Resilience in healthcare after Covid-19: Rethinking technologies, operations, supply chain and network

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Resilience in Healthcare after Covid-19: Rethinking Technologies, Operations, Supply Chain and Network

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Introduction

Resilience refers to the ability of organizations to adapt their operations before, during, and after events, ensuring the ongoing delivery of essential services under both expected and unexpected circumstances (Barasa et al., 2018; Blanchet et al., 2017). This concept has gained significant recognition in healthcare research, as it provides a theoretical framework to understand how various disturbances can be mitigated and what constitutes quality in healthcare provision even during crises (Barbash & Kahn, 2021; Cristian, 2018; Turenne et al., 2019). By integrating concepts and approaches from disciplines such as psychology, engineering, ecology, and safety management, the concept of resilience enriches the healthcare field by providing new perspectives aimed at enhancing system functioning from institutional, organizational, and individual levels, ultimately facilitating high-quality and safe patient care (Lyng et al., 2022). The healthcare system, characterized by compartmentalized structures, interactions among diverse stakeholders, and considerable variability in performance across multiple levels, demonstrates its inherent complexity even more clearly when facing crises (Aase et al., 2020; Bergami et al., 2024). Within this system, hospitals fulfil a critical role, tasked with providing health services to their surrounding communities, particularly during crises when they serve as primary responders (Thune & Mina, 2016; Sari et al., 2023). Furthermore, hospitals contribute to public health through surveillance and data collection, a mission extremely important that becomes threaten during disruptions (Climate Change and Health (CCH), Environment, Climate Change and Health (ECH), 2015). Prior to the COVID-19 pandemic, hospitals were already experiencing strain, with financial constraints, coupled with resource shortages and personnel deficits; however, the onset pandemic further compromised their operations, requiring a rapid restructuring of national health services to meet evolving demands (Coccia & Benati, 2024; Elhadidy et al., 2024). Given the current projections indicating that risks from various hazards will significantly intensify in the coming years, there is a growing consensus among researchers and practitioners in the healthcare sector regarding the need to further explore the hospital resilience

(Bailey, 2021; Righi et al., 2024). The most common definition of hospital resilience refers to the capacity of hospitals to return to a 'normal' state of functioning following a disruptive event, to cope with pressures through flexibility without compromising system performance, and to adapt to a new normality where system functioning is reorganized or improved in response to the disruption (Marmo et al., 2022; Ridde et al., 2023; Traverson et al., 2021). Thus far, this concept has remained theoretical, with discussions primarily centered on definitions, concepts, and principles, underscoring the need for enhanced conceptual clarity to strengthen the overall understanding of the concept (Bai et al., 2024; Seyghalani Talab et al., 2024). Greater emphasis has been growing on the need to explains why certain hospitals have proven more effective than others in mitigating the impact of crises (Ali et al., 2017; Wiig et al., 2020). In this regard, previous studies on resilience have made significant contributions by identifying effective elements, namely strategies, factors, and practices, developed and implemented by hospitals. However, these factors have generally been examined in isolation, mapping only linear relationships between organizational elements and resilience. What remains to be addressed is the delineation of a framework that considers the complex configurations and combinations of these elements, capturing how resilience is achieved within this multifaceted context. While these studies represent an initial step toward enriching the concept of hospital resilience, they often lack appropriate contextualization for resilience, and empirical validation remains a critical area for further investigation. To define and operationalize the concept of hospital resilience, it is essential to provide a precise contextualization of the types of crises under examination as well as the specific phases of these crises being targeted. Once this foundation is established, it becomes possible to define congruent dimensions of resilience (proactive or reactive) and practices and resources that hospitals can adopt and leverage across different phases (pre-, during, and post-crisis). Throughout all three chapters of the thesis, contextualization is clearly articulated, with specific references to the phase of resilience being studied and the corresponding proactive or reactive dimensions. In this thesis, the practices and resources associated with each dimension are defined as organizational characteristics, specifically categorized as resources and capabilities, following the theoretical lens

of the Resource-Based View (RBV). This perspective enables a deeper understanding of how and when hospitals can achieve resilience outcomes. In particular, the thesis aims to address the gaps in three main phases. First, this thesis aims to organize and systematize the existing knowledge on which organizational characteristics strengthen hospital resilience, highlighting the interactions and synergies among them (Größler, 2007). The findings specify the organizational characteristics essential for each phase of the crisis and the corresponding strategies that can be effectively implemented. Next, I focused on specific resources and capabilities relevant to hospital resilience to strengthen reactive strategies implemented immediately following the onset of the pandemic (World Health Organization, 2023). In this phase, through a quantitative analysis, I seek to explore how digital technologies (digital applications, platforms, electronic devices, and wireless technology) and staff skills (including relational, professional, and technical competencies) and integration information capabilities (the process by which an organization acquires, shares, and implements timely information) are integrated with each other and if they directly impact hospital resilience. In this way, this thesis seeks to respond to the increasing calls for empirical quantitative studies from clinical and managerial hospital staff on the essential resources and capabilities that hospitals must possess to effectively adapt to and respond to disruptive crises, aimed at optimizing resource allocation, updating emergency plans, and ultimately reducing patient risk (Boeriu, 2018; Brende and Sternfels, 2023). In the third phase, throughout a second quantitative study, I seek to explore the role of hospital contingencies on the relationship between information and communication technologies (ICTs), digital skills, internal and external information integration and hospital resilience, expanding the knowledge of how their effects are dependent on contingencies linked to service complexity and operational efficiency (Agostini et al., 2023; Chakraborty et al., 2021; Foroughi et al., 2022; Ignatowicz et al., 2023). The three phases described above also matches the three chapter of this thesis. Specifically, in the first chapter intitled *Resilience of hospitals in an age of disruptions: A systematic literature review on resources and capabilities,* I conducted a systematic literature review with the aim of gaining a better understanding of the hospital organizational characteristics classified

as property- and knowledge-based resources (Kim *et al.*, 2015; Miller and Shamsie, 1996; Yarbrough and Powers, 2006) and capabilities that impact on hospital resilience. By adhering to the systematic literature review methodology and following the guidelines set forth by the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement (Moher et al., 2010), I developed a protocol that culminated in the inclusion of 164 journal articles that examine (qualitatively, quantitatively and theoretically) resources and/or capabilities useful for obtaining resilience during the last pandemic. To systemize and organize the findings, I developed a narrative synthesis differentiating resources and capabilities according to their impact on each of the five dimensions of resilience, namely the ability to anticipate, adapt, respond, recover and learn. The first dimension represents the proactive ability to identify and monitor potential events and risks, helping to avoid unexpected surprises. The concurrent abilities to adapt reflect the hospital's capacity to make adjustments and modifications to resources and routines, thereby enhancing flexibility and building redundancy. The second concurrent dimension, the ability to respond, enables hospitals to find effective and rapid solutions in order to minimizing the impact of an ongoing crisis, leveraging communications and coordination. The final two dimensions, which focus on post-event capacities, equip hospitals to restore operations to pre-event levels and to learn from both successes and failures, ultimately preparing them better for future crises. The resulting integrated frameworks provide a comprehensive illustration of these characteristics and their synergistic effects, identifying the optimal combination or bundle of various organizational attributes for each resilience dimension. A research approach based on resources and capabilities facilitates a greater comprehension of organisational dynamics and the development of structured and replicable resilience research (Alameddine et al., 2019). Finally, I use the literature review as a springboard to outline opportunities for future research. Next, guided by the gaps identified in the literature review, in the second and the third chapters I focus on specific categories of hospital organizational characteristics and investigate both their interactions and how they influence hospital resilience. In the second chapter, titled *The effect of digital technologies and staff skills on hospital resilience: The role of supply chain*

