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Monica Giancotti, Marianna Mauro, Giorgia Rotundo

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# Exploring the Extent of Digital Transformation in Italian Public Health: Insights from a Web-based Survey

Monica Giancotti, PhD Researcher
of Business Economics Department of Law, Economics and Social sciences. Magna Graecia University of Catanzaro, Italy.

Marianna Mauro, PhD Full Professor
of Business Economics Department of Clinical and Experimental Medicine. Magna Graecia University of Catanzaro, Italy.

Giorgia Rotundo, PhD Research Fellow
in Business Economics Department of Clinical and Experimental Medicine. Magna Graecia University of Catanzaro, Italy.

**Corresponding Author:**

Monica Giancotti

*mgiancotti@unicz.it*

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**ABSTRACT**

Digital transformation is increasingly vital in healthcare, driven by technological advances and the need for efficient, patient-centered services. Despite global interest, limited research exists on digital transformation in Italian public healthcare. This study investigates the extent of digital technologies adoption across Italian public healthcare structures, focusing on administrative and clinical use, investment needs, training, and ICT-specialized personnel availability. An anonymous web-based survey, hosted on Qualtrics, was sent to 184 public healthcare institutions in Italy: 51 public hospitals (Aziende Ospedaliere), 25 teaching hospitals (Aziende Ospedaliere Universitarie), and 108 local health authorities (Aziende Sanitarie Locali). The survey achieved a 28.5% response rate. It collected data on digital technology adoption, investment levels, and training practices. Technologies were mapped by domain of use, investment requirements, and training intensity. Findings reveal heterogeneous adoption rates. Commonly used technologies include remote monitoring, cloud computing, digital sensors, telemedicine, and social media. Clinical areas mainly use remote monitoring, sensors, telemedicine, and collaborative robots, while administrative areas rely more on big data and cloud computing. Big data, artificial intelligence/machine learning, blockchain, collaborative robots, and 3D printing require higher investments. Training involves both the clinical and administrative staff, yet a shortage of ICT specialists limits full digital integration. While digital transformation is progressing in Italian public healthcare, uneven technology adoption and resource allocation persist. Identifying widely used technologies and those needing greater investment can support strategic planning and enhance more effective implementation.

La trasformazione digitale riveste un ruolo sempre più centrale nel settore sanitario, spinta dai progressi tecnologici e dalla necessità di garantire servizi efficienti e incentrati sul paziente. Nonostante l'interesse a livello globale, la letteratura sulla trasformazione digitale nella sanità pubblica italiana risulta ancora limitata. Il presente studio analizza il grado di adozione delle tecnologie digitali nelle strutture sanitarie pubbliche italiane, con particolare attenzione agli ambiti di utilizzo (clinico e amministrativo), ai fabbisogni di investimento, alla formazione e alla disponibilità di personale specializzato in ICT. È stata condotta un'indagine anonima online, tramite la piattaforma Qualtrics, rivolta a 184 enti sanitari pubblici in Italia: 51 Aziende Ospedaliere, 25 Aziende Ospedaliere Universitarie e 108 Aziende Sanitarie Locali. Il

tasso di risposta è stato del 28,5%. L'indagine ha raccolto dati sull'adozione delle tecnologie digitali, sui livelli di investimento e sulle pratiche formative. Le tecnologie sono state mappate in base al dominio di utilizzo, alle necessità di investimento e all'intensità della formazione. I risultati evidenziano tassi di adozione eterogenei. Le tecnologie più diffuse sono il monitoraggio remoto, il cloud computing, i sensori digitali, la telemedicina e i social media. In ambito clinico prevalgono il monitoraggio remoto, i sensori, la telemedicina e i robot collaborativi; in ambito amministrativo si ricorre maggiormente a big data e cloud computing. Tecnologie come big data, intelligenza artificiale/apprendimento automatico, blockchain, robot collaborativi e stampa 3D richiedono investimenti più elevati. La formazione coinvolge sia il personale clinico sia quello amministrativo, ma la carenza di figure specializzate in ICT rappresenta ancora un ostacolo all'integrazione digitale completa. Nonostante i progressi compiuti, la trasformazione digitale nella sanità pubblica italiana presenta ancora disparità nell'adozione delle tecnologie e nella distribuzione delle risorse. L'individuazione delle tecnologie più utilizzate e di quelle che necessitano di maggiori investimenti può supportare la pianificazione strategica e favorirne una più efficace implementazione.

**Keywords**: Digital transformation; Public health; Digital technology adoption; Web-based survey; Italian National Health System

## 1 – Introduction

The past two decades have seen various drivers prompt institutional players and managers of healthcare organizations to adopt alternative approaches and business models (Massaro, 2023; Kraus *et al.*, 2021). Such drivers include: an aging population, increases in public health expenditure and the consequent need to reduce costs (Caley & Sidhu, 2011; Lum *et al.*, 2020), the global pressure towards the improvement of patient outcomes, inclusiveness, and equity of care (Marques & Ferreira, 2020; Kraus *et al.*, 2021; Massaro, 2023).

In this framework, the pervasive development and diffusion of Information and Communication Technologies (ICT) and digital technologies (DTs) for health management and delivery (Elton & O'Riordan, 2016; Halford *et al.*, 2009) have represented a further incentive for change, giving rise to a process known as "digital transformation". The term is used to describe the adoption of new DTs that enable the shift towards secure and high-quality care, through combinations of information, computing, communication, and connectivity technologies (Vial, 2019; Haggerty, 2017, Secundo *et al.*, 2018; Saifudin *et al.*, 2021, Aulenkamp *et al.*, 2021).

Although introducing the Internet has influenced communication processes among healthcare sector actors since the mid-1990s (Arni & Laddha, 2017; Suggs, 2006)—when the term "e-health" was coined (Aceto *et al.*, 2018)—digital transformation in healthcare has become steadily more relevant over the last two decades (Marques & Ferreira, 2020; Tuzii, 2018; Ford *et al.*, 2017). The past decade, in particular, has seen the development of a multitude of digital tools and technologies that are revolutionizing how healthcare organizations behave and operate (Cohen *et al.*, 2017; Nambisan, 2017; Ramaswamy & Ozcan, 2018; Yoo *et al.*, 2010). New DTs—such as social media, Artificial Intelligence(AI)/Machine Learning(ML), big data, Internet of Things (IoT), Cloud computing, etc.—enable healthcare structures to streamline operations—enhancing patient experience at the same time (Fitzgerald *et al.*, 2014; Tortorella *et al.*, 2020b)—and support workflow practices (Kraus *et al.*, 2021).

The application of DTs in healthcare has originated the term Healthcare 4.0 (H4.0) (Thuemmler & Bai, 2017), a technology-driven approach that enables real-time customization of

healthcare, facilitating the transition to a patient-centered environment (Wang *et al.,* 2018; Tortorella *et al.,* 2022b). In parallel with this technological advancement, digital transformation requires significant organizational, human, and financial resources. These include capital investments in IT infrastructure (Gopal *et al.*, 2019), skilled human capital such as data analysts and digital engineers (Kakale, 2024), and continuous training programs to foster digital literacy among clinical and administrative staff (Borges do Nascimento *et al.*, 2023). Moreover, the sources of these resources are often external to healthcare organizations themselves—such as public investments programs—which often earmark resources specifically for capital expenditures rather than current spending (Longo *et al.*, 2024). The main destinations of these resources tend to include digital infrastructure, training programs, and platforms for clinical and administrative integration (Raimo *et al.*, 2023; Mauro *et al.*, 2024).

