expansive range of initiatives, from the adoption of public platforms to the integration of advanced data analytics into public service delivery (Meijer and Thaens, 2021). At its core, DT leverages digital technologies to improve efficiency, automate processes, enhance data-driven decision-making, and create new forms of value (Vial, 2019; Verhoef et al., 2021). Unlike simple digitization, which involves converting analog data into digital form, or digitalization, which focuses on improving processes through digital technologies, DT represents a more profound organizational transformation, requiring a fundamental rethinking of business models, infrastructure, and user engagement (Mauro et al., 2024; Mergel et al., 2019).

Literature has identified several "key themes" (summarized in Table 1) that are essential for successfully guiding DT from beginning to end. These themes should not only be acknowledged but also measured

Table 1
Key themes in DT reference literature.

Key Themes	Description	References
Resources and Infrastructure	Financial and technological resources, human capital and skills, data management, and digital infrastructure enable DT by providing the necessary foundation for innovation and efficiency.	(Dal Mas et al., 2023; Dobrolyubova, 2021; Kraus et al., 2021a; Marques and Ferreira, 2020; Massaro, 2023; Mauro et al., 2024; Vial, 2019)
Technology Adoption and Integration	Successful DT requires implementing advanced digital tools while ensuring interoperability, stakeholder communication, and regulatory compliance.	(Dal Mas et al., 2023; Dobrolyubova, 2021; Mauro et al., 2024; Mergel et al., 2019; Schiavone et al., 2021; Verhoef et al., 2021)
Digitalization of Services and Operations	DT reshapes the delivery of services by creating optimized digital workflows and decision-making processes. By leveraging digital technologies, organizations can streamline processes, reduce redundancies, and foster more informed and agile decision-making environments, improving the responsiveness of service delivery.	(Dal Mas et al., 2023; Humbeck et al., 2019; Kraus et al., 2021a; Massaro, 2023; Mauro et al., 2024)
Outcomes: technical and user-reported measures	DT aims to enhance both technical outcomes, like the actual accessibility to digital services and enhanced healthcare delivery through digital tools, but can also have an impact on user experience and satisfaction. These experiences can be leveraged to orient policies and stimulate services co-production.	(Dal Mas et al., 2023; Dobrolyubova, 2021; Massaro, 2023; Mauro et al., 2024; Scupola and Mergel, 2022; Verhoef et al., 2021)
Other relevant themes	**Patient Safety**: DT can improve safety but also introduces new risks (e.g., information overload, usability issues), demanding indicators to track IT-related incidents. **Data Portability**: Enabled by GDPR Article 20 and strengthened by the EHDS proposal, this principle enhances data sovereignty and interoperability, but practical adoption is still limited, requiring better awareness and measurement.	(De Hert et al., 2018; Li and Quinn, 2024; Ricciardi et al., 2019; Sittig and Singh, 2010; Sobolewski and Paliński, 2021)

to fully grasp the DT journey in all its phases and nuances systematically (Singh et al., 2020; Dobrolyubova, 2021). From the seminal works on DT, it is possible to unveil four key themes: i) technical resources and infrastructure; ii) technology adoption and integration; iii) digitalization of services and operations; iv) outcomes: technical and user-reported. (See Table 1.)

A key enabler of DT is the availability of resources and infrastructure, including financial and technological investments that allow organizations to develop digital capabilities, strengthen cybersecurity, and foster innovation (Marques and Ferreira, 2020; Mauro et al., 2024). Beyond financial capital, human capital and skills play a crucial role, as DT is not only a technological shift but also an organizational and cultural transformation, demanding continuous upskilling and reskilling of employees to adapt to new digital environments (Kraus et al., 2021a; Vial, 2019). Additionally, data and information resources are fundamental in a digital world where decision-making is increasingly data-driven, and organizations must efficiently collect, process, and securely share large volumes of data to succeed in digital initiatives (Dal Mas et al., 2023; Massaro, 2023). Furthermore, infrastructure investments, particularly in cloud computing, IoT networks, and interoperable digital platforms, significantly influence the efficiency and scalability of digital solutions (Dobrolyubova, 2021; Mauro et al., 2024).

Beyond infrastructure, technology adoption and integration are crucial for DT, requiring the implementation of advanced tools and systems such as AI, IoT, blockchain, and automation technologies (Dal Mas et al., 2023; Schiavone et al., 2021). However, successful transformation is not just about technology deployment but also about the adoption and seamless integration of digital services across organizations, ensuring that workflows and stakeholder collaboration remain efficient and interconnected (Dobrolyubova, 2021; Verhoef et al., 2021). A persistent challenge is interoperability and stakeholder communication, as DT often involves multiple actors and requires systems that can securely exchange information across platforms and organizations (Mauro et al., 2024; Mergel et al., 2019).

As organizations advance in their DT journey, the digitalization of services and operations becomes a fundamental priority. DT enables service delivery innovation, shifting organizations towards virtual interactions, automation, and personalized digital experiences (Dal Mas et al., 2023; Massaro, 2023). Moreover, data-driven decision-making and information management are increasingly critical, allowing real-time monitoring, predictive analytics, and AI-assisted operations to optimize performance (Mauro et al., 2024; Vial, 2019). The automation and digitalization of administrative and operational processes further contribute to greater efficiency, cost reduction, and improved service quality (Humbeck et al., 2019; Kraus et al., 2021a).

At its core, DT is ultimately about creating an impact on the overall system with the outcomes. Enhanced digital services not only can have a positive effect in increasing accessibility and efficiency but also promote greater user engagement (Dobrolyubova, 2021; Verhoef et al., 2021). Additionally, personalization and user empowerment through digital platforms allow users to interact with services in more meaningful ways, though concerns around digital literacy and accessibility must still be addressed (Dal Mas et al., 2023; Massaro, 2023). DT also facilitates the engagement with users' participation. This approach constitutes a pivotal element within the broader DT strategy implemented by national governments, hereby enhancing the value of the services rendered through co-production (Pleger et al., 2020; Scupola and Mergel, 2022). However, trust and security remain central to successful digital transformation, as ensuring data privacy, cybersecurity, and reliable digital governance models is crucial for fostering user confidence and regulatory compliance (Dobrolyubova, 2021; Mauro et al., 2024).

In addition to the foundational themes, current literature also underscores transversal themes that are critical to understanding and measuring DT, especially in the healthcare realm. On this domain, two salient aspects are *patient safety* and *data portability*. Digital systems have introduced new patient safety concerns, such as information overload, usability challenges, and increased cognitive burden on healthcare workers, which may result in clinical errors (Flott et al., 2021; Nijor et al., 2022; Ratwani et al., 2018). As a result, scholars and practitioners advocate for the systematic integration and monitoring of this aspect (Ricciardi et al., 2019; Sittig and Singh, 2010). Similarly, *data portability* has emerged as a cornerstone of user-centered digital governance, particularly within the EU regulatory context (European Union, 2016). Anchored in Article 20 of the GDPR and further reinforced by the proposed European Health Data Space (EHDS), data portability promotes users' sovereignty and interoperability among services (De Hert et al., 2018; Li and Quinn, 2024). Despite its potential to foster competition, innovation, and user empowerment (OECD and European Commission, 2024), practical implementation remains limited, highlighting the need for awareness and measurement strategies that capture its adoption and perceived value (Sobolewski and Paliński, 2021).

In the reference literature, certain factors are frequently discussed. While some of these can be incorporated into the digitalization strategies of healthcare in various countries, others have yet to be fully integrated into the DT of healthcare. Moreover, appears that few studies on DT focus on measurement, particularly in terms of monitoring systems that support DT and its overall impact on the healthcare system. Building on this knowledge, a conceptual framework can help systematize and enhance comparison and monitoring efforts, particularly by incorporating quantitative measures to assess the progress of DT in healthcare.

3. Methodology

This section outlines the methodology employed in this study, structured as follows. First, we present the analytical approach that guided us during the retrieval of cases under study. This step serves as a precursor to our analysis and is integrated with key themes previously identified in the literature on DT, constituting the foundation for both the presentation of results and the development of our conceptual framework. Subsequently, we describe the study design, providing context and information on the actual methods used and clarifying the inclusion and exclusion criteria applied in our analysis. Finally, in the case study selection section, we explain the process implemented to guide the analysis of our findings.

3.1. Approach

In this article, we employed the concepts of Input-Process-Output-Outcome (IPOO) to retrieve and cluster the existing KPIs related to the digitalization of healthcare across EU countries.

- Input refers to the necessary resources, knowledge, and capabilities for innovation. Even intangible inputs, such as ideas, information, and know-how, can be relevant when it comes to innovation sectors (Hauser and Zettelmeyer, 1997). Otley (1999) noted that management control systems must incorporate input-related measures to assess whether an organization has the necessary resources to execute its strategy effectively. Chan and Ngai (2011) asserted that inputs act as antecedents to processes.
- Process is the translation of inputs into outputs via defined activities, operations, and workflows. Organizations generate value through processes, which can be anything from straightforward operational duties to elaborate strategic plans. Implementing and monitoring processes helps identify deviations from the initial input, enabling quick corrective solutions.
- Outputs are the immediate results generated from processes, such as new products, services, or organizational processes per se. They are often quantifiable and serve as indicators of process efficiency and effectiveness. Otley (1999) argues that outputs represent the tangible and measurable aspects of organizational performance, such as financial results, production volumes, or service delivery metrics. Outputs can offer insights for improving system efficiency, especially in resource-constrained settings such as public healthcare.
- Lastly, outcome refers to the broader and often long-term effects that result from outputs (Otley, 1999). Unlike outputs, which are immediate and quantifiable, outcomes are more complex and reflect the overall impact of organizational activities. Outcome encompasses the broader impacts and consequences of innovation, including the long-term effects on organizational performance, societal changes, and economic implications (Boyne, 2002).