information integration, I investigate the contributions of digital technology, staff skills and information integration capabilities in fortifying hospital resilience, following a disruptive crisis, thereby enhancing hospitals' capacity to adapt and respond effectively. All these resources are considered enablers of hospital resilience during COVID-19, particularly in the dimensions of adaptation and response. Digital technologies facilitate adaptability through remote monitoring (I. Ali & Kannan, 2022), while hospital staff competencies, particularly in communication and teamwork, are crucial for effective crisis management (David et al., 2023). Furthermore, the ability to manage information flows both within hospitals and beyond their boundaries, known as supply chain information integration (SCII), is vital for operational coordination (Bergami et al., 2024). In line with the RBV theory, I develop a baseline hypothesis arguing positive impact of resources and capabilities on hospital resilience. I also assert that interactions among these resources and capabilities manifest in the positive influence of digital technologies and staff skills on both internal and external information integration. Finally, I examine the potential mediating role of both the two forms of information integration. The objective extends beyond merely assessing the direct impacts on resilience; it also aims to explore how these resources enhance resilience through their relationships with capabilities, which serve as mediators in this context. To test these hypotheses, I collected data to construct a dataset of Italian hospitals through an online survey, obtaining responses from 130 different hospitals. All measures of the variables were derived from previous studies and validated through confirmatory factor analysis. The results of the structural equation modeling (SEM) analysis reveal several key findings regarding the relationships among digital technologies, staff skills, external information integration, and hospital resilience. Specifically, the analysis supports a direct positive impact of digital technologies and external information integration on hospital resilience. Furthermore, it highlights that digital technologies and staff skills significantly influence external information integration. Notably, external information integration plays a critical role as a full mediator in the relationship between staff skills and hospital resilience, signifying that the positive effect of staff skills on resilience is fully realized when external information integration is in place.

Conversely, external information integration serves as a partial moderator in the relationship between digital technologies and hospital resilience, suggesting that while, digital technologies contribute to resilience, their impact on resilience is also explained by their use in facilitating external information integration.

In the third chapter, titled *Antecedents of hospital resilience: integrating resources, capabilities, and contingencies,* I study the role of contingencies on the relationships between resources, capabilities and hospital resilience. Contingencies has been defined in the Contingent RBV as internal and external conditions that influence the resources and capabilities needed to drive resilience performance (Brandon-Jones et al., 2014). Prior studies have investigated and highlighted the role of information and communication technology (ICTs) (Rubbio et al., 2019; Tortorella et al., 2022), digital skills (He et al., 2022; Koebe & Bohnet-Joschko, 2023) and the internal and external information integration in enhancing hospital resilience (Bergami et al., 2024; Bohnett et al., 2022; Donelli et al., 2022). If the ICTs enable telemedicine and remote monitoring, facilitating operational decongestion and improving community integration, the digital skills help hospital staff to effectively manage patient data and workflows, allowing them to identify issues and develop innovative solutions. As introduced before, internal information integration facilitates information sharing among operational units, ensuring coordination among healthcare professionals and supporting timely care delivery. Conversely, external information integration enhances collaboration among hospitals, improving resource allocation and crisis response through patient transfers and partnerships with external entities. However, there appears to be a lack of studies that go beyond the mere relationship between resources, capabilities, and resilience. There is a need for research that takes an additional step to consider the specific internal and external contingencies, such as hospital size and type, geographic location (Tortorella et al., 2021), as well as operational decisions like service complexity and operational efficiency (Parast, 2022), and investigate their impact on the relationships among resources, capabilities, and resilience. Aligning with the literature that considers resilience as an outcome rather than a resource itself, I have developed hypotheses on the direct impact of these

resources and capabilities on hospital resilience, as well as hypotheses on the moderating roles of two contingencies: service complexity and operational efficiency. Service complexity reflects the number and diversity of services provided by the hospital and the severity and range of patient conditions (Peng et al., 2020), while operational efficiency indicates the hospital's effectiveness in transforming inputs into outputs (Parast, 2022; Yang et al., 2017). The moderating hypothesis posits that high service complexity amplifies the benefits of ICTs, digital skills, as well as internal and external information integration on resilience by enhancing, improving, and expediting patient care while supporting staff in developing innovative solutions during crises. Similarly, hospitals with lower levels of operational efficiency may still leverage ICTs, digital skills, and information integration capabilities, both internal and external, to better respond to crises and mitigate disruptions. To test these hypotheses, data were collected through an online survey of Italian hospitals, supplemented by secondary data from online databases managed by the Italian Ministry of Health for contingencies. After matching primary and secondary data, the final sample used for analysis comprises 121 hospitals. Each variable measure was adapted from established studies and validated via confirmatory factor analysis. The study confirms the hypotheses regarding the direct effects of ICTs, digital skills, and information integration on hospital resilience. The supported moderating hypotheses include the impact of service complexity on the relationship between internal information integration and hospital resilience, as well as the impact of operational efficiency on the relationships between ICTs, digital skills, and hospital resilience.

Chapter 1

Resilience of hospitals in an age of disruptions: A systematic literature review on resources and capabilities

Abstract

Hospitals serve a core function in the healthcare system because, as medical service centres, they are expected to guarantee continuity of effective and timely care, especially during crises. The pandemic event highlighted significant weaknesses and vulnerabilities that undermined this overriding goal, raising growing concern about how to develop resilience, namely the capacity of hospitals to withstand, absorb, and respond to disasters. Based on the resource-based view, I conducted a systematic literature review aimed at identifying organizational characteristics in terms of resources and capabilities and their synergistic effects that contribute to hospital resilience by enhancing the ability to anticipate, adapt, respond, recover, and learn. The results show that digital technologies have a particular impact on anticipating and adapting abilities. Additionally, the organizational capabilities of reorganising roles, tasks, and spaces improve the ability to adapt, and finally, inter-organizational collaborations and cooperation between hospitals and suppliers increase hospitals' responsiveness. The study provides substantial theoretical and practical contributions. It expands knowledge of hospital resilience in light of recent disruptive events and promotes integration capabilities as determinants for the majority of resilience dimensions. All organizational and inter-organizational collaboration, cooperation, and coordination are deemed crucial for hospital resilience.