A further push towards the digital transformation of healthcare systems was represented by the spread of the COVID-19 pandemic (Cobianchi *et al.,* 2020; Drago *et al.*, 2023; Madhavan *et al.*, 2021; Tortorella *et al.,* 2021): according to a report drawn up by Deloitte (2020), about 65% of healthcare organizations accelerated their adoption of digital technologies in response to the crisis, aiming to support operational workflows and patient care, thereby enhancing their overall resilience (Tortorella *et al.*, 2022a). (Tortorella *et al.*, 2022a).

This confirms that digital healthcare technologies, if adopted in a targeted manner and implemented cost-effectively, can reduce healthcare inequalities, improve the quality of care provided while containing costs, and enhance the well-being of citizens (Locatelli *et al.,* 2010; Secundo *et al.,* 2018; Saifudin *et al.,* 2021).

Looking at the specific technologies involved in the digital transformation processes of healthcare organizations, the main tools are big data, the IoT, biomedical/digital sensors, cloud computing, remote control or monitoring, collaborative robots, augmented reality, 3D printing, telemedicine and AI/ ML (Tortorella *et al.,* 2020a,b; Eze *et al.,* 2020; Garai *et al.,* 2017; Spanò & Ginesti, 2022).

These technologies cover two main distinct domains of digital transformation application: health treatments and hospital support processes (Tortorella *et al.,* 2020b). The first refers to patient treatment and care, including therapy, diagnosis, and surgical practices (Wolf & Scholze, 2017; Ali Malik *et al.,* 2018). The second includes all managerial back-office processes that support the provision of care, such as financial transactions (Alharbi *et al.,* 2016), equipment maintenance (Gomez & Carnero, 2011), and the management of drugs (Agha, 2014).

In clinical settings, DTs contribute to reducing healthcare inequalities, improve the quality of healthcare provided, and to have updated information about patient treatments (Galetsi *et al.,* 2019; Jahmunah *et al.,* 2021; Park *et al.*, 2021).

In administrative settings, DTs can contribute to the improvement of healthcare decision-making by allowing the collection, management and analysis of new and large sets of data (Kamble *et al.,* 2019; Hasselgren *et al.,* 2020; Secundo *et al.,* 2021). All these activities generate value for patients (Kaplan & Porter, 2011).

While the topic of digitalization in the healthcare sector has been widely studied, there are still some gaps in the literature. To date, several studies have mapped the evolution of digital transformation in the healthcare sector (Marques & Ferreira, 2020; Dionisio *et al.*, 2023; Kakale, 2024). However, differences across application domains (administrative and clinical), as well as managerial implications, implementation challenges, and resource allocation issues, have not been adequately addressed (Raimo *et al.*, 2023; Mauro *et al.*, 2024).

More recent studies have begun to highlight the importance of training, organizational culture, and financial resources (Kakale, 2024), though without providing country-specific empirical insights.

In this framework, this study aims to address two main gaps in existing literature.

The first concerns the provision of empirical evidence at the European country level regarding the progression toward digital transformation in healthcare institutions, also from a perspective of monitoring the outcomes of planned initiatives.Indeed, the importance of digital transformation in the healthcare sector has led to the emergence of numerous policies, programs, regulations and directives aimed at supporting the digitalization of healthcare systems. These interventions mainly refer to the European context. In particular, in 2018, the European Commission published a final communication that detailed the previous actions taken to promote the digitalization of health and a series of further commitments to further promote digital transformation (Deloitte, 2020). *The European Strategic Plan* 2019–2024 (EU, 2020) confirms digital health as a key strategic priority.

In this context, monitoring the progress of healthcare structures toward digital transformation is essential.

The second gap in literature concerns understanding the relationship between digitalization and staff training. Recent studies have highlighted that the skills and competencies of employees are the most crucial determinants—and at the same time the major barrier—for ensuring successful digital transformation (Cannavacciuolo *et al.,* 2023; Madhavan *et al.,* 2021; Mauro *et al.,* 2024; Borges do Nascimento *et al.,* 2023). Engaging with digital applications in the healthcare sector requires learning Digital Competencies (DiCo), as training in this area promotes acceptance and enables correct usage (Aulenkamp *et al.,* 2023). In this context, the presence of internal personnel specialized in ICT takes on a key role in promoting dialogue and understanding between the technology supplier and users across the entire department (Cannavacciuolo *et al.,* 2023).

The relevance of the training is confirmed by the Regional Digital Health Action Plan for the WHO European Region 2023–2030 which includes a critical regional focus area on strengthening digital literacy skills and capacity-building in the general population, with particular attention to the health workforce, for the use of digital health services and disease prevention and management (Borges do Nascimento *et al.,* 2023).

Despite this awareness, currently the involvement of clinical and administrative staff in training processes aimed at the digitalization of healthcare organizations remains unclear.

This article seeks to address these gaps by providing evidence from Italy. We *a)* examine the use of DTs in both the administrative and clinical settings, *b)* map the current state of digital transformation in Italian healthcare facilities, with a particular focus on necessary investments and target audiences for training, as well as the presence of human resources specialized in ICT.

We conclude the paper with a graphical representation that illustrates each digital technology in relation to the investment requirements and training extent.

The focus on the Italian context is dictated, on the one hand, by the important efforts that the national government is making in order to ensure that digital health solutions integrate and improve the delivery models of existing health services, and on the other hand, by the strong disparity in the degree of digital transformation of healthcare structures due to the still heterogeneous implementation of regulatory interventions among the Italian regions (Odone *et al.,* 2018).

In addition, the Italian National Health System (INHS) as the primary beneficiary, in absolute terms, of the two main investment programs of the European Commission, the Recovery and Resilience Facility plans and the REACT-EU plan, which involves several major national-level reforms to modernize and digitize the healthcare system (Cacciatore *et al.,* 2024).

The study is organized as follows: Section 2 presents the background of this study. Section 3 describes the research design, while Section 4 and Section 5 respectively present and discuss the results. Finally, Section 6 draws conclusions.

## 2 – Advancing Digital Transformation in healthcare: the case of Italy

The INHS initiated its digitalization process by transitioning paper-based procedures into digital formats including electronic health records (EHRs) and e-prescriptions. It has advanced to encompass the incorporation of sophisticated DTs like the IoT, AI, virtual reality, and cloud computing (Raimo *et al.,* 2023). The process started in the early 2000s when the Permanent Committee for political issues between central and regional authorities (*Conferenza Stato-Regioni*) mandated the establishment of a national health information system to oversee regions (Domenichiello, 2015). The establishment of the eHealth board, known as "*Tavolo di Lavoro Permanente per la Sanità Elettronica*", played a pivotal role in advancing progress. Central and regional governments collaborated to set e-health development policies that aligned with national and European efforts. The board implemented the "Shared Policy for eHealth" in 2005, aligning with the goals of the European e-Health Action Plan 2004 to oversee and promote the use of ICTs management of clinical services. Since 2008, the e-health board has advanced the "Architectural Strategy for e-Health", an initiative aimed at enhancing information systems. The board has specified four key areas for intervention, including access to services, availability of patients' clinical history, innovation in primary care, and service restructuring through telemedicine and remote services. Subsequently, these were formalized through specific regulations established over the years, including Law 221/2012 and Legislative Decree 179/2012 concerning EHRs (Arena *et al.*, 2021).