Brown and Svenson (1988) was the first to propose the IPOO perspective as a way to assess innovative processes. It was initially created for innovation management and envisioned a research and development (R&D) lab as a system in which resources, including funds, facilities, and human capital, flow into processes like experimentation and hypothesis testing to produce outputs like publications, patents, and new technologies. The wider effects, like cost reductions, product enhancements, and commercial success, are then measured by outcomes (Brown and Svenson, 1988). Since then, numerous studies have adopted the IPOO perspective to classify indicators and measures of more complex and broader concepts. For instance, the concepts have been adapted to the healthcare sector to monitor therapeutic interventions, medical research, and patient outcomes (Humbeck et al., 2019; Sun and Li, 2020). To make sure that resources result in benefits for society, public sector budgeting has also moved from merely analyzing financial inputs and outputs to assessing policy outcomes (OECD, 2002). In the education field, Chinta et al. (2016) use IPOO to assess institutional performance in higher education by linking faculty and curricular resources as inputs to student learning processes, graduation rates as outputs, and long-term employment success as outcomes. Mitchell (2019) employs IPOO to quantify the impact of research, looking at the process by which scholarly work goes from initial funding to practical influence. Using IPOO, Chan and Ngai (2011) examine the interactions between consumer behavior and electronic word-of-mouth in marketing, relating user motivations as inputs to message dissemination processes, consumer engagement as outputs, and purchase decisions as outcomes.

The IPOO perspective was selected over other sector-specific model, thanks to its cross-sectoral applicability, although our focus was on examining how EU countries have developed and integrated the concept of DT into their Health System Performance Assessments (HSPAs). Indeed, this study aims to go beyond the traditional focus on quality of care, striving to develop a model that can be adapted and scaled to other fields of study. According to the World Health Organization (Papanicolas and Smith, 2013), HSPA is a country-owned, participatory process that allows the health system to be assessed as a whole and linked to national health strategies whenever possible. It is intended to measure the performance of the healthcare system using key domains and performance indicators, facilitating international benchmarking (Kringos et al., 2021). HSPAs often structure quality-of-care measurements using a refined version of IPOO, such as the Donabedian model (Donabedian, 1988). This principle also applies when considering metrics for evaluating DT performance, such as digital health tools, services, and applications that are intricately connected with the national definition and development of the e-government concept. Thus, the efficacy and suitability of digital health initiatives should be assessed within each country's unique context, circumstances, and priorities. To the best of our knowledge, only a limited number of contributions provide metrics for assessing DT performance. For instance, certain studies have devised indicators to evaluate technology readiness within the manufacturing sector (Agostino and Costantini, 2022), emphasizing Industry 4.0 or concerning healthcare, specifically the readability of regional websites (De Rosis et al., 2020; Pirrotta et al., 2022; Vinci et al., 2025). However, as seen before, a comprehensive overview of country-owned assessment metrics related to DT performance and a framework that systematizes these metrics into a unified framework is still lacking.

3.2. Study design

We conducted a documental analysis of the European Countries to retrieve the KPI related to DT in health, following a similar approach used by Vainieri et al. (2024) who analyzed the concept of resilience in healthcare through the KPI of HSPA. The decision to focus on the EU was driven by three main factors. Firstly, the European Union has played a central role in supporting and endorsing DT. ICTs, originating from the Lisbon Strategy and further developed in the 2010 Digital Agenda for Europe (Deloitte Centre for Health Solutions, 2020), have been recognized as essential to achieving the goals of the European Union. Following these steps, the Digital Agenda was further developed by the 2015 Digital Single Market Strategy (Europe fit for the digital age, n.d.), which outlined three main pillars: first, guaranteeing improved access to digital goods and services across Europe; second, creating favorable conditions for digital networks and services; and third, optimizing the potential for the growth of the digital economy. Finally, the Digital Compass for 2030, introduced in 2021, outlines the EU's digital goals for the following ten years, adding even more to this approach (*Europe's Digital Decade: 2030 Targets*). Secondly, there is a standard practice of publicly disclosing health system information in the European context through initiatives like the European Commission's biennial Country Health Profiles (Country Health Profiles - European Commission, 2024), which contain various performance metrics, including health status, health system governance, accessibility, and resilience (Brito Fernandes et al., 2021; D. D. Kringos and Klazinga, n.d.; Noto et al., 2019; Nuti et al., 2018; Paoli et al., 2019; Vainieri et al., 2024). Moreover, since their 2019 release, the Country Health Profiles have been actively tracking the digital transition both within individual EU nations and across countries. Lastly, the EU is progressing towards establishing a European Health Union (European Health Union - European Commission, 2024) to facilitate healthcare delivery across internal EU borders (Vollaard and Martinsen, 2017). While member states maintain sovereignty over healthcare, the EU has taken on an additional, albeit limited, regulatory role in the organization, financing, and delivery of healthcare. Consequently, this expansion delineates the EU's borders as incorporating an existing culture of coordination, which is now extending, at least in part, to the healthcare sector.

As the second phase of our process to pinpoint relevant case studies, we conducted a document analysis via Google Scholar. Document analysis is a structured and iterative process for interpreting and synthesizing information from documents, both scientific and grey literature (Dalglish et al., 2020). It can help provide context, generate questions, complement other research data, track changes over time, and confirm findings from different sources (Bowen, 2009). In this study, we collected and gained information from documents by applying the READ approach (Ready, Extract, Analyze, and Distill) (Dalglish et al., 2020). The steps consist of: (1) ready materials, (2) extracting relevant data segments, (3) analyzing the extracted data for patterns and themes, and (4) distilling findings to synthesize the information into a coherent set of results. In the Ready phase, we established the scope and parameters for our document collection and analysis. We defined our inclusion criteria based on our objective, focusing on digital health performance metrics in HSPAs. We limited the analysis to documents published in English since 2010 and included various types of documents from scientific and grey literature. We selected the year 2010 as our reference point for screening the HSPAs of the studied countries. This decision is rooted in the pivotal significance of this year. In 2010, the launch of the Digital Agenda for Europe underscored the crucial role of ICT in advancing the objectives of the EU. We decided to opt for Google Scholar for two main reasons. First, because of its broad scope, including peer-reviewed articles, books, conference papers, and other reports, including official and institutional documents. Second, we relied exclusively on Google Scholar for document collection as the objective was not to conduct a traditional literature review but to gather also national strategic documents related to HSPA. These documents are not empirical data but strategic instruments that reflect the policy direction of each country, given that most countries' healthcare systems are publicly funded and guided by strategic acts that outline key goals and measures. HSPA-related publications provide a lens through which to see how digital transformation goals and measures are established and implemented within national policies. These metrics not only represent strategic direction but also impact systemic behaviors. Because these performance indicators reflect each country's choices for enabling DT, they are among the most trustworthy sources for determining whether change is fostered and pushed by national planning and control mechanisms. Subsequently, as document analysis is an iterative process, we integrated this initial sample with information obtained from websites of ministries of health, national health boards, institutes, or agencies, as well as other government entities. Ultimately, we identified articles and reports addressing national HSPAs through a snowball technique, starting with the references of seminal studies focusing on country-specific HSPAs. In the Extract step, we first imported our data into an Excel spreadsheet, where each row is a document, and each column is a category of information. In this phase, we developed and agreed upon the inclusion and exclusion criteria. The first criterion was that the focus of the document had to be directed towards country-owned HSPAs, aiming to gain deeper insights into the levers employed by authorities to implement digital strategies within numerous post-pandemic initiatives and funding efforts. This implied that documents had to address the experience of country-owned HSPA and not provide a theoretical discussion on what generic HSPA should include. Furthermore, our inclusion criteria were met only if a comprehensive system-wide approach was the focus of the document, as performance assessment systems evaluating specific healthcare programs fell out of the scope of the study. Secondly, studies had to be published from the 1st of January 2010 until the 5th of March 2024, data in which the final documents were extracted. We did not limit the analysis to any language, as most of the HSPA strategic documents tend to be published in the country language. We relied on the “translate” function in Google to analyze non-English documents. To extract the data, we employed a screening process by examining the titles and abstracts of documents we retrieved with the document analysis. In this way, we obtained the final document, which constituted the basis for our case study analysis.

3.3. Case study selection and context

A total of 5.150 documents were obtained through the literature review of both scientific and grey literature, and the snowball technique. Most of these documents were excluded because they did not focus on national HSPAs; rather, they discussed HSPAs only at a theoretical level without analyzing country-owned ones. Furthermore, publications that explored specific healthcare topics without taking a comprehensive system-wide perspective were also excluded. After applying these criteria, the final sample consisted of 39 documents (see Fig. 1).

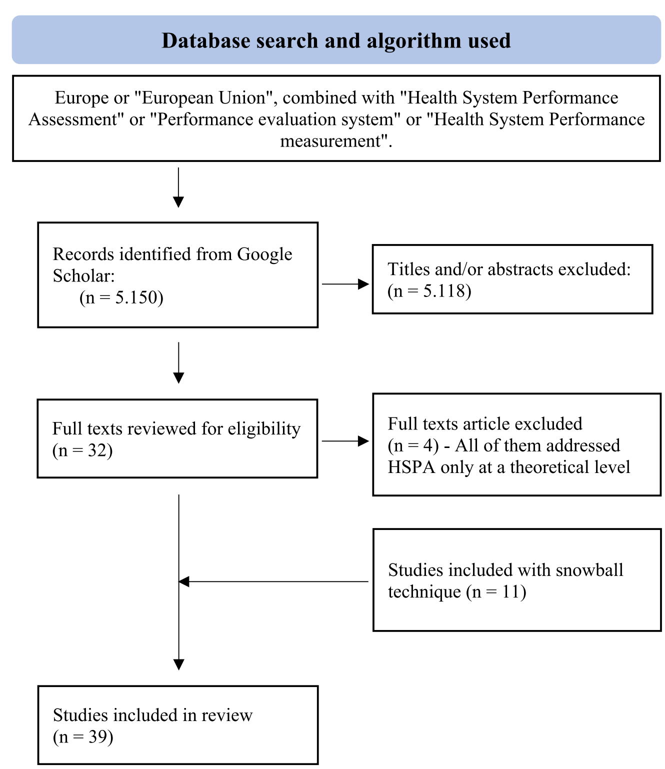

Fig. 1. – Flow chart and keywords.