Keywords: Resilience – Healthcare – Hospitals – Resources – Capabilities – COVID-19

1. Introduction

Globally, the healthcare system faced severe challenges over the years from climate change and natural disasters to financial crises and infectious diseases outbreaks (Biddle *et al.*, 2020). Among all the stakeholders which support the healthcare system, hospitals play a critical role in delivering healthcare services because, as centres and providers of medical services, they must guarantee the continuation of the cure even and especially when the crisis occur (Cristian, 2018). The most recent pandemic, more than ever before, threatened the overriding goal of hospitals to effectively provide timely and good-quality treatments. In particular, one of the most critical aspects revolved around a lack of understanding regarding how to sustain care delivery, as several weaknesses have badly compromised the overall healthcare services in hospitals (Achour *et al.*, 2022; Tippong *et al.*, 2022). Among weaknesses there are the interruption or cancellation of medical services, inadequate staff, insufficiency of equipment and spaces on hospital sites, inappropriate coordination between facilities and suppliers, and inaccessibility of facilities (Donelli *et al.*, 2022; Tantri and Amir, 2022). Given its uniqueness, COVID-19 provides a rare opportunity to assess the preparedness, adaptiveness and responsiveness of hospitals in face of major disasters, and to understand why some hospitals overcame this disruptive event better than others. A current and notable area of research focuses on integrating the concept of resilience into the healthcare context. The objective is to provide healthcare organizations with the essential abilities to absorb, adapt, and transform in the face of disruptive events (Chen *et al.*, 2013; Marmo *et al.*, 2022; Sharma and Sharma, 2020). Previous literature reviews have explored the multifaceted concept of resilience within the healthcare domain from various perspectives (Table 1). These reviews exhibit diversity in their scopes, with some encompassing the broader response of the entire healthcare system to crises (Iflaifel et al., 2020; Biddle et al., 2020), while others specifically opted for a more focused examination, concentrating on the resilience of the healthcare organizations (Mahmood et al., 2023; Jolgehnejad et al., 2020; Khalil et al., 2022). Arji et al. (2023) approached the issue from a supply chain perspective, investigating the resilience of

healthcare supply chains and thoroughly examining the role of digital technologies in reducing disruptions throughout the supply chain. The primary emphasis in earlier research has centred around the conceptualization and implementation of the concept of resilience in the healthcare context. This is evident in their exclusive examination of empirical literature (Biddle et al., 2020; Jolgenhejad et al., 2020; Iflaifel et al., 2020; Barasa et al., 2018; Arji et al., 2023). Drawing upon organizational resilience concepts from industrial settings, Barasa et al. (2018) systematically reviewed organizational factors impacting resilience of healthcare organizations, among which material resources, information management, governance processes, social networks, and collaboration. Furthermore, Iflaifel et al. (2020) identified factors and methods that enable workers, teams, units, and organizations to adapt effectively to diverse situations. Beyond these examples, some efforts have also been made to conduct more targeted investigations into the factors that influence resilience in the hospital context. Jolgehnejad et al. (2020) identify four main key components to achieve resilience in hospital, namely the staff, infrastructure, management, and logistics. The scoping review by Khalil et al. (2022) examined how hospital resilience has been conceptualized, operationalized, and evaluated in empirical studies. As result, they encapsulate the components to make hospitals resilient within the framework of the 6 S's (space, staff, stuff, system, strategies, and services). Based on the existing literature, which has provided a general overview of the factors influencing hospital resilience, it appears that resilience develops through a series of organizational characteristics related to the structure, practices, and behaviours implemented by the organization, since they have reduced uncertainty and risk and improved adaptation. However, a critical aspect that emerges is the fact that these factors have been treated or listed indiscriminately, such as staff preparedness, communication, equipment. In particular, most studies have mapped linear relationships between organizational characteristics and hospital resilience, but few studies have depicted the complex set of configurations and combinations of them leading to resilience. What is lacking is a more in-depth investigation into how hospitals can effectively achieve resilience. A further step in developing the concept of hospital resilience more comprehensively, should lead to distinguish and detail the organizational

characteristics impacting hospital resilience, highlighting the interactions and synergies among them (Ambulkar et al., 2016). Studies in the field of operations management suggest embracing a resource perspective could lead to a better understanding of how to achieve resilience (Cheng and Lu, 2017; Ambulkar et al., 2016; Kamalahmadi and Parast, 2016). To provide an integrated framework that portrays these characteristics and their synergistic effects, we adopt the theoretical lens of the Resource-Based View (Chahal et al., 2020). This theoretical perspective explains the differences between firms and how they achieve and sustain better performance, looking at resources and capabilities (Lin et al., 2012). In terms of organizational characteristics, the Resource-Based View (RBV) makes a distinction between resources and capabilities, allowing for an analysis not only of what the hospital must possess in terms of tangible and intangible resources but also of capabilities—how resources are employed, incorporating the organizational process. This aims to enhance the productivity of hospital resources and improve efficiency in the final service (Amit and Schoemaker, 1993). For instance, Brandon-Jones et al. (2014) state that to obtain resilience performance within the supply chain, a firm must develop resources such as technological infrastructure, fast and quality information sharing, along with the capability of visibility. Adopting a perspective that considers resources, capabilities, and resilience can be extremely advantageous, as it enables the identification of the optimal combination or bundle of various organizational characteristics. This approach, as highlighted by Lin et al. (2012), translates into significant practical implications. By acknowledging, for instance, that integration capability is essential for enhancing crisis response and making the effort to identify the necessary resources for developing such capability, practitioners are equipped with a comprehensive and practical view of what is needed to build resilience.

Hence, based on the RBV theory, this chapter aims to answer the following research question (RQ): Which resources and capabilities of hospitals lead to resilience in an age of disruptions?

In order to answer this question, I systematically collected all organizational characteristics of hospitals, in the form of resources and capabilities, and interpreted them in the light of the resilience implications. The rest of the paper is outlined as follows. In Section 2, I provide the relevant

background and fundamental theories pertinent to this topic. Section 3 details the research methods employed in the Systematic Literature Review. Finally, in Sections 4, 5, 6, and 7, I present the descriptive findings, conduct a thematic analysis, engage in a discussion of the results, outline directions for future research, and provide the conclusion.

Table 1. Representative healthcare resilience literature.