Beyond the e-health board, the digital transformation has been further propelled by the establishment in 2012 of the Agency for Digital Italy and the Italian Digital Agenda, aligned with the European Digital Agenda and eGovernment Action Plans. This agency is tasked with leading digital transformation across public institutions, including those within the INHS. Since its inception, the Agency has issued regular three-year plans to advance the adoption of ICT, aiming to create a more efficient and transparent public administration (Arena *et al.,* 2021). It has provided guidelines for EHRs, centralized booking systems for health services, and telemedicine, with a focus on emerging DTs such as blockchain (highlighted in the 2017–2019 Plan), as well as AI, ML, big data, and analytics (emphasized in the 2024–2027 Plan).

The latest plans, along with their updates, have increasingly integrated the National Recovery and Resilience Plan (NRRP), presenting a unique opportunity to expedite digital transformation in public administration. Following the COVID-19 pandemic, the European Commission introduced the Next Generation EU, a recovery initiative that includes the Recovery and Resilience Facility and REACT-EU instruments. These initiatives aim to support the digital transition across European nations, including healthcare organizations, under the EU4Health program for 2021–2027. Italy has emerged as the primary beneficiary, in absolute terms, of both instruments. A total of €191.5 billion from the Recovery and Resilience Facility

Plan has been allocated to Italy and converted by the Italian NRRP into reforms that prioritize the digital transformation of healthcare systems (Cacciatore *et al.,* 2024).

However, a critical limitation emerges in the funding structure: these resources are almost exclusively earmarked for capital investments—such as digital infrastructure, cloud platforms, and AI-based systems—while current expenditures, including training programs and specialized human capital, receive minimal support (Longo *et al.*, 2024). This imbalance raises concerns about the long-term sustainability of digital transformation initiatives, especially given that successful implementation requires not only technological upgrades but also human resource development and change management capacity (Kakale, 2024; Borges do Nascimento *et al.*, 2023).

Indeed, the effective deployment of DTs hinges on three core resource pillars: financial capital for infrastructure, skilled personnel with digital competencies, and organizational capability to integrate innovations into existing workflows (Stoumpos *et al.*, 2023; Dionisio *et al.*, 2023). Empirical studies have shown that without proper training and ICT-specialized staff, the benefits of new technologies remain largely untapped (Aulenkamp *et al.*, 2023; Cannavacciuolo *et al.*, 2023). Moreover, while NRRP resources address the supply side of digital tools, the demand side—i.e., digital maturity among users and cultural readiness for transformation—is often neglected (Rosalia *et al.*, 2021). This mismatch can generate resistance, implementation delays, or ineffective outcomes (Vassolo *et al.*, 2021).According to projections based on the national budget, the INHS is expected to face underfunding relative to similar systems, such as the British NHS, with government healthcare spending predicted to fall below 6% of Gross Domestic Product (GDP) over the next three years (Longo *et al.*, 2024). This fiscal constraint adds further pressure on public hospitals to make optimal use of limited resources, highlighting the need for resource prioritization strategies that balance investments in hard infrastructure with those in soft capabilities such as workforce training and cross-functional governance (Raimo *et al.*, 2023; Mauro *et al.*, 2024).

Balancing these dynamics will be one of the INHS's main challenges. The effective management of administrative and operational processes will be crucial in handling the necessary trade-offs, ensuring that healthcare organizations remain responsive, efficient, and effective, while allowing healthcare professionals to focus on core clinical functions.

## 3 – Method

In light of its exploratory nature, this research employed an empirical approach as its methodological framework (Goodwin, 2005). Among the existing methods of data gathering for empirical research purposes, the survey method is frequently adopted due to its various advantages, such as its low cost and the standardized nature of the stimuli provided to all respondents (Lieberman & Montgomery, 2013). The method proposed in this paper consists of four main steps:

(i) sample selection and profiling;

(ii) development of the data collection instrument and operational measures;

(iii) assessment of construct validity and reliability**;**

(iv) data analysis procedures**.**

The subsequent sections provide detailed information on these steps.

## 3.1 – *Sample selection and characterization*

Our survey focused on Italian public healthcare structures. Consistent with the classification of healthcare companies by the Ministry of Health (https://www.salute.gov.it/portale), the initial total sample was composed of 184 public healthcare structures. Specifically, these included 51 public hospitals (*Aziende Ospedaliere – AO*), 25 teaching hospitals (*Aziende Ospedaliere Universitarie – AOU*) and 108 Local health authorities (*Aziende Sanitarie Locali – ASL*).

These organizations serve distinct roles within the healthcare system and are all undergoing significant digital transformation processes aimed at enhancing efficiency, accessibility, and quality of healthcare delivery through digital integration.

Specialized in providing advanced care, AO act as a regional center for specialized treatments and emergency services (France *et al.,* 2005). The digital transformation in these structures is centered on optimizing patient management and clinical processes (Ahmadi,2024).

AOUs, as well as offering healthcare services, collaborate with universities and function as centers for medical education and research (D'Aniello *et al.,* 2022). In this context, digital transformation supports academic training and scientific research through advanced digital platforms and the application of AI tools for health data analysis, also enabling innovative advancements in clinical and educational practices (Petrazzuoli, 2016). ASLs are responsible for providing primary and preventive healthcare services to the population. Digital transformation in ASLs improves service accessibility by using teleconsultation and remote patient monitoring (Pennestrì & Banfi, 2023).

In summary, digital transformation aims to create a more integrated and connected healthcare system, reducing inefficiencies and improving healthcare delivery nationwide.

## 3.2 – *Development of data collection instruments and measures*

Following the method also used in previous studies (Davies & Willing, 2023; Wao, 2015; Wong *et al.,* 2022; Lee *et al.,* 2015), we drew up a questionnaire, available online through the *Qualtrics* software from January to March 2024. Qualtrics is a secure and widely used online survey platform designed for research data collection. It offers advanced features such as logic branching, response validation, and customizable survey flow, ensuring that participants receive a consistent and user-friendly experience. In this study, Qualtrics allowed for real-time monitoring of response rates and facilitated the export of structured data for subsequent analysis. Access to the platform was restricted to the research team, and responses were collected anonymously, with no IP tracking enabled, thus ensuring participant confidentiality and data integrity.

In order to send the questionnaire, the email addresses of healthcare structures were extracted from the Ministry of Health's database. The missing email addresses were retrieved from the official websites of the selected public structures.

The administered questionnaire comprises 5 questions aggregated into 3 main sections.

Initially, the collection of information on the respondents' characteristics was conducted to determine the profile of the healthcare structure (AO, AOU, or ASL).

The first section (Q1) was constructed to provide an overview of the technologies most adopted in healthcare, both for supporting clinical and administrative activities.