The methodology adopted in this study is both deductive and inductive. Deductive, as it employs the key themes identified from existing literature in the theoretical background paragraph, to structure the empirical analysis of healthcare monitoring systems used across the EU, and to empirically validate theoretical constructs. Inductive, because the analysis highlights and expands upon areas that have not been thoroughly addressed or emphasized in theoretical frameworks but emerge as particularly significant from a practical perspective. For this reason, the Analyze and Distil phases of the findings from the final document corpus followed a structured three-step approach.

As already explored, the first step was to identify European countries that have established HSPAs and determine the number of these that have implemented specific KPIs for monitoring digital health. This step provided an initial landscape of digital health assessment efforts across European nations.

The second phase involved coding and categorizing the KPIs using a layered approach. We used the IPOO concepts as the theoretical basis for coding. In the first layer, we deductively grouped each KPI into one of the IPOO domains (input, process, output, or outcome) based on the indicator's description. This first layer provided a first systematization of the KPIs. To facilitate a comprehensive analysis, we also categorized these KPIs into various thematic domains. For the second layer, we identified sub-domains that arose from the key themes in DT (see Table 1). In the third and most granular layer of coding, we classified indicators into "groups" of indicators, depending on their rationale and purpose, and placed the grouped indicators on each of the identified sub-categories. With a greater level of detail, this data-driven layer highlighted unique country experiences in putting digital health initiatives into practice. The iterative process between theory and data guaranteed that the first- and second-layer categories remained generalizable, while the third-layer categories reflected the variety of the retrieved KPIs.

In the third and final step, leveraging on all the previous steps, we conceptualized a deductive framework designed to integrate all elements. This framework also considers the relationships among the various IPOO phases.

To ensure the practical relevance and usability of our research, we then proposed a set of indicators for each phase of the conceptual framework, enabling a more standardized and actionable assessment of digital health transformation strategies. As a final step in our methodology, we revisited the key themes identified in the literature to inductively highlight important areas in healthcare monitoring systems that have not yet been addressed. These areas emerge from the literature as critical aspects of DT in healthcare.

4. Findings

Our analysis identified 17 countries that have adopted comprehensive, system-wide HSPAs. However, only 11 of these countries have incorporated digital health KPIs into their HSPAs (The full list of countries analyzed is available in Annex Table 1). Among the identified countries' HSPAs, it was possible to identify a total of 93 KPIs specifically monitoring DT in healthcare. According to our categorization, 16 of these belonged to inputs, 34 to processes, 23 to outputs, and 20 to outcomes (The full list of indicators is available in Annex Table 2). This preliminary process was crucial for the subsequent deductive conceptualization of the domains and sub-domains within the conceptual framework.

Four countries out of eleven have developed metrics for each of the four phases (input, process, output, and outcomes). However, it is essential to note that only two countries have incorporated fully computable metrics into their HSPAs, meaning these indicators can be measured and analyzed using the currently available data.

The following sections present the findings organized by domains, sub-domains, and groups of indicators (Details about the full list of indicators are available in Annex Table 3).

4.1. Input

In the input phase, related to the key theme of Resources and Infrastructure, KPIs were grouped into sub-categories including financial and technological resources, infrastructure, human capital and skills, and information and data resources. Financial and technological resources indicators encompass investments in digital health equipment, telecommunications, software, and cybersecurity, monitored by three countries. Connectivity and broadband coverage, reflecting digital infrastructure readiness, were assessed by two countries. Human capital and skills indicators, specifically measuring data literacy and digital competencies among healthcare staff and citizens, were identified in three countries. Information and data resources indicators included the availability of online datasets and information related to health services online, tracked by three countries. Collectively, these KPIs reflect foundational elements critical for enabling effective digital health strategies.

4.2. Process

In the process phase, focusing on Technology Adoption and Integration, KPIs addressed the implementation of digital health tools, adoption and integration of eHealth services, electronic communication between stakeholders, and health information integration. Indicators related to the implementation of digital health tools, particularly the use of Electronic Health Records (EHRs) by health authorities and physicians, were tracked by five countries. Adoption and integration of eHealth services, especially regarding electronic or dematerialized prescriptions by physicians, were monitored by six countries, while physicians' use of eHealth tools, including online appointment booking, was tracked by three countries. Electronic communication between stakeholders, specifically between patients and healthcare providers, was monitored by two countries. Health information integration indicators, capturing system interoperability, were monitored by three countries. These indicators demonstrate the operational processes necessary for successful digital health integration within healthcare services.

4.3. Output

Within the output phase, focusing on the Digitalization of Services and Operations, KPIs were grouped into digital health service delivery, health information management and sharing, and healthcare services digitalization. Digital health service delivery, particularly video consultations, was widely monitored across eight countries. Indicators related to health information management and sharing, including the percentage of providers maintaining exclusively electronic medical records, sharing patient medication information with hospitals, and conducting e-consultations between healthcare providers, were monitored by two countries. Healthcare services digitalization, specifically information digitalization within primary care services, was assessed in one country. These output indicators result from prior investments and implementation efforts, indicating substantial progress in healthcare digitalization.

4.4. Outcomes

In the outcomes phase, KPIs were divided into technical outcomes and user-reported outcomes. Technical outcomes focused on access to healthcare services through digital tools and included indicators measuring the use of internet/electronic services for making medical appointments (three countries), communication with healthcare or social welfare professionals (one country), and searching health information online (four countries). User-reported outcomes were categorized into efficient use of electronic health records and user engagement and satisfaction. Indicators assessing the efficient use of electronic health records by citizens and caregivers were identified in three countries. User engagement and satisfaction KPIs included user experiences—such as satisfaction, perceived obstacles, and ease of use with electronic and digital services—and availability of staff support mechanisms, monitored by two countries. These outcome indicators offer crucial insights into user interaction with digital health services, reflecting their effectiveness and impact from the users' perspective.

5. Discussion

5.1. Framework conceptualization

As outlined in the methodological section, to systematically capture the different dimensions of the DT journey in healthcare, we developed a novel conceptual framework encompassing both theoretical and practical dimensions (Fig. 2). Theoretically, our framework leverages the concepts of IPOO, which are frequently employed in healthcare systems analysis, and the key themes derived from the literature. Practically, each phase is further divided into specific sub-dimensions representing essential groups of indicators that should be systematically monitored to track and evaluate healthcare DT effectively. These sub-dimensions have been derived deductively by integrating insights from the key themes identified in the relevant DT literature, the document analyses, and the actual KPIs retrieved from the HSPAs.

In this section, we first outline the proposed conceptual framework, detailing its primary domains, sub-domains, and the logical interrelationships among these phases, contextualizing them within existing scholarly literature. Next, we operationalize the framework by assigning specific KPIs to each sub-domain., Leveraging the inductive aspect of our methodology, we identify some areas that warrant further development and monitoring, underscoring their growing importance in current academic discourse. As a final and complementary step to enhance the practical applicability of our framework, we proposed a set of KPIs for each domain and sub-domain (Table 2). These KPIs are derived from the comprehensive list identified during our analysis (see Annex Table 2). While the proposed KPIs do not constitute an exhaustive or exclusive list, they can serve as a valuable starting point, particularly for countries that are still in the process of developing a comprehensive monitoring strategy for DT in healthcare.

As a first step, monitoring DT should start with tracking input elements, as they form the foundation for the entire process. Ensuring these inputs are adequate helps create the right conditions for successful digital initiatives, facilitating subsequent digital processes. Infrastructure quality, particularly connectivity coverage, affects digital healthcare initiatives; inadequate connectivity hinders the adoption of advanced digital solutions (Ricciardi et al., 2019). Evaluating digital skills across stakeholders, including healthcare providers and patients, is also essential, as successful digital transformation requires robust digital literacy and training programs to ensure effective technology utilization (Vial, 2019). Insufficient inputs, such as inadequate funding or infrastructural deficits, can substantially impede the successful implementation of digital healthcare services (Heeks, 2006). Specifically, KPIs such as medical technology investment and broadband coverage serve as direct indicators of foundational readiness for digital interventions. Similarly, KPIs monitoring digital literacy skills among healthcare staff and citizens ensure that the human capital necessary for DT is adequately prepared, reducing potential barriers to technology adoption and maximizing effective use.

In the process phase, resources are practically utilized to implement digital health tools and specific activities. Key indicators monitored here, such as practitioners' effective use and management of electronic health records (EHRs), influence the diffusion and integration of digital health technologies within clinical practice (Agarwal et al., 2010). Similarly, e-prescription adoption rates signal the degree to which digital tools have penetrated routine healthcare operations, reflecting readiness for further digital innovations (Kierkegaard, 2013). Tracking these process indicators provides essential insights into digital healthcare tools' eventual availability and usability for the broader population. For instance, measuring the percentage of dematerialized prescriptions and the number of GP practices enabling online booking directly