Authors	**Aim**	**Research methodologies adopted by the retrieved studies**	**Organizational characteristics**	**Context**	**Resilience dimensions**
Arji et al. (2023)	How the main digital technologies foster resilience within the healthcare supply chain	Empirical, case study, modelling, analytical studies	Resources (Digital technologies)	Healthcare SC	None
Mahmood et al. (2023)	How disruptive events impact on healthcare systems	Simulation studies	Resources (structural, non-structural components, equipment)	Hospital	None
Barasa et al (2018)	Identifying the factors that influence Organizational resilience	Empirical studies	Resources (i.e. material resources; governance processes, human capital, organizational culture, leadership) and Capability (redundancy)	Organizations	None
Iflaifel et al. (2020)	How literature conceptualizes the Resilience in Healthcare, highlighting the research methods employed and the essential factors for its development.	Empirical, case study, modelling, analytical studies	Resources (managerial skills: redesign socio-technical systems; teamwork; staff experience, adherence to guidelines and protocols, workaround)	Healthcare system	anticipate, monitor, respond and learn
Jolgehnejad et al. (2020)	Identifying the influencing factors on Hospital resilience	Empirical, case study, modelling, analytical studies	Resources (Staff, Infrastructure, Management, Logistics)	Hospital	Preparedness Response Recovery and Growth
Biddle et al. (2020)	How the concept of healthcare resilience has been operationalized in empirical studies	Empirical studies	Resources (infrastructural components, staff competences) Capability (external collaborations between community, government)	Healthcare system	Absorptive, adaptive, transformative capacities
Khalil et al. (2022)	How literature conceptualizes, operationalizes, and evaluates the hospital resilience.	Qualitative, quantitative studies	Resources (Space, stuff, staff, systems, strategies, services)	Hospital	Risk assessment and planning, preparedness, response, recovery

2. Theoretical background

2.1. Resilience in Healthcare

The concept of resilience has become more prominent in the global healthcare sector over the past few years, as a result of the succession of shock events that have affected the healthcare systems. Although the concept of resilience is still highly fragmented due to its multidisciplinary nature, it denotes the ability of healthcare organizations, to "adjust their functioning prior to, during and following events and, thus, sustain required operations under expected and unexpected conditions" (Barasa *et al.*, 2018; Iflaifel *et al.*, 2020). Hospital resilience is considered an essential capacity that helps hospitals withstand, absorb, and respond to the shock of disasters without disrupting critical healthcare functions and routine operations, returning to their original state or adapting to a new one (Zhong *et al.*, 2015). According to the literature, resilience is defined in five dimensions, namely the ability to *anticipate* unforeseen disruptive events, to *adapt* and withstanding disruptions, to *respond* quickly to disruptions, to *recover* from disruptions, returning to steady-state conditions, and to *learn* from what has been done and anticipate future failures (Ali *et al.*, 2017; Duchek, 2020; Lundberg and Johansson, 2015). Focusing on the healthcare sector there are significant conceptualization issues regarding the meaning of resilience. Turenne *et al.* (2019) state that the concept of resilience in healthcare is dependent on one's perception, one's discipline, one's function. In other words, it refers to the fact that literature about resilience in healthcare sector could differ according to the type of crisis studied and the scale focus or context analysed. Referring to the first one, crisis could be internal or external to organization, or referred to chronic stress or acute shock. Regarding to the focus of the analysis, it can range from individual level, investigating how healthcare workers implement coping strategies to overcome a trauma, to organisational level, investigating the strategies implemented in healthcare organizations (i.e., local health units, hospitals, and clinics), reaching even a national level, analysing the political and governmental initiatives to improve healthcare systems (Alameddine *et al.*, 2019; Hillmann and Guenther, 2021). In view of these different perspectives, prior studies have

examined the topic of resilience with a focus on healthcare service delivery policy (Kozuki *et al.*, 2018), healthcare workforce, or governance issues (Falegnami *et al.*, 2018). However, from an organizational perspective, still little has been done, and the greatest challenge remains to understand how to improve resilience in hospitals. This challenge is made more complex due to the fact that, by providing a service, hospitals engage in activities with essentially intangible outputs. Services are even more dependent on information technologies and on the intangible assets associated to human skills, knowledge, and culture (Yarbrough and Powers, 2006). Hence, it can be beneficial to examine the organizational characteristics that allow hospitals to be resilient even in the face of disruptive events such as COVID-19.

2.2. Resource-Based View Theory

The Resources Based View (RBV) theory has been extensively used by scholars to ground their studies investigating the relationship between firm resilience and its resources and capabilities (Ambulkar *et al.*, 2015; Blackhurst *et al.*, 2011; Gupta *et al.*, 2018). The basic concept of this theoretical lens is that firms can improve their performance, including resilience, by properly creating bundles, namely the integration of strategic and dissimilar resources and/or capabilities (Barney, 2001; Brandon-Jones *et al.*, 2014; Pal *et al.*, 2014). Resources, namely something a firm possesses or has access to, can be classified into two main categories, which are property- and knowledge-based resources (Kim *et al.*, 2015; Miller and Shamsie, 1996; Yarbrough and Powers, 2006). The former refer to resources protected by regulatory practises, both tangible, such as physical resources, infrastructures, technology, and intangible, such as intellectual property rights and patents (Fahy, 2002). The second category, concerning the knowledge-based view resources, refers to intangible assets including technical know-how, skills, culture, education, and training of employees (Skilton, 2009; Tseng *et al.*, 2007). The RBV suggests that by creating a "bundle" (grouping or set) of resources, it is possible to develop unique capabilities that generate value and enable gaining a competitive advantage (Barney, 2001; Huemer and Wang, 2021). For instance, exploiting and

combining information technologies, human resources, and organizational culture, firm is able to develop organizational capabilities, namely information-based tangible or intangible processes (Do *et al.*, 2022). Technological know-how, training, and information technology infrastructure components enable the development of technological capability referring to the ability to utilise recent technology to achieve innovative processes and services (Bustinza *et al.*, 2019; Heredia *et al.*, 2022; Krasuska *et al.*, 2020). Exploiting resources such as technical know-how, skills, and technological resources enables firms to develop other capabilities such as visibility (Sharma *et al.*, 2022), flexibility (Brusset and Teller, 2017), redundancy (Munoz *et al.*, 2022; Ramezani and Camarinha-Matos, 2020). Finally, in a similar manner, firm are able to develop integration capabilities which involves a cooperative management of processes within the organization (internal integration) and with external actors (external integration) including supply chain partners (supply chain integration) (Chahal *et al.*, 2020; Cheng and Lu, 2017). In addition, according to the RBV, resources and capabilities depend on each other, namely, not only resources enable the development of capabilities but also capabilities may affect the way resources are sustained, deployed, and integrated in order to generate services and products (Größler, 2007). For instance, the effective utilization of information technologies requires information system capabilities, which, in turn, depend on resources of a technological, human, and relational nature (Brandon-Jones et al., 2014).

In this chapter I use the RBV to examine the resources and capabilities that enhance a hospital resilience in its five various dimensions, namely the ability to anticipate, adapt, respond, recover, and learn from disruptions, as depicted in Figure 1.