The respondent was provided with a list of 12 DTs, chosen based on those that are considered the most relevant for healthcare, according to the recent literature (Tortorella *et al.,* 2020 a,b; Raimo *et al.,* 2023; Chen & See, 2020; Ng *et al.,* 2021; McCall, 2020). For each technology,

respondents were asked to indicate its predominant use (clinical setting, administrative setting, or both). Additionally, an open-ended section was provided to allow a description of the primary uses in these contexts.

The second section (Q2) aimed to investigate how much of the financial resources had been allocated to the digitalization of activities in the last three years, while questions included in section 3 focused a) on the existence of a specialized figure at departmental or central level supporting of digitalization processes (Q3), b) on staff training (Q4) and c) on investments in training (Q5).

Each section included closed-ended questions with a single possible option. In particular, the selectable answer options were constructed based on a 5-point Likert scale, except for the question Q3 (section 3) which required a yes/no answer. The full-translated questionnaire can be found in Appendix.

The survey was conducted according to the Italian Code regarding the protection of personal data (*General Data Protection Regulation - GDPR*), and all the participants consented to the use of their information, provided in anonymous form: anonymity and confidentiality of the study were announced upfront to respondents.

### 3.3 – *Verification of constructs' validity and reliability*

Before starting the online survey, a preliminary investigation was conducted on a sample of 5 healthcare structures to verify the constructs' validity and reliability. Specifically, the questionnaire was sent to the email addresses of the healthcare structures. During this phase, no critical issues emerged regarding question clarity or the questionnaire's overall validity**.**

Consequently, no section of the original questionnaire was modified.

### 3.4 – *Data analysis*

The answers from the respondents were extracted from *Qualtrics* and processed using Excel spreadsheets. The data analysis involved three phases: In the first phase, the technologies used by respondents were counted to map the adoption of technologies in Italian healthcare organizations, distinguishing between exclusively clinical use, administrative use, or both (Figure 1 – section 4.1). In the second phase, a four-quadrant chart (Chart 1 – section 4.2) was created to provide a clear overview for each respondent regarding: the type of public healthcare structure (AO, AOU, or ASL), the DTs employed, the setting (clinical, administrative, or both), investments in training and target groups, and the percentage of investment in DTs.

Finally, a manual count was performed to determine the frequency of each technology in relation to the percentage of resources invested in digitalization and the level of investment in training. This allowed for a mapping of the various DTs to provide an overview based on their required investment levels (high or low) and staff training intensity (high or low) (Chart 2 – section 4.3).

## 4 – Results

This section describes the results of the analysis of the questionnai**r**e submitted by the respondents**.**

Out of a total sample of 184 public healthcare structures, we received responses from 52 hospitals, resulting in an overall response rate of approximately 28.5% (Table 1).

The following sub-sections outline the results, organized according to each section of the survey.

**Table 1 – Starting sample and respondents**

| Healthcare structure | Starting sample | Respondents | % |
|---|---|---|---|
| **AO** | 51 | 22 | 43 |
| **AOU** | 25 | 11 | 44 |
| **ASL** | 108 | 19 | 17 |
| ***Total*** | **184** | **52** | **28.5** |

## 4.1 – *Digital technologies in Italian public healthcare structures: adoption and uses in clinical and administrative settings*

The first section of our survey focused on DTs adopted in Italian public healthcare structures. We describe the state-of-the art regarding their adoption and analyze their use in clinical and administrative settings. Response options were categorized into five levels of investment/usage: no investment, no use (available but not yet in use), used only in clinical settings, used only in administrative settings, and maximum use (both in clinical and administrative settings).

The responses provided a distinct scenario regarding the integration of advanced DTs. Varied levels of utilization were observed in both the clinical and administrative settings (Figure 1).

Remote control or monitoring technology is the most widespread digital technology in Italian public healthcare organizations, with 40 out of 52 structures having it, although 2 are not yet using it. The majority of them are classified as AO (20). Its primary utilization is within the clinical setting (as reported by 24 healthcare structures). Using this technology in clinical settings allows continuous patient monitoring, chronic disease management, and post-operative care, all of which contribute to improved patient outcomes.

In administrative settings, 14 hospitals use this technology for various purposes that enhance operational efficiency and security. In particular, this digital technology is crucial for asset management, for tracking the location and status of medical equipment, ensuring availability and functionality when needed. Environmental monitoring is another key application, with these systems maintaining optimal conditions such as temperature, humidity, and air quality in different hospital areas, thus ensuring a safe and comfortable environment for both patients and staff.

*Cloud computing* is the second most widespread digital technology (adopted by 30 healthcare structures). As in the previous case, it is widespread mainly in the AO (15); the use is joint, both in the clinical and administrative settings.

*Cloud storage* is a service model in which data is transmitted and stored on remote storage systems, where it is maintained, managed, backed up and made available to users over a network (Gai & Li, 2012). In healthcare settings, cloud computing supports online health data storage, remote monitoring of patients, sharing and editing of health data, and, most

importantly, provision of online treatment and diagnosis (Borges do Nascimento *et al.*, 2023; Mbunge *et al.*, 2021).

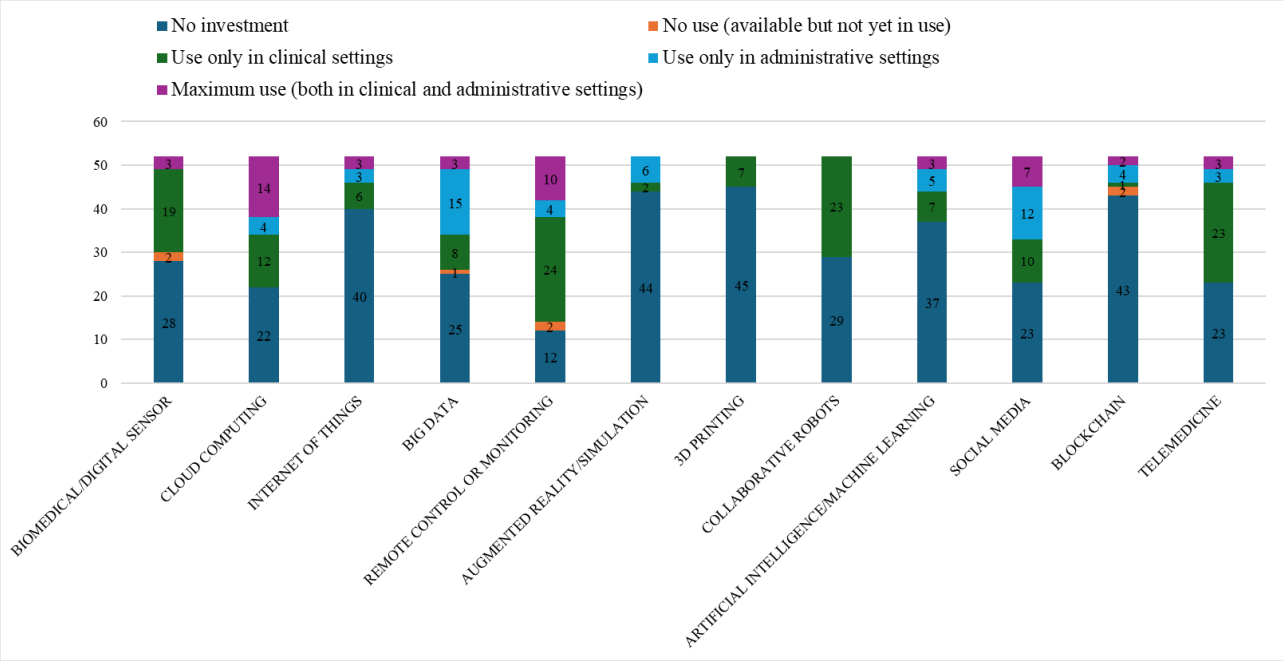


**Fig. 1 – Use of digital technologies in public healthcare structures** (*Source*: Authors' elaboration)

The flexibility of this computing service has opened many possibilities for healthcare organizations: it helps to store, process, analyze, and manage patients' health data with reduced data storage cost and increased efficiency (Sultan, 2014).