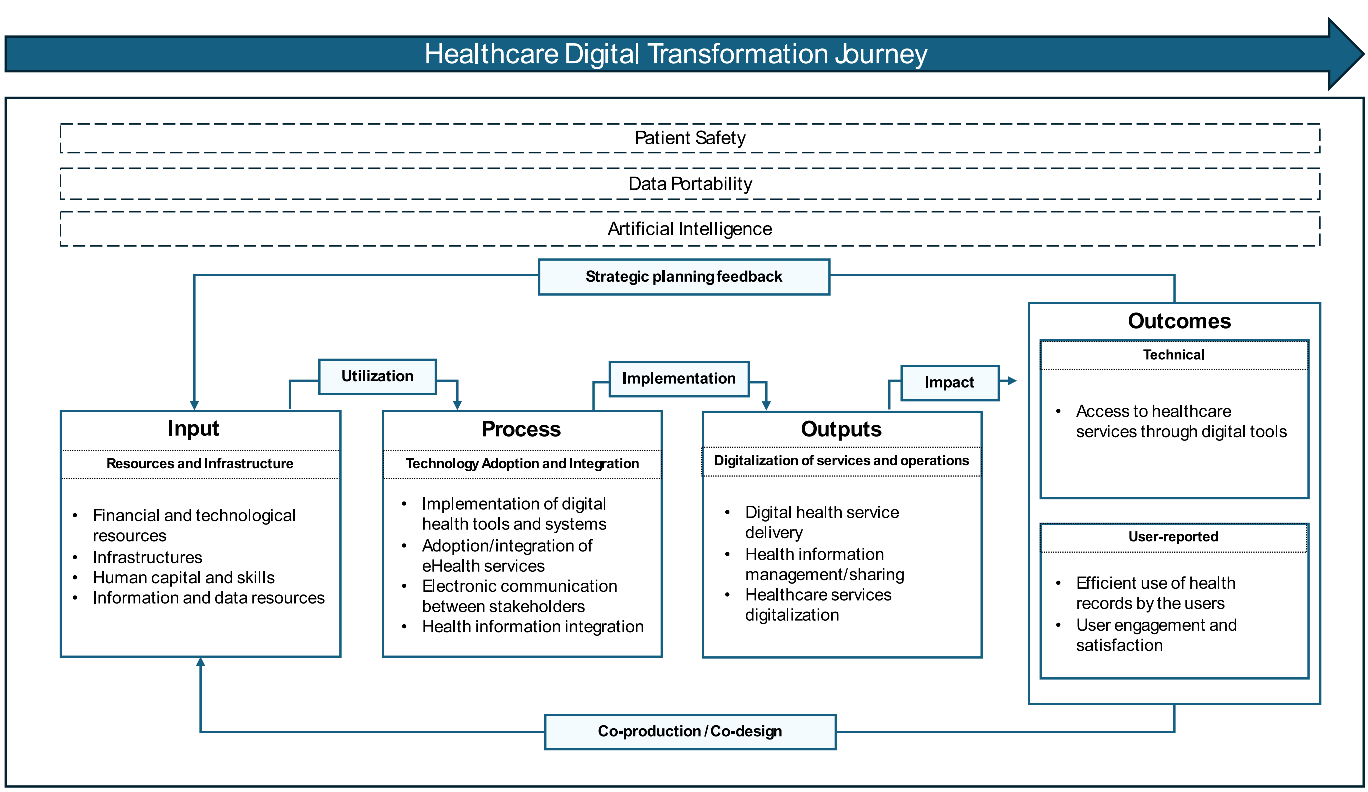

Fig. 2. –The Healthcare Digital Transformation Journey Framework.

Table 2
– Examples of KPIs to be monitored for each Phase, Domain, and Sub-domain of the proposed conceptual framework.

IPOO Phase	Key Theme (Domain)	Sub-domain	Examples of KPIs to be monitored, inspired by the full list of KPIs retrieved from the country's specific HSPAs.
Input	Resources and Infrastructure	Financial and technological resources	• Medical technology investment in hospital care (Euros million) per inhabitant • Tangible and intangible investment in digital health equipment and devices, telecommunications, and software, by health authorities per inhabitant
		Infrastructure	• Percentage of households (or population) covered by broadband • download/upload speed (Mbps)
		Human capital and skills	• Healthcare staff with basic or above information and data literacy skills • Individuals with basic or above data literacy and digital skills
		Information and data resources	• Share of Digitally Available Health Reports (%)
Process	Technology Adoption and Integration	Implementation of digital health tools	• Electronic Health Record (use by citizens, Health authorities feeding and using the EHR, Physicians feeding and using the EHR)
		Adoption/integration of eHealth services	• Percentage of pharmaceutical/specialist prescriptions dematerialized • GP practices (/%) with the ability to book appointments online
		Electronic communication between stakeholders	• Use of secure asynchronous electronic communication between patients and healthcare service providers
		Health information integration	• Number (%) of registries/administrative data with linking features to electronic health records
Output	Digitalization of Services and Operations	Digital health service delivery	• Percentage of video-consultation
		Health information management/sharing	• *E*-consultations between healthcare providers per 100,000 population
		Healthcare services digitalization	• Percentage of individuals accessing digitalized healthcare services
Outcomes	Technical	Access to healthcare through digital tools	• Percent of appointments booked online
	User-reported	Efficient Use of Electronic Health Records by the Users	• Recent Use (within 90 days) of EHR by citizens with activated accounts (%)
		Users' engagement and satisfaction	• Satisfaction for the clinician with the different eHealth services, tools, and actions • Satisfaction with e-consultations

evaluates the operational adoption of digital tools, reflecting the healthcare system's maturity in integrating digital solutions into routine care processes. Furthermore, the use of secure asynchronous electronic communication between patients and providers and the degree of integration between administrative data registries and EHRs indicate how effectively digital systems facilitate efficient communication and interoperability, essential for coherent and sustainable healthcare delivery.

The output phase reveals the initial tangible effects of digital healthcare tools. Monitoring telehealth consultation proportions, for example, provides evidence of digital tools' practical effectiveness on patients, healthcare professionals, and healthcare systems (Bashshur et al., 2014). Additionally, assessing the digitalization of fundamental healthcare services, such as online General Practitioner selection, ensures users can effectively achieve healthcare objectives digitally, reflecting improved access, efficiency, and patient satisfaction (Gjellebæk et al., 2020). KPIs such as the percentage of video consultations, frequency of e-consultations among healthcare providers, and public usage rates of digitalized healthcare services concretely measure the outputs of implemented digital initiatives. These indicators confirm the extent to which prior input and process efforts have resulted in accessible, effective, and patient-centred digital services.

The outcomes phase is where everything comes together, showing the real impact of digital interventions and measuring the progress made from earlier stages. Outcomes encompass both technical aspects, including the integration and effective use of digital tools for accessing healthcare services (e.g., online appointment bookings or patient-provider communications), and user-reported experiences like satisfaction, perceived barriers, and ease of use (Greenhalgh et al., 2017). On one hand, monitoring and assessing technical outcomes, such as accessibility to various services through digital means, can initiate a strategic planning feedback phase. This feedback creates a loop back to the input phase, guiding the development and implementation of more effective policies. In turn, these policies can ensure the appropriate allocation of resources to achieve the intended outcomes and enhance them as needed (Bryson et al., 2014; Sittig and Singh, 2010). On the other hand, systematically capturing user experiences is essential for developing co-production strategies that address gaps and drive continuous improvement. This approach supports targeted adjustments, such as reallocating resources or enhancing infrastructure, to better meet evolving needs (Greenhalgh et al., 2017; Heeks, 2006). Technical outcome indicators, like the percentage of appointments booked online, directly reflect enhanced service accessibility resulting from successful DT. Simultaneously, user-reported indicators, such as citizen usage rates of EHRs and clinician satisfaction with digital services, demonstrate the perceived value and effectiveness of digital healthcare from an end-user perspective. These user-centered indicators not only validate the technical achievements but also provide critical insights necessary to foster continuous improvement and strengthen user engagement, ultimately ensuring a sustained, user-oriented digital transformation in healthcare.

While some of these KPIs represent valuable and unique experiences from specific countries that may lead the way, others represent known international practices. KPIs such as investment in digital health and technologies, broadband coverage, and digital skills reflect well-established enablers of digital readiness (OECD and European Commission, 2024). EHR adoption and e-prescription usage KPIs align with eHealth benchmarking commonly monitored at the international level (World health Organization, 2022). Video consultation-related KPIs, which are monitored by the majority of countries in our analysis, are considered a standard in digital health evaluation (OECD, 2023). Ultimately, outcome indicators, including clinician and patient satisfaction and engagement, are increasingly acknowledged as crucial for evaluating the qualitative impact of digital health on system performance and user experience. This recognition facilitates a virtuous cycle of feedback among all phases of the healthcare system's digital transformation (World health organization, 2023).

5.2. *Missing areas and evolutionary directions*

During the analysis of the KPIs and the conceptualization of the framework, we observed that several elements discussed in the literature did not emerge from the review of indicators included in the HSPAs of the countries analyzed. These themes, although present in theoretical discourse, were not consistently associated with a specific IPOO phase. As a result, we chose to explicitly incorporate these areas—where a gap between theory and practice persists—into the framework as dotted blocks, and we provide a focused discussion of the most relevant aspects in the section that follows. This serves a dual purpose: first, to highlight critical missing areas in current monitoring systems; and second, to position these themes as potential avenues for future development, supporting the integration of key socio-technical dynamics into comprehensive digital transformation monitoring frameworks in healthcare.

As a first aspect, a growing concern is the one related to patient safety in digital healthcare. Although digital technologies can enhance patient safety in some areas, they simultaneously introduce new risks, like information overload (Nijor et al., 2022) and usability (Ratwani et al., 2018), as well as increase cognitive burden for staff, exacerbating the risk of error (Flott et al., 2021). Current literature emphasizes the need for dedicated measures to assess these risks effectively; for example, measuring the number and type of clinical IT-related safety incidents can inform risk management strategies (Sittig and Singh, 2010). Consequently, integrating specific patient safety indicators into digital performance frameworks could enhance healthcare delivery quality and user safety (Ricciardi et al., 2019).

Another important aspect emerging from both literature and practice is data portability, which holds particular significance within the context of the European Union. This concept was introduced through the General Data Protection Regulation (GDPR), specifically under Article 20. This enables individuals to "transmit their data to another data controller without hindrance, provided that the processing is based on consent or a contract and is carried out by automated means" (European Union, 2016). This provision aims to enhance users' data sovereignty and promote interoperability among online services, ultimately fostering a user-centric digital environment (De Hert et al., 2018; Kuebler-Wachendorff et al., 2021). In the healthcare sector, the European Commission has recently proposed a Regulation to establish a European Health Data Space (EHDS). The proposed European Health Data Space (EHDS) aims to enhance individuals' access to and control over their electronic health data, effectively strengthening the Data Portability provision (Li and Quinn, 2024). This initiative is expected to yield multiple benefits: generating € 11 billion in savings over the next decade through improved data accessibility, enhancing healthcare service efficiency across EU member states, driving a 20–30 % expansion in the digital health sector, strengthening policy development and scientific research, and leading to better health outcomes for European citizens (European Commission, 2025). Given the recent advancements in policy and the growing research interest around Data Portability, it is essential to start thinking about measures that integrate this aspect into the healthcare system as a part of the DT journey.