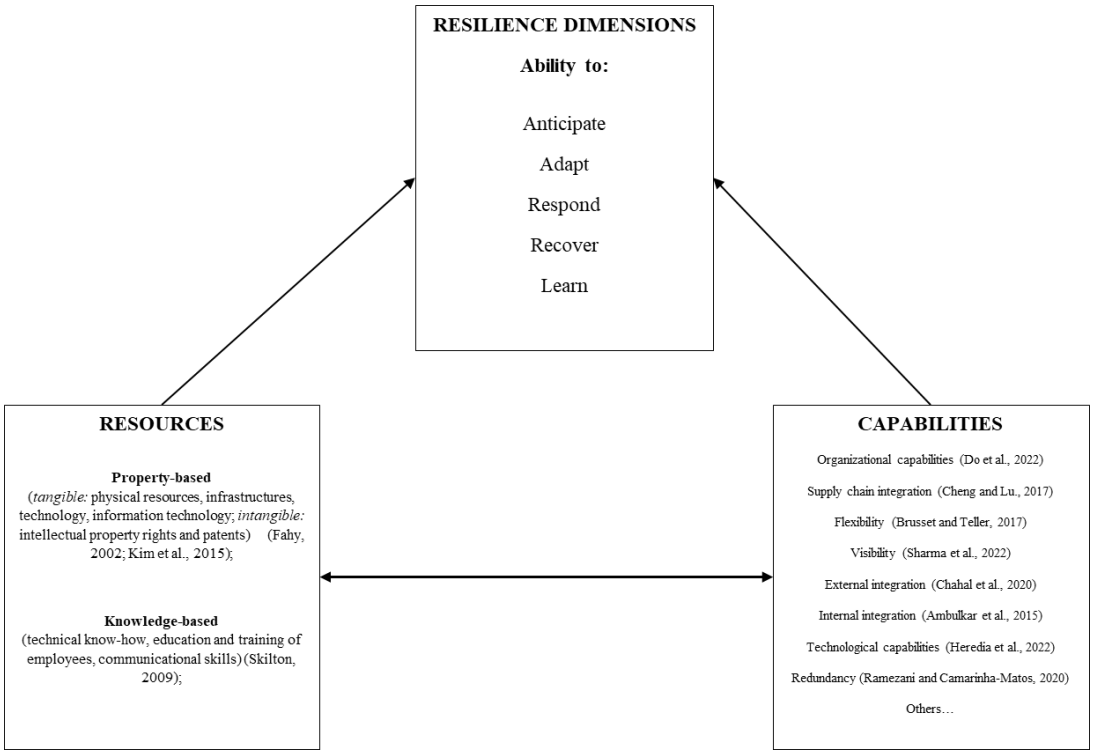


Figure 1. Resource-Capabilities-Resilience framework.

3. Methodology

Literature review is a methodology which aims to map and evaluate the existing literature in order to highlight the boundaries of knowledge and identify potential research gaps (Munn et al., 2018). I conducted a review of literature following systematic review methodology according to the guidelines proposed by the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement (Moher et al., 2009). It represents a well-established procedure for conducting a systematic literature review and has been utilized in the context of healthcare management (Biddle et al., 2020; Barasa et al., 2018). This methodology involves gathering all the evidence for a particular research question and follows a transparent and reproducible methodology for searching, assessing quality, and synthesizing studies with a high degree of objectivity (Bacelar-Silva et al., 2022). The review process consisted of: 1. Source identification, 2. Screening, 3. Eligibility, 4. Analysis (see Fig. 2). The overview of the article search process is presented and explained in the following subsections.

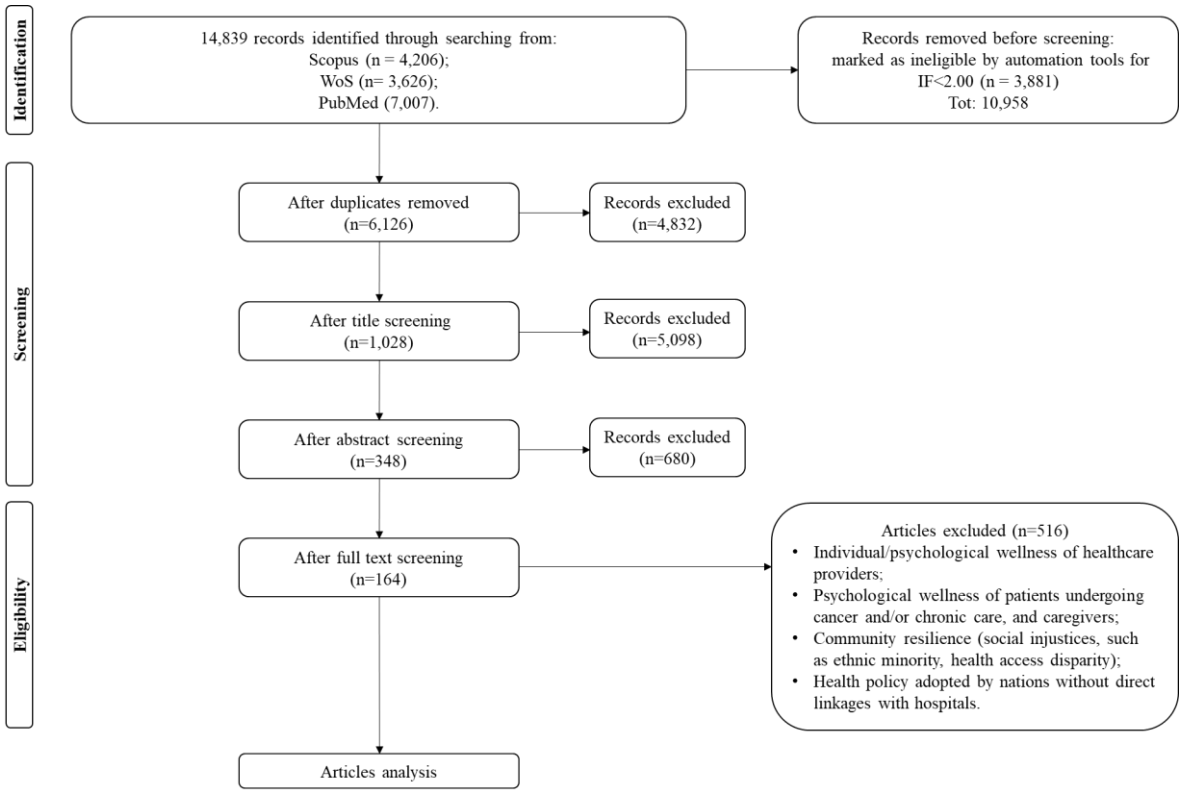


Figure 2. Prisma flow diagram.

3.1 Source identification

The literature identification involved an initial step of selecting keywords related to the theme, followed by a more refined and structured search using these keywords (Paul and Criado, 2020). I retrieved existing literature related to hospital resilience from the Scopus, WoS and Pubmed databases using the following search combinations: resilien* AND (hospital OR healthcare OR "health care") AND NOT ("psychology* resilience" OR "personal resilience" OR "mental health"). The keyword search in Scopus and WoS was set to include titles, abstracts, and keywords in order to retrieve all the relevant publications. On those three databases we applied filters on language (including only articles written in English), on type of document (including only articles). The search period was set to include articles published between January 2019, and Decembre 2022. The complete search strategy is provided in Appendix 1.

Because resilience in healthcare is a multidisciplinary concept, I chose general keywords; in this manner, I avoided the issue of having overly specific and narrow keywords, which run the risk of excluding relevant articles (Mokhtar et al., 2019). As suggested by Turenne et al. (2019), I have

excluded in the keyword chain all those related to the psychosocial sphere. The extraction was limited to the period from 2019 to 2022, in which disruptive events occurred more rapidly and unpredictably than ever before. Moreover, I restricted the search to publications written in English and considered exclusively articles as document type. A structured search with keywords appearing in title, abstract and article keywords yielded a total of 14,839.