In clinical settings, cloud computing is pivotal in enabling efficient storage, access, and analysis of patient data. Healthcare providers utilize cloud-based systems to maintain EHRs, which can be accessed across multiple locations, enhancing care coordination. Furthermore, these systems facilitate telemedicine, where doctors can provide virtual consultations and monitor patients remotely.

In administrative settings, cloud solutions support the management of large volumes of patient and operational data, enabling seamless processing and analysis. These systems help in billing, patient scheduling, and inventory management, improving the efficiency of administrative tasks.

However, the implementation requires robust cybersecurity measures and the presence of a stable internet connection, as using cloud storage requires the simultaneous presence of one or more physical servers (Mauro *et al.*, 2024).

Cloud computing is followed by *social media* and *telemedicine* (29 respondents stated that they use these DTs), distributed in all three types of healthcare facilities.

The first is considered as a web 2.0–based platform for individuals to get access to, share, and generate content. Consistent with the literature on this topic, the use of social media for health purposes includes goals related to the promotion of health interventions, health campaigns, medical education disease outbreak surveillance, and health promotion and behavior change (Wang *et al.*, 2021).

Social media are also used by health institutions and researchers to advance their practices and research. In some cases, social media are also used for personnel recruitment (Wang *et al.,* 2021).

Last, as social media incorporates more functions - such as sending reminders, registering for events, and linking payment methods - these DTs become useful in facilitating offline health-related services and events, such as making appointments and providing visiting guides.

In this sense, social media serve as tools for medical service and administration. Finally, in the administrative setting, these may also affect marketing and customer relationship functions through reputational and sentiment analysis. Indeed, social media is a tool that puts citizens in direct contact with the facility: many healthcare organizations have a team of people who spend many hours a day responding to users asking for information through social media (Mauro *et al.,* 2024).

Regarding *telemedicine*, this digital technology represents a digital innovation solution to guaranteeing the continuity of care, and patient and personnel safety in an environment with limited budgets and costs (Cannavacciuolo *et al.,* 2023). The World Health Organization (WHO, 2022) defines telemedicine as "*the delivery of health care services, where distance is a critical factor, by all health care professionals using ICTs for the exchange of valid information for the diagnosis, treatment and prevention of disease and injuries, research and evaluation, and for the continuing education of health care providers, all in the interests of advancing the health of individuals and their communities*." From this definition, it is possible to deduce the benefits and uses of telemedicine in both clinical and administrative settings.

Despite its potential benefits and its rapid acceleration in use during the Covid-19 pandemic, the diffusion of telemedicine services remains limited (Greenhalgh *et al.,* 2017; Cannavacciuolo *et al.*, 2023). The major barriers concern financial (funding, cost, reimbursement, benefits), organizational (planning, workforce, accessibility, cooperation), and legal issues (Otto & Harst, 2019; Stoumpos *et al.,* 2023).

Taking the fifth spot on the list is *big data*, with 26 healthcare facilities reporting its use as a digital technology. The majority of respondents (18) identified administrative settings as the main application of this technology.

The term "big data" is used to describe data that is large and unmanageable. Like every other industry, healthcare organizations are producing data at a tremendous rate that presents many advantages and challenges at the same time. Sources for big data include hospital records, medical records of patients, results of medical examinations, and devices that are a part of internet of things. This data requires proper management and analysis in order to derive meaningful information (Dash *et al.,* 2019). The use of big data enables the handling of large volumes of data from diverse sources and formats to gain intelligence (Mauro *et al.,* 2024).

The utilization of big data in clinical settings is primarily focused on biomedical research. In particular, in order to generate a map of a given biological phenomenon of interest, multiple simplified experiments are needed. Each of these individual experiments generates a large amount of data with more depth of information than ever before. Therefore, one usually finds oneself analyzing a large amount of data obtained from multiple experiments to gain novel insights (Dash *et al.,* 2019).

The use of *big data* helps in managing this extensive information.

The main obstacle to their full diffusion is the implementation of high-end computing tools, protocols and high-end hardware in the clinical setting (Gandomi & Haider, 2015; Dash *et al.,* 2019).

*Biomedical and digital sensors* are adopted by 22 healthcare structures. This technology is widespread in all three types of healthcare companies, without significant differences (6 AO, 7 AOU, 9 ASL). 2 healthcare structures declare that they have it but do not use it yet.

Overall, the prevalent use is in the clinical field (19 healthcare companies). Healthcare structures use these sensors for patient monitoring, diagnostics, and improving treatment precision. In administrative setting, digital sensors improve real-time administrative decision-making and resource allocation by tracking patient metrics and processing large-scale data (Mbunge *et al.,* 2021; Jones *et al.,* 2022).

*Collaborative robots* are widespread exclusively in AO (12) and AOU (11); their use is exclusively in the clinical setting. The utilization of collaborative robots in public hospital clinical settings reflects an emerging trend in healthcare, driven by advancements in digital technology. The scope of their applications ranges from surgical assistance (models that integrate robotic systems with human surgeons to enhance precision and reduce surgery duration) (Ram *et al.,* 2024), to rehabilitation (collaborative robots assist healthcare providers by enabling precision in repetitive rehabilitation exercises) (Kebede *et al.,* 2024).

The limited adoption of this technology in public healthcare settings is primarily due to high implementation costs and the need for extensive staff training (Ram *et al.,* 2024).

*AI/ML* appears in the responses of 15 interviewees (4 ASL, 5 AO, 6 AOU). It is used in both the clinical and administrative settings, without any particular differences. This technology refers to the ability of a machine to learn from experience, adjust to new inputs and perform human-like tasks.

Within the clinical settings, AI has been applied to many areas of medicine, especially to aid the detection and prevention of disease (Long & Ehrenfeld, 2020), to predict epidemic trends (Yang *et al.,* 2020) and patients at risk for more severe illnesses based on clinical parameters (Jiang *et al.,* 2020).

In administrative setting, AI/ML improves interaction with patients through chatbots, case mix planning at the healthcare system level, operations management at the healthcare organization level (such as supply chain management and inventory management), maximization of revenues in diagnosis-related group systems (i.e. analysis of invoicing), and clustering of patients (Mauro *et al.,* 2024). AI allows also to use administrative flows to plan the utilization of operating rooms (Mauro *et al.,* 2024).

In summary, AI and ML are used to analyze complex datasets, optimize clinical workflows, predict patient outcomes, and improve administrative tasks such as scheduling and resource management. However, there are also challenges associated with the adoption of these technologies, such as ensuring data security, avoiding bias in predictive algorithms, and the ethical implications of automated decision-making (Scott *et al.,* 2020; Chen & See, 2020; Plana *et al.,* 2022; Mauro *et al.,* 2024).