Lastly, although the growing introduction of AI in healthcare yet a few measures being developed to monitor this phenomenon. The rapid adoption of AI across various sectors of healthcare necessitates systematic monitoring of both its diffusion and its impact on healthcare delivery and service integration (Topol, 2019). Indeed, for some time already, AI tools have been much more integrated into healthcare (Appio et al., 2021). Despite its potential to transform the field, AI-based technologies do not exist in isolation; they must be effectively integrated within organizational contexts (Ali Mohamad et al., 2023). Previous research has demonstrated that organizational strategies for implementing health information technologies and the prevailing organizational culture can influence both adoption and utilization (K. Cresswell and Sheikh, 2013). For instance, a lack of integration with existing health information systems can hinder system performance, impede practical use, and negatively affect safety and user experience (Cresswell et al., 2017). To effectively address both the advantages and challenges posed by AI, health systems should not only develop metrics focused on this critical aspect but also create frameworks that facilitate the safe integration of AI within existing organizational structures and processes (Cresswell et al., 2024).

Focusing on the areas mentioned above will be essential shortly to address the challenges and opportunities arising from the DT of healthcare. It is also fundamental to prioritize the development of measures to track advancements in these fields.

6. Conclusions

In our exploration of metrics to measure and monitor DT within European healthcare systems, we have uncovered both promising advancements and notable gaps. This study specifically examines how metrics related to the digital transformation of the healthcare sector across EU countries are integrated and operationalized within HSPAs. It underscores the importance of making these measures concrete to provide actionable insights for managing DT initiatives.

These efforts are essential to strengthen resilience and ensure healthcare systems are better prepared to effectively handle future challenges and crises. Recognizing the significance of established metrics that assess the general digitalization within the European Union, such as the DESI (cfr. Paragraph 1), our study offers a multi-dimensional insight into the specifics of healthcare systems across Europe, with a focus on the HSPAs. It is important to emphasize that HSPAs do not limit their scope to digital health; rather, they address the complexities of healthcare systems by analyzing various other aspects as well.

Based on our investigation, we have gained insights into the incorporation of digital health into HSPAs. Many European countries have shown a strong commitment to evaluating the digitalization of their healthcare systems by developing specific KPIs, which highlight the importance of measuring and tracking digital health initiatives. In light of this, several areas of focus in digital health integration have emerged. Firstly, there is a significant emphasis on monitoring digital health service usage, particularly in terms of internet-based health information seeking. This reflects a shared interest among countries in assessing digital health literacy and engagement among their populations. Additionally, the adoption of EHRs is prioritized to digitize health information, aiming to enhance accessibility and interoperability within healthcare systems. Furthermore, increasing attention is directed towards telemedicine and teleconsultations, signaling a shift towards remote healthcare delivery methods to improve accessibility and efficiency. Investments in digital health infrastructure, including broadband coverage, underscore the importance of robust connectivity to support digital health initiatives effectively. It is, however, important to recognize that relatively few indicators related to inputs have been developed in comparison with the other phases of IPOO, as seen in the findings. Given the increasing significance of digital health, it will be essential in the future to continue monitoring this crucial phase by developing even more specific measures. As a final note, efforts to monitor patient engagement and satisfaction are significant in certain countries but have not been widely implemented. In a healthcare landscape increasingly focused on patient-centeredness, it is essential to monitor how digital tools and applications affect patients. This will enable the establishment of virtuous cycles that involve them in the development of improved digital tools.

Still, as highlighted in the framework conceptualization paragraph, some factors identified as relevant in the literature are not monitored in practice. This suggests potential time lags between what is considered important for DT and countries' ability to implement or adjust their measurement systems, possibly due to data availability constraints, which almost appear as a paradox when talking about DT. Moving forward, it is crucial to tackle future challenges and gaps in digital health integration and KPIs development. Specifically, there is a need to identify and develop KPIs that reflect the evolving landscape of digital health, including measures related to patient safety, data portability, and AI applications. Additionally, enhancing standardization across healthcare information systems will be essential for facilitating meaningful cross-country comparisons and evaluations.

6.1. Implications

Our study offers some implications for scholars, practitioners, healthcare organizations and policymakers. Across the analyzed countries, where the operationalization and systematization of digital health indicators are prioritized, there exists a concerted effort to evaluate the level of digitalization through the development of KPIs into HSPAs. First, our analysis advances the growing stream of literature regarding DT in.

Our study contributes to the growing literature on DT in healthcare (Dal Mas et al., 2023; Kraus et al., 2021b; Leone et al., 2021; Marques and Ferreira, 2020) by offering a comprehensive and structured framework that synthesizes the main themes identified in prior research—such as infrastructure readiness, technological integration, service digitalization, and outcome measurement (Mauro et al., 2024; Vial, 2019). This study attempts to consolidate these main themes into a unified perspective, operationalized through the IPOO framework and empirically supported by the analysis of KPIs. In doing so, we try to bridge the gap between theoretical constructs and real-world implementation by highlighting not only which digital KPIs are being used but also how they align with different stages of transformation. This enables scholars to understand the managerial and policy levers necessary to drive effective DT in healthcare systems. Furthermore, the study provides a foundation for future case studies and/or comparative research on the intertwined nature of DT and performance measurement, highlighting the fundamental importance of "measurement" for effective "management". HSPAs serve the purpose of setting out the goals and priorities for a health system, with KPIs monitoring the investment strategies and measuring progress towards the achievement of goals. In this sense, our conceptual framework, which incorporates measurable indicators of DT organized into domains and sub-domains, favors the integration of standardized, quantitative metrics that enable comparison across contexts and over time. Consequently, systematically comparing KPIs could support scholars, managers, and policymakers in mapping the direction of DT initiatives across countries and benchmarking their initiatives. Our study establishes a foundation for future research by consolidating the current understanding of metrics related to DT in healthcare across various countries and proposing a conceptual yet applicable framework that takes into account the complexity of healthcare delivery in Europe, making different systems comparable By identifying a set of KPIs to cover all the phases of DT in healthcare and by unveiling key gaps and areas for further exploration, our research enhances the basis for other impactful studies.

Practitioners and healthcare organizations, such as hospitals and clinics, can also benefit from this study by integrating the framework's phases and its digital KPIs into their internal governance structures. A practical approach could involve establishing dedicated monitoring committees comprising stakeholders from various domains, including clinical leaders, practitioners, administrative managers, patient representatives, and IT specialists. These committees would be tasked with the regular review of KPI progress, swift identification of issues, and ensuring accountability across departments. To facilitate real-time decision-making, the implementation of interactive KPI dashboards accessible to managers and other relevant stakeholders is recommended. These dashboards would offer actionable insights into digital service adoption metrics. Moreover, publicly disclosing this data is a fundamental action that not only enhances accountability and transparency but also helps in identifying best practices, thereby influencing and driving change across the healthcare sector. Given the rapid and continuous pace of DT in healthcare, these dashboards must be updated regularly to reflect shifting priorities and emerging challenges. This dynamic approach ensures that healthcare organizations remain responsive and adaptive, fostering a culture of continuous improvement and update. Moreover, the establishment of systematic KPI-related performance audits within public organizations represents a valuable tool for strengthening administrative transparency, enhancing performance, and fostering a results-oriented organizational culture by sharing best practices. These audits can be conducted both internally and across different organizations to create a collaborative network that critically analyzes performance management processes, promoting mutual improvement and learning. At the same time, targeted training for the stakeholders involved in the organizational processes should be encouraged to ensure the development of the necessary analytical and evaluative competencies. This fosters a more informed and capable workforce, enhancing the quality of decision-making. Finally, policymakers are central stakeholders in the DT of healthcare systems, and this study offers them a strategic tool to guide policy development, implementation, and evaluation. The adapted IPOO framework provides a structured approach to identify priority areas, allocate resources effectively, and monitor the impact of digital health initiatives. By analyzing specific KPIs and their interrelations, policymakers can gain insights into the readiness, adoption, and outcomes of digital health interventions, facilitating evidence-based decision-making. Although the framework has been deliberately designed to maintain a general structure that captures the macro dimensions of DT, it provides a basis for the development of context-specific KPIs informed by both national and international experiences. This approach is consistent with the widely acknowledged principle that HSPAs must be tailored to the distinct goals, values, and contextual needs of individual countries, thereby rendering a universal, one-size-fits-all solution unfeasible. Nonetheless, this study offers a significant contribution towards the establishment of a shared European framework for assessing DT in healthcare, promoting the creation of collaborative spaces similar to existing communities of experts within the HSPA ecosystem (Paoli et al., 2019). Such collaborative platforms would play a role in defining, refining, and updating priority areas of intervention related to DT in healthcare. However, despite a collective commitment among European countries to advance digital health agendas, persistent challenges—including resource constraints and limited data availability—may hinder the development of comprehensive monitoring and evaluation systems. For this reason, the potential guiding role of supranational organizations may prove instrumental in fostering alignment and standardization of digital health monitoring practices. These entities could facilitate the coordination of methodological approaches, promote data harmonization, and support the development of shared indicators, thereby enabling countries to overcome individual limitations.

6.2. Limitations and future research

This study has some limitations worth noting. Firstly, it only focuses on European Union countries, which, while clearly stated, limits the possibility of discovering other relevant experiences that could potentially add value to this research. Future studies could expand their scope to include different geographical areas. Secondly, this research relies on Google Scholar as its primary database for searching. While this was due to its extensive and comprehensive documentation regarding the countries under analysis, it could bring challenges in ensuring that all relevant sources of information were included. Additionally, the study only considers the HSPAs or other performance measurement systems as frameworks to analyze the availability of the KPIs under study. This means that other potential sources of KPIs are excluded.