Given the high number of publications, I decided to apply an additional filter, selecting only those published in journals with an Impact Factor above 2.00, as suggested by Paul et al. (2021), with a total of 10,958 records remained.

3.2. Screening

By removing duplicates, 4,832 records were eliminated. Due to the high number of retrieved publications, I followed a three-stage screening process, examining titles, abstracts, and full text (Biddle et al., 2020). After reading the titles, 5,098 irrelevant records were excluded, and following the abstract screening, an additional 680 records were eliminated. At the end of this stage, 348 publications remained for eligibility assessment.

3.3. Eligibility

During this stage, the relevance of the content of the selected publications is assessed, defining the boundaries of the analysis and clear selection criteria. Articles discussing the individual resilience of patients in the care pathway, as well as resilience to specific drugs, were excluded. Articles pertaining to the mental health of patients (oncological or chronic illnesses, elderly individuals, war veterans), providers, and caregivers were eliminated. Additionally, articles addressing resilience at community and national-level (social injustices, such as ethnic minority, health access disparity) and as well as those describing the health policy that should be adopted by society (psychological support and resource distribution) were also eliminated. Finally, all publications addressing the resilience of materials used for technological resources such as how to enhance the resilience of information

systems, wearable technology, connectivity have been excluded. After this stage, 184 articles were excluded during the full-text screening, leaving 164 articles for the analysis.

3.4. Inclusion

In this phase, no additional publications were identified for inclusion in cross-referencing, maintaining the total eligible publications at 164. Subsequently, information pertaining to each publication, including authors, publication year, journal, country of study, methodology, and key findings were recorded.

3.5. Analysis

The critical analysis of the articles represents the last step of the SLR and involve summarising the findings of the remaining articles and highlighting key messages that require greater attention from researchers and practitioners. The data analysis was performed using Microsoft Excel and the articles were then read and classified according to the proposed resources-capabilities-resilience framework.

4. Thematic analysis and main findings

I conducted a thematic analysis to identify which organizational characteristics in terms of resources and capabilities affect hospital resilience, with respect to the different resilience dimensions, namely the ability to anticipate, adapt, respond, recover, and learn, as detailed in the sequel.

4.1 Ability to anticipate

The ability to anticipate, which is a proactive skill required to identify and monitor potential events or situations and changes, as well as their effects before the functioning of the hospital is affected, could be gained by hospitals by exploiting digital technologies' resources and digital capabilities (Tortorella *et al.*, 2022) (Figure 3). Digital technologies could be defined as interconnected digital

applications, digital non-invasive care, electronics, and microstructure technologies, which leverage the main baseline technologies of IoT, big data, and cloud computing, while digital capabilities refer to the ability of hospital staff to use such digital technological tools (Tonetto *et al.*, 2021).

Digital technologies create an information infrastructure and collect a great amount of relevant data, supporting information sharing, favoring communication between clinicians and among clinicians and patients, and uncovering hidden clinical information through data mining (Rubbio *et al.*, 2019). The combination of digital technological resources and digital capabilities enables, thus, to get more accurate information in real time and to predict with greater precision patient conditions (Marques da Rosa *et al.*, 2021). In this way, they help avoid complications and errors in patient processing that can require extraordinary use of personnel, space, and resources whose availability may not be guaranteed, resulting in inefficiency throughout the hospital and thus negatively affecting hospital resilience. Moreover, digital technologies enhance vendor-managed inventory monitoring, increasing the integration of healthcare supply chain via Electronic Record Planning (ERP) and digital platforms that support supplier relationship management. In fact, cloud computing, wireless sensors, and IoT allow collecting and communicating real-time data across multiple layers of healthcare supply chains, as well as making intelligent decisions (Tortorella et al., 2021). In so doing, digital technologies help improving situational awareness by increasing the visibility of hospital supply chain, thus increasing the ability to anticipate (Tortorella et al., 2022; Chowdhury et al., 2021).

The resources of digital technologies and the digital capabilities support the ability to anticipate avoiding the risks of cyberattacks or data disasters that could disrupt the continuity of operations and activities (Awan et al., 2021; Hirano et al., 2020; Marulli et al., 2022). Specifically, cloud and fog computing are two prominent approaches to delivering timely and safe computing resources and services to end-users (Guo et al., 2021); blockchain technology, cloud-first and zero-trust security strategy are frequently used for data privacy, traceability, transparency, and immutability, giving only authorised stakeholders access to information (Ali and Kannan, 2022; Ejaz et al., 2021).

Recognizing the importance of digital technology in daily activities of hospital management and in order to facilitate the implementation process of such technologies, external integration between hospitals physicians and designers of Health Information Technology (HIT) could be extremely useful (Barrett, 2019). Supporting collaboration between physicians and HIT designers has a preventive function that leads to more effective implementation and acceptance of technology within hospitals. A few selected articles suggest that the ability to anticipate could be gained by hospitals exploiting knowledge-based resources and related capabilities. As stated by Moss et al. (2021) skills of managers in managing the drug inventory in the hospital pharmacy helps prevent shortages, significantly improving the ability to anticipate. The culture of quality and quality management in hospitals, which involves the adoption of lean management and total quality management tools, help detect vulnerabilities in internal operations and external supply chain issues (Hundal et al. 2022; Alemsan et al. 2021; Kuiper et al. 2022). Among lean management tools, visual management, value stream mapping, and standardised work could allow hospitals to improve their transparency and visibility, as they create a visual guide of each step of the healthcare delivery processes and report critical and useful information (Hundal et al., 2021; Papalexi et al., 2021). Studies that investigated the impact of lean tools for Inventory Management, such as Just in Time, Kanban and Kaizers, on healthcare supply chain performance, arrived at opposite conclusions. On one hand, they argued that lean tools enable hospitals to improve visibility of inventory so as promptly account for situational awareness within the healthcare supply chain, directly related to the ability to anticipate (Kuiper et al., 2022; Hussain et al., 2022; Patrone et al., 2020). On the other hand, an exaggerated waste elimination, due to the adoption of lean tools, could reduce efficiency while increase vulnerabilities (Alemsan et al. 2021; Hundal et al., 2021).

Finally, the hospital ability to anticipate is also supported by the organisational capability of establishing an effective protocol implementation with the goal of preparing hospital staff for emergencies by means of a pre-established hierarchical structure and task-specific definition (Hines and Reid, 2021; Hassan and Mahmoud, 2020; Lim et al., 2020).