Another big player of the healthcare sector digitalization process is represented by *IoT*.

This digital technology is currently used by 12 healthcare facilities (1 ASL, 5 AO and 6 AOU), and its use is mainly in the clinical field.

The term refers to the networking of physical objects using embedded sensors and other devices that collect and transmit information about real-time activity within the network (Harbert, 2017).

In the past, objects like cars, watches, refrigerators, and health-monitoring devices did not have the capacity to create or manage data and did not possess internet connectivity. The incorporation of computer chips and sensors in such objects has introduced new possibilities.

Within healthcare, the IoT is seen as a growing trend (Dash *et al.,* 2019). IoT devices create a continuous stream of data while monitoring the health of people (or patients) (Dash *et al.,* 2019). Using the web of IoT devices, a doctor can measure and monitor various parameters from his/her clients in their respective locations, for example, home or office. Therefore, through early intervention and treatment, a patient might not need hospitalization or even visit the doctor, resulting in significant cost reduction in healthcare expenses. Some examples of IoT devices used in healthcare include fitness or health-tracking wearable devices, biosensors, clinical devices for monitoring vital signs, and other types of devices or clinical instruments.

In administrative setting, this technology (IoT) has an immediate potential to automate processes by enabling certain data to be captured continuously from devices. It can provide support for clinical engineering, equipment maintenance, operations management and patient flow logistics, and risk management (Mauro *et al.,* 2024).

The *blockchain* is used by 7 healthcare structures, of which 2 AO, 2 AOU and 3 ASL. 2 respondents declared that they have it but do not use it at the moment, presumably due to lack of staff training.

Blockchain technology is a digital method that refers to a verifiable permanent ledger system that can be used to store health care–related information (Chen & See, 2020).

Blockchain has been proposed as a solution to healthcare's crucial problems, such as safe medical record sharing and compliance with data privacy laws. It is essentially a method for storing data in a transparent, distributed, and immutable manner (Tapscott & Tapscott, 2016).

Despite blockchain technology can support digital transformation in the healthcare sector, several concerns have been raised about its real applicability. Regulatory barriers, the unfamiliarity of users with the real advantages of the technology, and the time and cost required to implement blockchain projects are some of the main elements that can slow down blockchain implementation (Massaro, 2023).

Finally, augmented reality and 3D printing are present in 8 and 7 cases respectively.

The prevalent use of *augmented reality* is in the administrative field, while the use of 3D printing is exclusively in the clinical field. These results are in line with previous study: in a recent literature review, Tortorella *et al.* (2019) found a lower pervasiveness of other ICTs, such as 3D printing, and augmented reality/ simulation, confirmed by a smaller number of studies reporting their utilisation in hospitals.

*3D printing* is the first of the least adopted technologies (45 of 52 public hospitals declared "no use"). This suggests that the use of this technology in hospitals is still being explored and expanded. The high costs of 3D printers and the materials required for printing can be a first barrier. Regulatory requirements for 3D printed medical devices can be stringent, adding complexity to their adoption.

*Augmented reality* is another technology with significant underutilization. With 44 hospitals reporting no investment and a minimal presence in both the clinical (2 hospitals) and administrative (6 hospitals) settings, it is clear that AR faces barriers such as high implementation costs, technical complexity, and potentially a lack of trained personnel. Its applications, which could range from medical training and simulation to enhanced patient care

through interactive diagnostics, are not fully realized in public healthcare structures included in our sample.

## 4.2 – *State-of-the art: overview through a chart analysis*

Once we determined the technologies used by the hospitals, we requested information on the percentage of resources allocated to acquiring these technologies and the resources spent on staff training, specifying if the training targeted medical staff, administrative staff, or both.

Responses allowed us to outline the positioning of public hospitals in terms of investment in DTs and staff training.

We decided to map the state-of-the-art using a four-quadrant chart. The chart, as constructed, allowed for the graphical representation of various types of information simultaneously, such as:

a) type of healthcare structure (AO, AOU, or ASL);

b) DTs adopted by each structure (see the legend "DTs Adopted" in Chart 1);

c) usage domain for each technology and structure (clinical - C, administrative - A, or both – C&A; see the legend "Technology Use Setting");

d) total percentage investment in DTs (from 0% to >15%);

e) total investment in training (from <20,000 to >90,000); and

f) training recipients in each structure (medical staff only, administrative staff only, or both).

Healthcare structures are positioned within the four quadrants as follows:

1. the upper right-hand quadrant contains the facilities that have invested in training for administrative staff only;

2. the lower right-hand quadrant maps facilities that have invested in training for both medical and administrative staff;

3. the upper left-hand quadrant includes facilities that have trained only medical staff;

4. finally, the lower left-hand quadrant shows the facilities that report they are currently in the planning phase of training investments for staff.

An overview shows that all healthcare organizations, except one, adopt multiple technologies. This first result is in line with previous studies demonstrating that the utilization of a single ICT may not be sufficient to support significant improvements in either administrative processes or healthcare treatments (Tortorella *et al.*, 2019).

Looking at the different types of healthcare facilities, teaching hospitals (AOUs) are the most advanced in terms of digitalization. Of the 11 hospitals, 9 (82%) have integrated between 7 and 12 DTs. Additionally, all AOUs possess Collaborative Robots (CR).

AOs possess a range of 2 to 12 technologies, with 50% incorporating CR. The ASLs have between 1 and 6 DTs and do not have CR.

Initial considerations concern the recipients of training. Overall, most facilities provide training for both categories of staff (clinical and administrative), with 32 out of 52 healthcare structures located in the lower right-hand quadrant.

AO facilities seem to invest the most in training for both the administrative and medical staff, with 16 out of 22 (72%) dedicating training to both categories. This is followed by AOU facilities, where 6 out of 11 (54%) provide training for both staff groups. As for ASLs, 9 out of 19

(47%) have planned training for both categories; 5 ASLs have allocated training solely for medical staff, in two cases training is still only in the planning stage, and in the remaining 3 cases, training is designated for administrative staff only.