Another aspect worth mentioning is the one related to the data availability aspect. In our analysis, we deliberately included all relevant indicators identified, including those that are currently not fully computable due to data availability constraints. Although incorporating these future-oriented indicators enriches the comprehensiveness of our framework, data availability issues may currently limit its practical applicability.

While the study intended to focus on HSPAs, future research could delve deeper into a single country's experience or single indicators/areas to provide more detail and develop a more comprehensive discussion around these metrics. Our focus on HSPA may have caused us to overlook internal systems or procedures internal to countries that may be specifically designed to monitor digitalization.

Another limitation is that the concept of DT and HSPA experiences evolves rapidly, which means that this research should be updated regularly to reflect the evolution of practices regarding the implementation and operationalization of digital health KPIs into HSPA or other countries' performance evaluation systems. Future research could explore interconnected effects and strategic decisions concerning technology, organizational structure, and environmental factors that facilitate the digital transformation of countries through cross-country comparative analyses.

CRediT authorship contribution statement

Alessandro Vinci: Writing – review & editing, Writing – original draft, Visualization, Project administration, Methodology, Data curation, Conceptualization, Investigation, Resources. **Andrea Vandelli:** Writing – review & editing, Writing – original draft, Conceptualization, Investigation, Resources. **Alessia Caputo:** Writing – review & editing, Writing – original draft, Methodology, Data curation, Investigation, Resources. **Milena Vainieri:** Validation, Supervision, Data curation, Conceptualization, Writing – review & editing, Project administration.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this article.

Acknowledgments

We are grateful to the Digital Transformation Society (DTS) board for their invaluable feedback, which enriched this study and allowed us to present a preliminary version of this work at the conference. The authors wish to express their gratitude to the editor of Technological Forecasting and Social Change and to the reviewers for their invaluable feedbacks and guidance, which greatly enhanced the impact of this study and strenghtened its adherence to research standards. This research was co-funded by the Management and Healthcare Laboratory (MeS), Institute of Management, Sant'Anna School of Advaced Studies.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.techfore.2025.124340.

Data availability

Data will be made available on request.

References

Agarwal, R., Gao, G. (Gordon), DesRoches, C., Jha, A.K., 2010. Research commentary—the digital transformation of healthcare: current status and the road ahead. Inf. Syst. Res. 21 (4), 796–809. https://doi.org/10.1287/isre.1100.0327.

Agostino, D., Costantini, C., 2022. A measurement framework for assessing the digital transformation of cultural institutions: the Italian case. Meditari Accountancy Research 30 (4), 1141–1168. https://doi.org/10.1108/MEDAR-02-2021-1207.

Ali Mohamad, T., Bastone, A., Bernhard, F., Schiavone, F., 2023. How artificial intelligence impacts the competitive position of healthcare organizations. J. Organ. Chang. Manag. 36 (8), 49–70. https://doi.org/10.1108/JOCM-03-2023-0057.

Amankwah-Amoah, J., Khan, Z., Wood, G., Knight, G., 2021. COVID-19 and digitalization: the great acceleration. J. Bus. Res. 136, 602–611. https://doi.org/10.1016/j.jbusres.2021.08.011.

Appio, F.P., Frattini, F., Petruzzelli, A.M., Neirotti, P., 2021. Digital transformation and innovation management: A synthesis of existing research and an agenda for future studies. J. Prod. Innov. Manag. 38 (1), 4–20. https://doi.org/10.1111/jpim.12562.

Barlow, J., 2017. Managing innovation in healthcare. WORLD SCIENTIFIC (EUROPE). https://doi.org/10.1142/q0044.

Bashshur, R.L., Shannon, G.W., Smith, B.R., Alverson, D.C., Antoniotti, N., Barsan, W.G., Bashshur, N., Brown, E.M., Coye, M.J., Doarn, C.R., Ferguson, S., Grigsby, J., Krupinski, E.A., Kvedar, J.C., Linkous, J., Merrell, R.C., Nesbitt, T., Poropatich, R., Rheuban, K.S., Yellowlees, P., 2014. The empirical foundations of telemedicine interventions for chronic disease management. Telemedicine and E-Health 20 (9), 769–800. https://doi.org/10.1089/tmj.2014.9981.

Baudier, P., Kondrateva, G., Ammi, C., Chang, V., Schiavone, F., 2023. Digital transformation of healthcare during the COVID-19 pandemic: patients' teleconsultation acceptance and trusting beliefs. Technovation 120, 102547. https://doi.org/10.1016/j.technovation.2022.102547.

Binci, D., Palozzi, G., Scafarto, F., 2021. Toward digital transformation in healthcare: a framework for remote monitoring adoption. TQM J. 34 (6), 1772–1799. https://doi.org/10.1108/TQM-04-2021-0109.

Bokolo, A. Jnr, 2021. Application of telemedicine and eHealth technology for clinical services in response to COVID-19 pandemic. Heal. Technol. 11 (2), 359–366. https://doi.org/10.1007/s12553-020-00516-4.

Bowen, G.A., 2009. Document analysis as a qualitative research method. Qual. Res. J. 9 (2), 27–40. https://doi.org/10.3316/QRJ0902027.

Boyne, G.A., 2002. Concepts and indicators of local authority performance: an evaluation of the statutory frameworks in England and Wales. Public Money Manag. 22 (2), 17–24. https://doi.org/10.1111/1467-9302.00303.

Brenner, M., Weir, A., McCann, M., Doyle, C., Hughes, M., Moen, A., Ingvar, M., Nauwelaerts, K., Turk, E., McCabe, C., 2023. Development of the key performance indicators for digital health interventions: A scoping review. Digital Health 9, 20552076231152160. https://doi.org/10.1177/20552076231152160.

Brito Fernandes, Ó., Barbazza, E., Ivanković, D., Jansen, T., Klazinga, N.S., Kringos, D.S., 2021. Engaging citizens in the development of a health system performance assessment framework: A case study in Ireland. Health Research Policy and Systems 19 (1), 148. https://doi.org/10.1186/s12961-021-00798-8.

Brown, M.G., Svenson, R.A., 1988. Measuring R&D Productivity. Research-Technology Management 31 (4), 11–15. https://doi.org/10.1080/08956308.1988.11670531.

Bryson, J.M., Crosby, B.C., Bloomberg, L., 2014. Public value governance: moving beyond traditional public administration and the new public management. Public Adm. Rev. 74 (4), 445–456. https://doi.org/10.1111/puar.12238.

Budd, J., Miller, B.S., Manning, E.M., Lampos, V., Zhuang, M., Edelstein, M., Rees, G., Emery, V.C., Stevens, M.M., Keegan, N., Short, M.J., Pillay, D., Manley, E., Cox, I.J., Heymann, D., Johnson, A.M., McKendry, R.A., 2020. Digital technologies in the public-health response to COVID-19. Nat. Med. 26 (8), 1183–1192. https://doi.org/10.1038/s41591-020-1011-4.

Chan, Y.Y.Y., Ngai, E.W.T., 2011. Conceptualising electronic word of mouth activity. Mark. Intell. Plan. 29 (5), 488–516. https://doi.org/10.1108/02634501111153692.

Chereka, A.A., Demsash, A.W., Ngusie, H.S., Kassie, S.Y., 2022. Digital health literacy to share COVID-19 related information and associated factors among healthcare providers worked at COVID-19 treatment centers in Amhara region, Ethiopia: A cross-sectional survey. Informatics in Medicine Unlocked 30, 100934. https://doi.org/10.1016/j.imu.2022.100934.

Chinta, R., Kebritchi, M., Ellias, J., 2016. A conceptual framework for evaluating higher education institutions. Int. J. Educ. Manag. 30 (6), 989–1002. https://doi.org/10.1108/IJEM-09-2015-0120.

Cobianchi, L., Dal Mas, F., Peloso, A., Pugliese, L., Massaro, M., Bagnoli, C., Angelos, P., 2020. Planning the full recovery phase: an Antifragile perspective on surgery after COVID-19. Ann. Surg. 272 (6), e296. https://doi.org/10.1097/SLA.0000000000004489.

Country Health Profiles—European Commission, 2024. https://health.ec.europa.eu/state-health-eu/country-health-profiles_en.

Cresswell, K., de Keizer, N., Magrabi, F., Williams, R., Rigby, M., Prgomet, M., Kukhareva, P., Wong, Z.S.-Y., Scott, P., Craven, C.K., Georgiou, A., Medlock, S., Brender McNair, J., Ammenwerth, E., 2024. Evaluating artificial intelligence in clinical settings—let us not reinvent the wheel. J. Med. Internet Res. 26, e46407. https://doi.org/10.2196/46407.

Cresswell, K., Sheikh, A., 2013. Organizational issues in the implementation and adoption of health information technology innovations: an interpretative review. Int. J. Med. Inform. 82 (5), e73–e86. https://doi.org/10.1016/j.ijmedinf.2012.10.007.

Cresswell, K.M., Mozaffar, H., Lee, L., Williams, R., Sheikh, A., 2017. Safety risks associated with the lack of integration and interfacing of hospital health information technologies: A qualitative study of hospital electronic prescribing systems in England. BMJ Qual. Saf. 26, 530–541. https://doi.org/10.1136/bmjqs-2015-004925.

Cucciniello, M., Porumbescu, G.A., Grimmelikhuijsen, S., 2017. 25 years of transparency research: evidence and future directions. Public Adm. Rev. 77 (1), 32–44. https://doi.org/10.1111/puar.12685.

Dal Mas, F., Massaro, M., Rippa, P., Secundo, G., 2023. The challenges of digital transformation in healthcare: an interdisciplinary literature review, framework, and future research agenda. Technovation 123, 102716. https://doi.org/10.1016/j.technovation.2023.102716.