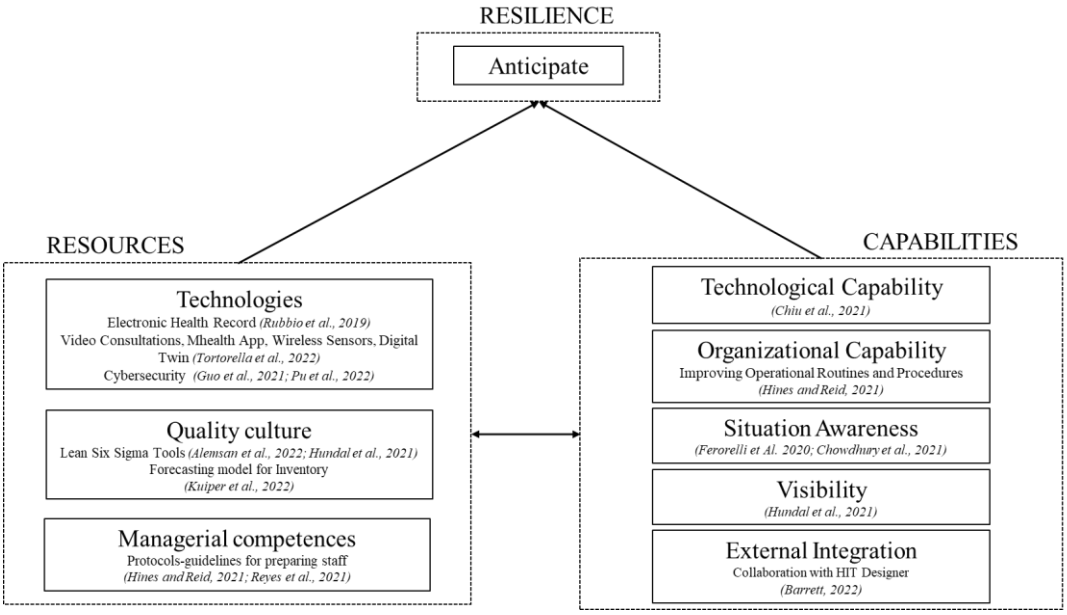


Figure 3. Resources and capabilities for the ability to anticipate.

4.2 Ability to adapt

Hospital's ability to adapt is related to their capacity to cope with unexpected disturbance or challenging conditions by managing and adjusting existing resources and organizational structure to guarantee proper healthcare services (Ali et al., 2017). Adapting involves having flexible intra- and inter-organizational processes, as well as building redundancy with extra capacity, extra personnel, and safety stocks (Behrens et al., 2022). This kind of ability to adapt to disruption is enabled both by property-based resources, such as remote technologies, and knowledge-based resources, for example skills and expertise of hospital staff in managing extraordinary situation (Figure 4). The COVID-19 pandemic accelerates digital transformation in hospitals, implementing a 'new normality' in delivery services through remote technologies (VanderWerf et al., 2022; Bhaskar et al., 2020b; Marques da Rosa et al., 2021). These resources promote flexibility in treatment processes, give interconnected medical emergency support (Tortorella et al., 2022; Milch et al., 2021; Ölcer et al., 2021), facilitate the internal integration among hospital staff, and improve external integration between hospitals, suppliers, and patients. The technologies most often utilised in remote care consultation of patients were artificial intelligence-enabled hospital platforms, telemedicine, video consultations, mHealth

app, and non-invasive digital care such as wireless sensors (Bhaskar et al. 2020; VanderWerf et al. 2021; Tonetto et al. 2021; Chen et al., 2022b; Shaw et al., 2022).

The literature agrees on recognising the importance of knowledge-based resources for the hospital ability to adapt to disruption, acknowledging the critical role of skills and experience of medical staff including epidemiologist, surgeons, infectivologists, virologists and administrative personnel in managing emerging pandemic-driven intensive care (Spieske et al., 2022; Dichter et al., 2022; de La Garza and Lot, 2022). To increase the availability of trained medical personnel, many hospitals engaged retired physicians and nurses, as well as research healthcare professionals (Behrens et al., 2022; Bessis et al., 2022; Lloyd-Smith 2020). Hospitals also included dentists as part of the hospital worker force for their experience in working in stressful situations, in dealing with infection control procedures, and for their habit of wearing Personal Protection Equipment (PPE) (Sacoor et al., 2020). Moreover, the ability to adapt is built on the internal integration resulting from formal coordination mechanisms, such as protocols and guidelines, and informal collaborative relationships among staff members (Ree et al., 2021; de La Garza and Lot, 2022; Minka et al., 2021; Pomare et al., 2022). By implementing formal coordination mechanisms with the aim of standardising procedures, prioritising tasks, and redeploying or creating new roles with specific job description, hospitals have delivered continuity of care during crisis (Donelli et al., 2022; Hybinette et al., 2021; Suresh et al., 2021). The emerging informal collaborative relationships, to exchange best practices between staff members, could facilitate adjustment in processes (Juvet et al., 2021; Veerapen and McKeown, 2021).

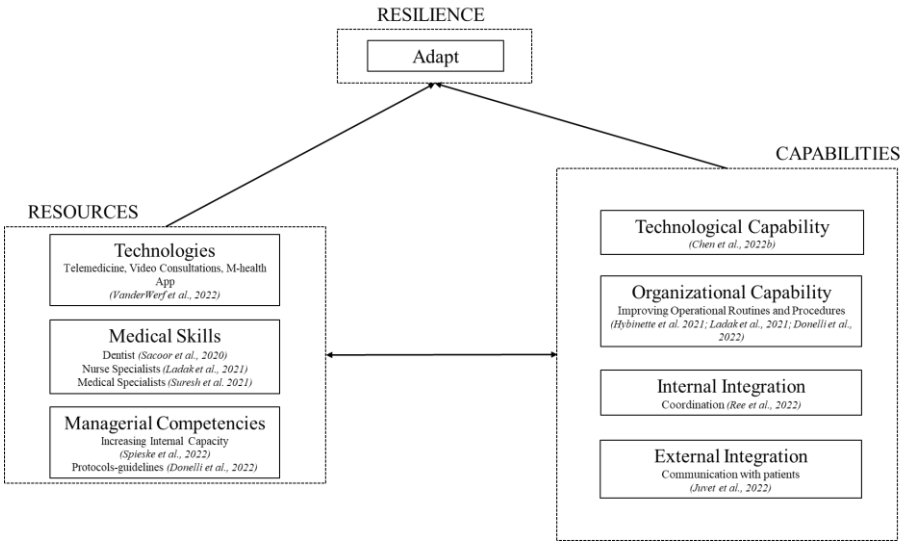


Figure 4. Resources and Capabilities for the ability to adapt.