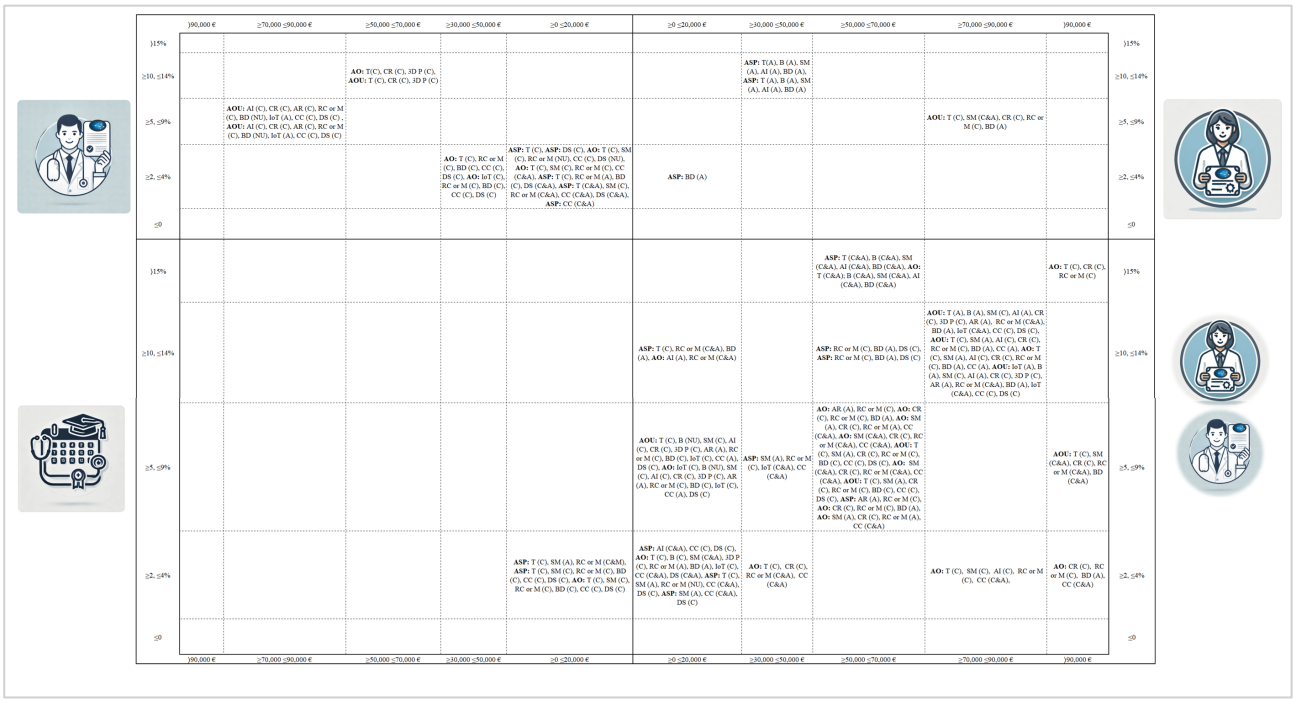


**Chart 1 – Digitalization in Italian public hospitals: mapping the state-of-the art** (*Source:* Authors' elaboration)

**[NOTE:** 52 healthcare structures; 22 AO, 11 AOU, 19 ASL. Upper right-hand quadrant: 3 ASL, 1 AOU.
Lower right-hand quadrant: 9 ASL, 16 AO, 7 AOU. Upper left-hand quadrant: 3 AOU, 5 AO, 5 ASL.
Lower left-hand quadrant: 2 ASL, 1 AO.
*DTs adopted*: T: Telemedicine, B: Blockchain, SM: Social media, AI: Artificial intelligence/Machine Learning, CR: Collaborative robots, 3D P: 3D Printing, AR: Augmented reality/Simulation, RC or M: Remote control or monitoring, BD: Big data, IoT: Internet of Things, CC: Cloud computing, DS: Digital sensor.
*Technology use setting:* (C): Technologies used only in clinical setting; (C&A): technologies used in clinical and administrative setting; (A): technologies used only in administrative setting.**]**

However, the final section of the questionnaire focused on the existence of specialized ICT personnel (Table 2).

Results show that the presence of specialized ICT personnel is minimal (the 42% of healthcare structures declared there is no human resource specialized in ICT), with a slight inclination towards central administration rather than departmental specialization. In fact, 33.3 % of the respondents confirmed the presence of specialized ICT personnel at the central administrative level but only 16.7% reveal a presence at each department. Only 8% of healthcare structures have a specialized role at both the departmental and central administrative levels. This suggests that the two factors, "training" and "presence of personnel specialized in ICT may

not be concurrently present, making the effective implementation of new DTs and procedures less likely.

**Table 2 – Presence of specialized human resources in ICT**

| | |
|---|---|
| At the central administrative level | 33.3 % |
| At each department | 16.7 % |
| At central administrative level and each department | 8.3 % |
| There is no human resource specialized in ICT | 41.7 % |

With regard to *training investments*, most healthcare structures (19 out of 52; 36.5%) report having invested between €0 and €20,000 over the past three years; the majority of these within this budget are ASLs (12 out of 19 ASLs). Six respondents (3 AOs and 3 ASLs) have invested between €30,000 and €50,000 (11%); 23 healthcare structures (10 AOs, 9 AOUs, 4 ASLs) have invested between €50,000 and €90,000 (44%). Two AOs and one AOU have invested over €90,000 in training.

Finally, regarding the *percentage of investments in DTs*, out of 52 healthcare structures, most of these (20; 9 AOs and 11 ASLs) are positioned in the quadrants corresponding to an investment percentage between 2% and 4%.

## 4.3 – Investments and training required: mapping DTs

The third phase of the study involved mapping DTs in a chart, to relate each technology to the levels of investment required and the breadth of training (Chart 2). The vertical axis represents the extent of training (from low to high), while the horizontal axis represents the level of investment (ranging from low to high) (see the legend). Technologies are grouped based on their positioning on these axes.

The distribution of DTs among healthcare structures highlights the varying levels of financial investment and training required for effective implementation. "High-investment technologies" (upper-right quadrant), such as AI/ML, Blockchain, Collaborative Robots, demand significant capital due to their advanced infrastructure needs. These technologies also require extensive training programs, encompassing both the administrative and medical staff, to fully harness their potential in improving patient outcomes and operational efficiency (Smith & Johnson, 2022). On the other hand, "lower-investment technologies" like Biomedical/Digital Sensors, Remote Control or monitoring, and Cloud Computing (upper-left quadrant) are more accessible, involving minimal costs (Park *et al.*, 2023). "Medium-level technologies" like Telemedicine and the Internet of Things (IoT) represent a balanced approach, requiring moderate investments and training that cater to diverse staff (Miller *et al.*, 2023). This distribution could support the decision-making needed in healthcare to align budgetary constraints with workforce preparedness, ensuring sustainable and effective digital transformation across healthcare structures.

# 5 – Discussions

In this study, we aimed to investigate the extent of digital transformation within Italian public healthcare structures, focusing on the adoption and utilization of DTs across both the clinical

and administrative settings. We also focused on necessary investments and target audiences for training (clinical or administrative staff).