Dal Mas, F., Piccolo, D., Edvinsson, L., Skrap, M., D'Auria, S., 2020. Strategy innovation, intellectual capital management, and the future of healthcare: The case of Kiron by Nucleode. In: Matos, F., Vairinhos, V., Salavisa, I., Edvinsson, L., Massaro, M. (Eds.), Knowledge, People, and Digital Transformation: Approaches for a Sustainable Future. Springer International Publishing, pp. 119–131. https://doi.org/10.1007/978-3-030-40390-4_9.

Dalglish, S.L., Khalid, H., McMahon, S.A., 2020. Document analysis in health policy research: the READ approach. Health Policy Plan. 35 (10), 1424–1431. https://doi.org/10.1093/heapol/czaa064.

De Hert, P., Papakonstantinou, V., Malgieri, G., Beslay, L., Sanchez, I., 2018. The right to data portability in the GDPR: towards user-centric interoperability of digital services. Computer Law & Security Review 34 (2), 193–203. https://doi.org/10.1016/j.clsr.2017.10.003.

De Rosis, S., Cerasuolo, D., Nuti, S., 2020. Using patient-reported measures to drive change in healthcare: the experience of the digital, continuous and systematic

PREMs observatory in Italy. BMC Health Serv. Res. 20 (1). https://doi.org/10.1186/s12913-020-05099-4.
Deloitte Centre for Health Solutions, 2020. Shaping the future of European healthcare. Deloitte.
Dobrolyubova, E., 2021. Measuring outcomes of digital transformation in public administration: literature review and possible steps forward. NISPAcee Journal of Public Administration and Policy 14, 61–86. https://doi.org/10.2478/nispa-2021-0003.
Donabedian, A., 1988. The quality of care: how can it be assessed? JAMA 260 (12), 1743. https://doi.org/10.1001/jama.1988.03410120089033.
Europe fit for the digital age - European Commission [WWW Document], n.d. URL https://commission.europa.eu/strategy-and-policy/priorities-2019-2024/europe-fit-digital-age_en (accessed 9.8.25).
European Commission, 2022. Digital economy and society index. https://digital-decade-desi.digital-strategy.ec.europa.eu/datasets/desi-2022/charts.
European Commission, 2025, March 7. European Health Data Space Regulation (EHDS). https://health.ec.europa.eu/ehealth-digital-health-and-care/european-health-data-space-regulation-ehds_en.
European Union, 2016. Art. 20 GDPR – right to data portability. *General data protection regulation (GDPR)*. https://gdpr-info.eu/art-20-gdpr/.
Fakhoury, R., Aubert, B., 2015. Citizenship, trust, and behavioural intentions to use public e-services: the case of Lebanon. Int. J. Inf. Manag. 35 (3), 346–351. https://doi.org/10.1016/j.ijinfomgt.2015.02.002.
Flott, K., Maguire, J., Phillips, N., 2021. Digital safety: the next frontier for patient safety. Future Healthcare Journal 8 (3), e598–e601. https://doi.org/10.7861/fhj.2021-0152.
Getachew, E., Adebeta, T., Muzazu, S.G.Y., Charlie, L., Said, B., Tesfahunei, H.A., Wanjiru, C.L., Acam, J., Kajogoo, V.D., Solomon, S., Atim, M.G., Manyazewal, T., 2023. Digital health in the era of COVID-19: reshaping the next generation of healthcare. Front. Public Health 11, 942703. https://doi.org/10.3389/fpubh.2023.942703.
Gil-Garcia, J.R., Dawes, S.S., Pardo, T.A., 2018. Digital government and public management research: finding the crossroads. Public Manag. Rev. 20 (5), 633–646. https://doi.org/10.1080/14719037.2017.1327181.
Gjellebæk, C., Svensson, A., Bjørkquist, C., Fladeby, N., Grundén, K., 2020. Management challenges for future digitalization of healthcare services. Futures 124, 102636. https://doi.org/10.1016/j.futures.2020.102636.
Graham, F.S., Gooden, S.T., Martin, K.J., 2016. Navigating the transparency–privacy paradox in public sector data sharing. Am. Rev. Public Adm. 46 (5), 569–591. https://doi.org/10.1177/0275074014561116.
Greenhalgh, T., Wherton, J., Papoutsi, C., Lynch, J., Hughes, G., A'Court, C., Hinder, S., Fahy, N., Procter, R., Shaw, S., 2017. Beyond adoption: A new framework for theorizing and evaluating nonadoption, abandonment, and challenges to the scale-up, spread, and sustainability of health and care technologies. J. Med. Internet Res. 19 (11), e8775. https://doi.org/10.2196/jmir.8775.
Hauser, J.R., Zettelmeyer, F., 1997. Metrics to evaluate R. D&E. Research-Technology Management 40 (4), 32–38. https://doi.org/10.1080/08956308.1997.11671140.
Heeks, R., 2006. Health information systems: failure, success and improvisation. Int. J. Med. Inform. 75 (2), 125–137. https://doi.org/10.1016/j.ijmedinf.2005.07.024.
Humbeck, P., Pfähler, K., Wiedenmann, M., Herzwurm, G., 2019. The impact of Servitization and digital transformation—A conceptual extension of the IPOO-framework. Procedia CIRP 81, 914–919. https://doi.org/10.1016/j.procir.2019.03.227.
Kierkegaard, P., 2013. E-prescription across Europe. Heal. Technol. 3 (3), 205–219. https://doi.org/10.1007/s12553-012-0037-0.
Kraus, S., Jones, P., Kailer, N., Weinmann, A., Chaparro-Banegas, N., Roig-Tierno, N., 2021a. Digital transformation: an overview of the current state of the art of research. SAGE Open 11 (3), 21582440211047576. https://doi.org/10.1177/21582440211047576.
Kraus, S., Schiavone, F., Pluzhnikova, A., Invernizzi, A.C., 2021b. Digital transformation in healthcare: analyzing the current state-of-research. Journal of business research 123, 557–567. Scopus. https://doi.org/10.1016/j.jbusres.2020.10.030.
Kringos, D. D., & Klazinga, D. N. (n.d.). Performance accountability for the Irish health system. *Final* Report.
Kringos, D.S., Boerma, W.G.W., Hutchinson, A., Saltman, R. B. (Eds.)., 2015. Building Primary Care in a Changing Europe. European Observatory on Health Systems and Policies. http://www.ncbi.nlm.nih.gov/books/NBK458728/.
Kringos, D.S., Klazinga, N.S., Barbazza, E., Fernandes, O.B., Ivankovic, D., Jansen, T., 2021. Methodological report : The development of the Irish Health System Performance Assessment Framework & its relation to the Health Information System Academic Medical Centre of the 1–80.
Kuebler-Wachendorff, S., Luzsa, R., Kranz, J., Mager, S., Syrmoudis, E., Mayr, S., Grossklags, J., 2021. The right to data portability: conception, status quo, and future directions. Inform. Spektrum 44 (4), 264–272. https://doi.org/10.1007/s00287-021-01372-w.
Lemieux-Charles, L., McGuire, W., Champagne, F., Barnsley, J., Cole, D., Sicotte, C., 2003. The use of multilevel performance indicators in managing performance in health care organizations. Manag. Decis. 41 (8), 760–770. https://doi.org/10.1108/00251740310496279.
Leone, D., Schiavone, F., Appio, F.P., Chiao, B., 2021. How does artificial intelligence enable and enhance value co-creation in industrial markets? An exploratory case study in the healthcare ecosystem. J. Bus. Res. 129, 849–859. https://doi.org/10.1016/j.jbusres.2020.11.008.
Li, W., Quinn, P., 2024. The European health data space: an expanded right to data portability? Computer Law & Security Review 52, 105913. https://doi.org/10.1016/j.clsr.2023.105913.
Marques, I.C.P., Ferreira, J.J.M., 2020. Digital transformation in the area of health: systematic review of 45 years of evolution. Heal. Technol. 10 (3), 575–586. https://doi.org/10.1007/s12553-019-00402-8.
Massaro, M., 2023. Digital transformation in the healthcare sector through blockchain technology. Insights from academic research and business developments. Technovation 120, 102386. https://doi.org/10.1016/j.technovation.2021.102386.
Mauro, M., Noto, G., Prenestini, A., Sarto, F., 2024. Digital transformation in healthcare: assessing the role of digital technologies for managerial support processes. Technol. Forecast. Soc. Chang. 209, 123781. https://doi.org/10.1016/j.techfore.2024.123781.
Meijer, A., Thaens, M., 2021. The dark side of public innovation. Public Perform. Manag. Rev. 44 (1), 136–154. https://doi.org/10.1080/15309576.2020.1782954.
Mergel, I., Edelmann, N., Haug, N., 2019. Defining digital transformation: results from expert interviews. Gov. Inf. Q. 36 (4), 101385. https://doi.org/10.1016/j.giq.2019.06.002.
Mitchell, V., 2019. A proposed framework and tool for non-economic research impact measurement. High. Educ. Res. Dev. 38 (4), 819–832. https://doi.org/10.1080/07294360.2019.1590319.
Ndayishimiye, C., Lopes, H., Middleton, J., 2023. A systematic scoping review of digital health technologies during COVID-19: A new normal in primary health care delivery. Heal. Technol. 13 (2), 273–284. https://doi.org/10.1007/s12553-023-00725-7.
Nijor, S., Rallis, G., Lad, N., Gokcen, E., 2022. Patient safety issues from information overload in electronic medical records. J. Patient Saf. 18 (6), e999–e1003. https://doi.org/10.1097/PTS.0000000000001002.
Noto, G., Corazza, I., Kļaviņa, K., Lepiksone, J., Nuti, S., 2019. Health system performance assessment in small countries: the case study of Latvia. Int. J. Health Plann. Manag. 34 (4), 1408–1422. https://doi.org/10.1002/hpm.2803.
Nuti, S., Noto, G., Vola, F., Vainieri, M., 2018. Let's play the patient's music: a new generation of performance measurement systems in healthcare. Manag. Decis. 56 (10), 2252–2272. https://doi.org/10.1108/MD-09-2017-0907.
OECD, 2002. OECD J. Budg. 1.
OECD, 2023. The COVID-19 pandemic and the future of telemedicine. OECD. https://doi.org/10.1787/ac8b0a27-en.
OECD & European Commission, 2024. Health at a glance: Europe 2024: state of health in the EU cycle. OECD. https://doi.org/10.1787/b3704e14-en.
Otley, D., 1999. Performance management: A framework for management control systems research. Manag. Account. Res. 10 (4), 363–382. https://doi.org/10.1006/mare.1999.0115.
Paoli, F., Schmidt, I., Wigzell, O., Ryś, A., 2019. An EU approach to health system performance assessment: building trust and learning from each other. Health Policy 123 (4), 403–407. https://doi.org/10.1016/j.healthpol.2019.02.004.
Papanicolas, I., Smith, P.C., 2013. Health system performance comparison: an agenda for policy, information and research, European observatory on health systems and policies series. WHO regional office for Europe, Copenhagen.
Paskaleva, K., Cooper, I., 2018. Open innovation and the evaluation of internet-enabled public services in smart cities. Technovation 78, 4–14. https://doi.org/10.1016/j.technovation.2018.07.003.
Peek, N., Sujan, M., Scott, P., 2020. Digital health and care in pandemic times: impact of COVID-19. BMJ Health & Care Informatics 27 (1), e100166. https://doi.org/10.1136/bmjhci-2020-100166.
Pirrotta, L., Guidotti, E., Tramontani, C., Bignardelli, E., Venturi, G., De Rosis, S., 2022. COVID-19 vaccinations: an overview of the Italian national health system's online communication from a citizen perspective. Health Policy 126 (10), 970–979. https://doi.org/10.1016/j.healthpol.2022.08.001.
Pleger, L.E., Mertes, A., Rey, A., Brüesch, C., 2020. Allowing users to pick and choose: A conjoint analysis of end-user preferences of public e-services. Gov. Inf. Q. 37 (4), 101473. https://doi.org/10.1016/j.giq.2020.101473.
Plsek, P.E., Greenhalgh, T., 2001. Complexity science: the challenge of complexity in health care. BMJ 323 (7313), 625–628. https://doi.org/10.1136/bmj.323.7313.625.
Porumbescu, G., Meijer, A., Grimmelikhuijsen, S., 2022. Government transparency: state of the art and new perspectives. Elements in Public Policy. https://doi.org/10.1017/9781108678568.
Ratwani, R.M., Hodgkins, M., Bates, D.W., 2018. Improving electronic health record usability and safety requires transparency. JAMA 320 (24), 2533–2534. https://doi.org/10.1001/jama.2018.14079.
Ricciardi, W., Pita Barros, P., Bourek, A., Brouwer, W., Kelsey, T., Lehtonen, L., Expert Panel on Effective Ways of Investing in Health (EXPH), 2019. How to govern the digital transformation of health services. Eur. J. Pub. Health *29* (Supplement_3), 7–12. https://doi.org/10.1093/eurpub/ckz165.
European Observatory on Health Systems and Policies. In: Saltman, R.B., Durán, A., Dubois, H.F.W. (Eds.), 2011. Governing Public Hospitals: Reform Strategies and the Movement towards Institutional Autonomy. Eds.
Schiavone, F., Mancini, D., Leone, D., Lavorato, D., 2021. Digital business models and ridesharing for value co-creation in healthcare: A multi-stakeholder ecosystem analysis. Technol. Forecast. Soc. Chang. 166. https://doi.org/10.1016/j.techfore.2021.120647.
Scupola, A., Mergel, I., 2022. Co-production in digital transformation of public administration and public value creation: the case of Denmark. Gov. Inf. Q. 39 (1), 101650. https://doi.org/10.1016/j.giq.2021.101650.
Singh, H., Grover, P., Kar, A.K., Ilavarasan, P.V., 2020. Review of performance assessment frameworks of e-government projects. Transforming Government: People, Process and Policy 14 (1), 31–64. https://doi.org/10.1108/TG-02-2019-0011.
Sittig, D.F., Singh, H., 2010. A new socio-technical model for studying health information technology in complex adaptive healthcare systems. Qual. Saf. Health Care 19 (Suppl. 3), i68–i74. https://doi.org/10.1136/qshc.2010.042085.

Sobolewski, M., Paliński, M., 2021. Welfare Assessment of the Gdpr Using a Discrete Choice Experiment.
Specht, A., Sarma, N., Linzbach, T., Hellmund, T., Hörig, M., Wintel, M., Equihua Martinez, G., Seybold, J., Lindner, A.K., 2022. Participatory development and implementation of inclusive digital health communication on COVID-19 with homeless people. Front. Public Health 10, 1042677. https://doi.org/10.3389/fpubh.2022.1042677.
Sun, Z., Li, J., 2020. The effects of performance of public sector health system on quality of life in China: evidence from the CGSS2015. Int. J. Environ. Res. Public Health 17 (8), 2896. https://doi.org/10.3390/ijerph17082896.
Topol, E., 2019. The Topol Review: Preparing the healthcare workforce to deliver the digital future (Indipendent Review). NHS.
Tortorella, G.L., Fogliatto, F.S., Saurin, T.A., Tonetto, L.M., McFarlane, D., 2022. Contributions of healthcare 4.0 digital applications to the resilience of healthcare organizations during the COVID-19 outbreak. Technovation 111, 102379. https://doi.org/10.1016/j.technovation.2021.102379.
Vainieri, M., Caputo, A., Vinci, A., 2024. Resilience dimensions in health system performance assessments, European Union. Bull. World Health Organ. 102 (7), 498–508. https://doi.org/10.2471/BLT.23.291102.
Venkatesh, V., Morris, M.G., Davis, G.B., Davis, F.D., 2003. User acceptance of information technology: toward a unified view. MIS Q. 27 (3), 425–478. https://doi.org/10.2307/30036540.
Verhoef, P.C., Broekhuizen, T., Bart, Y., Bhattacharya, A., Qi Dong, J., Fabian, N., Haenlein, M., 2021. Digital transformation: A multidisciplinary reflection and research agenda. J. Bus. Res. 122, 889–901. https://doi.org/10.1016/j.jbusres.2019.09.022.
Vial, G., 2019. Understanding digital transformation: A review and a research agenda. J. Strateg. Inf. Syst. 28 (2), 118–144. https://doi.org/10.1016/j.jsis.2019.01.003.
Vinci, A., Pirrotta, L., Venturi, G., Vainieri, M., 2025. From clicks to care: exploring the digital strategies of Italian health authorities in communicating "general practitioner selection" service. Health Policy, 105347. https://doi.org/10.1016/j.healthpol.2025.105347.
Vollaard, H., Martinsen, D.S., 2017. The rise of a European healthcare union. Comp. Eur. Polit. 15 (3), 337–351. https://doi.org/10.1057/cep.2016.3.
World health Organization, 2022. Monitoring the implementation of digital health. https://www.who.int/europe/publications/i/item/WHO-EURO-2022-5985-45750-65816.
World health organization, 2023. Digital health in the WHO European region: the ongoing journey to commitment and transformation. https://www.who.int/europe/publications/digital-health-in-the-who-european-region-the-ongoing-journey-to-commitment-and-transformation.
Zyzak, B., Sienkiewicz-Małyjurek, K., Jensen, M.R., 2024. Public value management in digital transformation: A scoping review. Int. J. Public Sect. Manag. 37 (7), 845–863. https://doi.org/10.1108/IJPSM-02-2024-0055.

Alessandro Vinci is a PhD candidate in Management at the Sant'Anna School of Advanced Studies (Pisa, Italy). Since 2021, he has been associated with the Management and Healthcare Laboratory (MeS), where he coordinates the Interregional Performance Evaluation System (IRPES), one of the core business of MeS. He has overseen different international projects and serves as the primary contact of the laboratory's digital health sector. His research interests focus on digital transformation within the healthcare ecosystem and on public services. In 2025, he carried out part of his research activity at the Nuffield Department of Primary Care, University of Oxford. He holds a bachelor degree in International Relations and a Masters' degree in Economics and International Management.

Andrea Vandelli Andrea Vandelli holds a Ph.D. in Health Science, Technology, and Management at the Sant'Anna School of Advanced Studies. She has a scholarship in digital health systems. She holds an LLM degree in law and an MSc in economics. In 2017, she successfully passed the bar exam on her first attempt. Her research focuses on healthcare management, with a particular emphasis on digital transformation and the legal-economic implications of introducing innovations such as privacy, liability, and risk management.

Alessia Caputo is a PhD candidate in healthcare management at Sant'Anna School of Advanced Studies (Pisa, Italy). She holds a bachelor's degree in economics and social sciences and completed her education with an M.Sc. in economics and management of government and international organizations and an MPA. Her research interests include performance measurement and evaluation in healthcare, public sector innovation, and healthcare management.

Milena Vanieri is a full professor in Management at Sant'Anna School of Advanced Studies of Pisa, where she obtained her PhD in Management, Innovation, and healthcare. She leads the Management and Health Laboratory at the Institute of Management and is responsible for the regional and interregional Performance Evaluation Systems. In 2016, she participated as an expert in the Joint Assessment Framework (JAF) in health for DG Employment, Social Affairs, and Inclusion. In 2020, she was called as an expert for DG REGIO to support the process of defining a priority list of interventions for the use of structural funds in health in Italy during the period 2021–2027. Since 2020, she has served as the Italian National Project Manager in the OECD initiative of Patient-Reported Indicator Survey. Furthermore, since 2021, she has been on the board of experts for monitoring the national Flu plan for the Italian Ministry of Health and is also on the board of directors of the National Agency for Healthcare (Agenas). Her research interests lie in performance evaluation and governance mechanisms in healthcare.