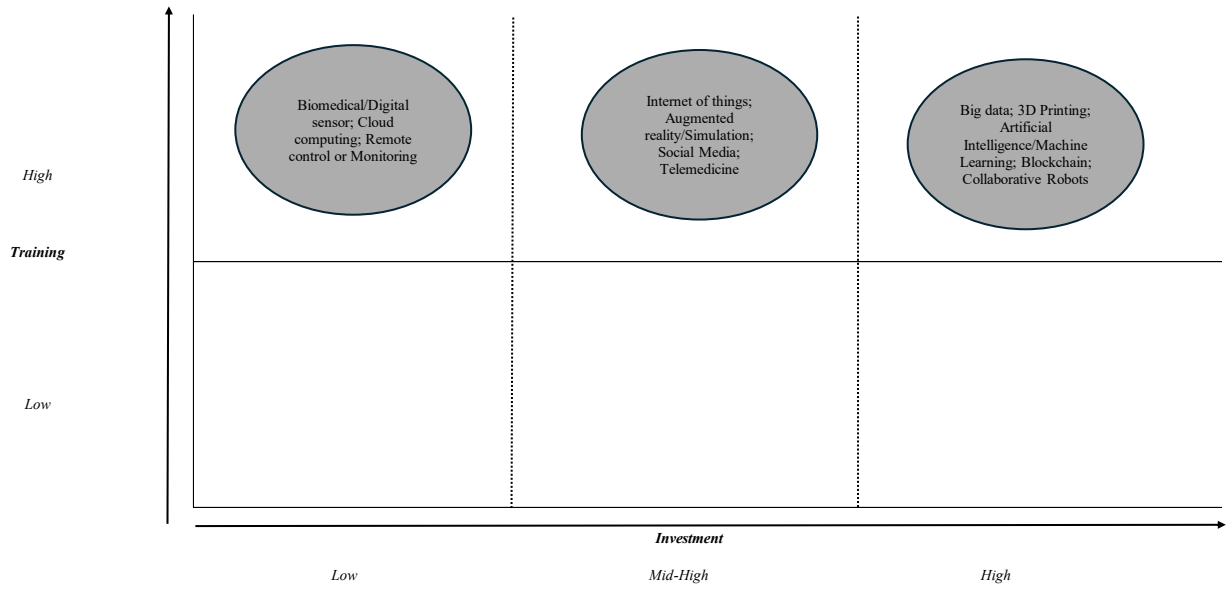


**Chart 2 - Mapping digital technologies** (*Source:* Authors' elaboration)

**[NOTE.** *Training low:* training for administrative staff only or medical staff only; *Training high:* training for both categories of staff. *Investment Low:* up to 4% of resources; *Investment Mid-Hight:* 5 to 9% of resources; *Investment High:* from 10 to 15% of resources.**]**

Regarding the use of DTs in administrative and clinical settings, results are summarized as follows:

a. Remote control or monitoring, cloud computing, digital sensors, telemedicine and social media are the most widespread DTs in Italian healthcare facilities. Remote control or monitoring, digital sensors and telemedicine are mainly used in clinical settings, while cloud computing and social media are used in both settings without significant differences.

b. Collaborative robots have a primary role in clinical applications, followed by 3D printing, which at the same time appears to be the least widespread technology. This delineation suggests that these technologies are crucial for patient care, as they have not yet found significant utility in the administrative domain. The main barriers to their adoption are probably related to high costs.

c. Big Data has the highest percentage of use in administrative settings. This shows that hospitals are leveraging Big Data analytics to streamline operations, enhance decision-making processes, and improve overall efficiency. Big Data enables hospitals to manage resources effectively, analyze operational metrics, and optimize administrative workflows.

This evidence is consistent with broader literature indicating that the utility of different DTs is often context-dependent: clinical vs. administrative settings require different types of support and face distinct barriers (Dionisio *et al.*, 2023; Kakale, 2024). Moreover, the high usage of cloud and data-related technologies in administrative areas aligns with international studies that highlight the growing importance of digital infrastructure in improving non-clinical performance (Gopal *et al.*, 2019; Vassolo *et al.*, 2021).

Regarding the investments required, Big data, AI/ML, Blockchain, Collaborative Robots and 3D printing, are among the technologies that demand greater capital due to their advanced infrastructure needs. These technologies also require extensive training programs, encompassing both the administrative and medical staff, to fully harness their potential in improving patient outcomes and operational efficiency.

Finally, regarding the training, our results show a high level of involvement of clinical and administrative staff in the digitalization processes of Italian healthcare companies, confirming that skills and competencies of employees are the most crucial determinants for ensuring successful digital transformation (Aulenkamp *et al.*, 2021).

Nevertheless, our findings suggest a persistent lack of dedicated ICT professionals, which weakens digital maturity and impairs the return on technological investment (Cannavacciuolo *et al.*, 2023; Mauro *et al.*, 2024).

This gap in internal expertise—combined with a training system often fragmented and unaligned with strategic investment—may hinder long-term digital resilience, despite the significant capital inflows from European recovery funds (Raimo *et al.*, 2023).

## 6 – Conclusions

This study stems from the critical need for a structured framework to support digital transformation in Italian healthcare facilities. Despite the widespread recognition of digitalization's importance in enhancing efficiency and patient care, Italy lacks a cohesive roadmap that could effectively guide hospitals through this transition. Our research fills this gap by mapping the current state of digital technology adoption across Italian healthcare structures.

Findings show that digital transformation in Italian healthcare is advancing, yet disparities in technology adoption, investments and training indicate an uneven distribution of resources.

The study offers *practical*, *theoretical* and *managerial* implications.

From a *practical perspective*, our results offer healthcare organizations concrete benchmarks regarding which technologies are most widely adopted (e.g., remote monitoring, cloud computing) and which require the greatest investments and training (e.g., AI/ML, collaborative robots, blockchain). By identifying these priorities, decision-makers can better allocate financial and human resources to maximize the impact of digital investments and avoid fragmented or misaligned implementations.

On a *theoretical level*, the study contributes to the broader discourse on digital transformation in healthcare by distinguishing between clinical and administrative adoption patterns and linking them to structural characteristics and workforce preparedness. The integration of training intensity and investment requirements with technology mapping provides a novel analytical framework that can be extended in cross-country comparative studies or used to explore causal relationships with health outcomes in future research.

From a *managerial standpoint*, the findings emphasize the critical role of training and the availability of ICT-specialized personnel in enabling successful digital transformation. Managers should consider digital literacy not only as a technical competency but as a strategic lever to drive cultural change and operational integration. Moreover, the results highlight the importance of synchronizing technology adoption with targeted training programs across all

staff levels and departments, which can facilitate smoother implementation and greater organizational readiness.

Despite the insights generated, some limitations must be acknowledged. First, although the study reached 52 respondents, representing a 28.5% response rate, the total number remains modest relative to the entire population of Italian public healthcare structures. While this sample provides an informative cross-section—including hospitals (AO), teaching hospitals (AOU), and local health authorities (ASL)—it may not fully capture the diversity and complexity of digital transformation efforts across the country. Therefore, caution is warranted in generalizing the findings to all Italian healthcare organizations.

Moreover, the representativeness of the sample should be considered within the context of self-selection bias: organizations more advanced or interested in digitalization may have been more inclined to participate in the survey. These limitations underline the need for continued investigation: future studies should aim to expand the sample and consider stratified approaches to ensure broader geographic and institutional representation, to validate and extend the conclusions drawn here.

Future research could also investigate the direct impact of digitalization levels on patient outcomes, providing a more comprehensive evaluation of the benefits of digital transformation in healthcare.

Overall, this study provides a foundational tool to support healthcare institutions in making informed strategic decisions about their digital transformation journey. It also lays the groundwork for further investigation into how digital maturity influences organizational performance and patient outcomes. Future studies could build on this work by expanding the sample size, including private sector institutions, and exploring longitudinal data to assess the long-term effects of digital investments in healthcare systems.

## 7 – Authorship Contribution Statement

All authors were involved in the research design and contributed to writing the manuscript. In particular:

- Giorgia Rotundo wrote sections 1 and 2.
- Monica Giancotti wrote sections 3 and 4.
- Marianna Mauro wrote sections 5 and 6.

All authors provided comments to the various drafts and approved the final version.

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