4.3 Ability to respond

Responding means reacting on time and efficiently in front of a disruption (Kamalahmadi and Parast, 2016). Hospitals have faced a disproportionate flow of patients seeking care, resulting in a shortage of critical resources such as hospital staff, PPE, medicines, and disinfectants. To address these challenges, hospitals reacted by leveraging specific knowledge-based resources, namely the expertise of both procurement departments and medical personnel, as well as by exploiting external integration capability (Lyng et al., 2021; Casiraghi et al., 2020; Mervyn et al., 2019; Koch et al., 2022), namely the ability to manage hospital supplies, establish cross-hospital partnerships, coordinate the supply network (Figure 5). In fact, to resolve the disparity between the growing demand for resources reported by medical personnel and the supply difficulties experienced by manufacturers, procurement departments have identified alternative suppliers or implemented new procurement initiatives and strengthened the relationship within the supply chain (Zamiela et al., 2022; Pandit et al., 2021). The urgency of gaining access to alternative source of supply led some hospital procurement departments to eliminate the intermediary node of distributors creating direct links with geographically dispersed suppliers (Scala and Lindsay, 2021) and to collaborate with companies from other industries for medical supplies, such as ethanol from spirits producers and automotive medical masks (Spieske et al., 2022). During disasters, the external integration capability related to the ability to establish

relationships between hospitals in the form of coalitions, collaborations, consortia and expertise sharing (Liu et al., 2020; Kazemi Matin et al., 2021; Jordan et al., 2022) allowed hospitals to avoid overcrowding of patients through a redistribution of the load of care services among referral hospitals (Chen et al., 2022; Hines and Reid, 2021; Ceferino et al., 2020). Other forms of coalitions that have proven effective include those between external pharmacies and laboratories, as highlighted by Sigala et al. (2022), Hannan et al. (2021), Hossain et al. (2022) and Jordan et al. (2022). In particular, the hub & spoke model proved particularly efficient thanks to home healthcare management or low and medium care facilities for patients with non-serious or chronic symptoms (Donelli et al., 2022; Kihlström et al., 2022, Bohnnett et al., 2022). This capillary model encourages access to care for the population, reducing patient transfers across the territory, alleviating congestion in emergency departments, and minimizing hospital-based cross-contamination among users and healthcare staff (Capolongo et al., 2020). The cross-hospital relationship is not just a matter of redistributing patients, but also leads to the creation of alternative sourcing through the so-called lateral transhipment (Aldrighetti et al., 2022), which means that hospitals create shared central warehouses for most medical products (Spieske et al., 2022). Lastly, during the COVID-19 pandemic crisis, external integration capability has also resulted in a stricter collaboration between governments and hospitals, enabling timely and accurate pandemic-data sharing. (Zamiela et al. 2022).

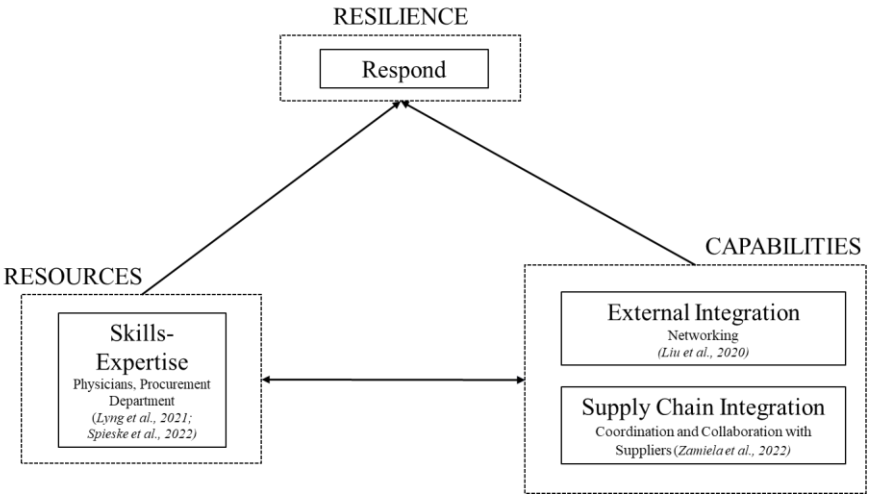


Figure 5. Resources and capabilities for the ability to respond.

4.4 Ability to recover

Recovery refers to actions taken after the adverse event to return to the original normal state or move to a new, suitable state (Ali et al., 2017). This ability is enabled by managerial skills of hospital top managers as well as external integration capability (Figure 6). Both of them, resource and capability, allow hospital to jointly formulate with public authority strategic plans of reconfiguration and restoration of normal operations (Bhaskar et al., 2020a; Scala and Lindsay, 2021; Bozorgmehr et al., 2022; Hossain et al., 2022). Moreover, it has been proved that place-based collaborative networks, established thanks to hospital external integration capability, not only have increased hospital resilience during disruptions but they have also improved healthcare quality and value (Wiig et al., 2021). These collaborative networks represent a fertile ground to develop a culture of learning and to foster innovation, because of they allow sharing expertise among clinicians, and to secure better health outcomes, because of they enable combined resources and assets (Winkelmann et al., 2022; Harland et al., 2021).

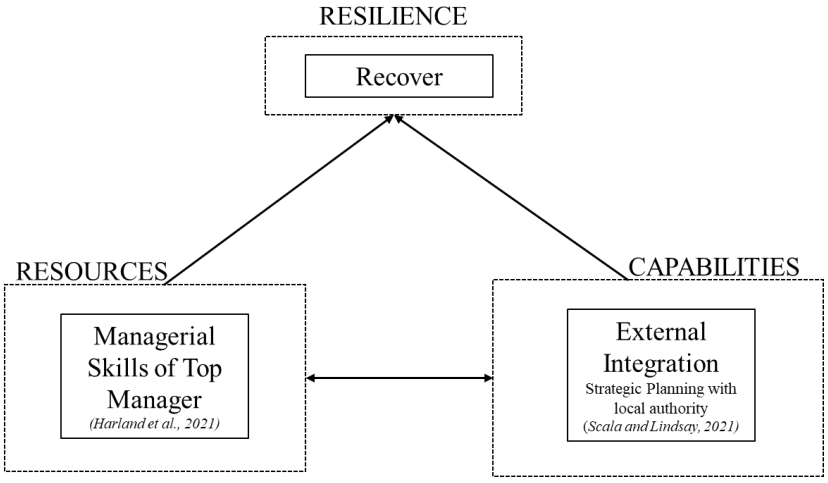


Figure 6. Resources and Capabilities for the ability to recover.

4.5 Ability to learn

Learning is the ability, required after a disruptive event, to recognize what happened in the past, what were successes and failures, and to improve future performance with changes in behaviour as a result of experience (Tortorella et al., 2022). The ability to learn requires the creation of frequent learning

opportunities (Wiig *et al.*, 2021). In this vein, hospital results on a higher learning ability when it provides training and education programs to its staff, for the acquisition of new knowledge and competences (Huey and Palaganas, 2020; Turan et al., 2021). Beside training and drills, internal integration capability effectively contributes to improve organizational learning processes, based on formal and informal knowledge transfer and information sharing mechanisms (Blackhurst et al., 2011) (Figure 7). As a result of COVID-19, two training requirements for staff members arose. First, it was necessary to redesign the organizational structure (e.g., introduce new roles and generate ever-changing COVID-19 instructions) in order to address the potential staffing shortage, with a focus on emergency management-qualified personnel. To this end, hospitals implemented training programs, tailored to the context of the pandemic, with the aim of transferring the skills inherent to the new tasks and new ways of working (Sawyerr and Harrison, 2022; Johnson et al., 2020; Kagawanja et al., 2020). Second, it was necessary to ensure that the healthcare workforce was adequately motivated and fully committed to the hospital mission during the emergency. To this end, hospitals provided a trauma-informed care or psychoeducation programs to support the development of the skills required to deal with stress associated with job changes and the management of newly assigned responsibilities (Appelbom et al., 2021; Haraldseid-Driftland et al., 2022; Jordan et al., 2022).

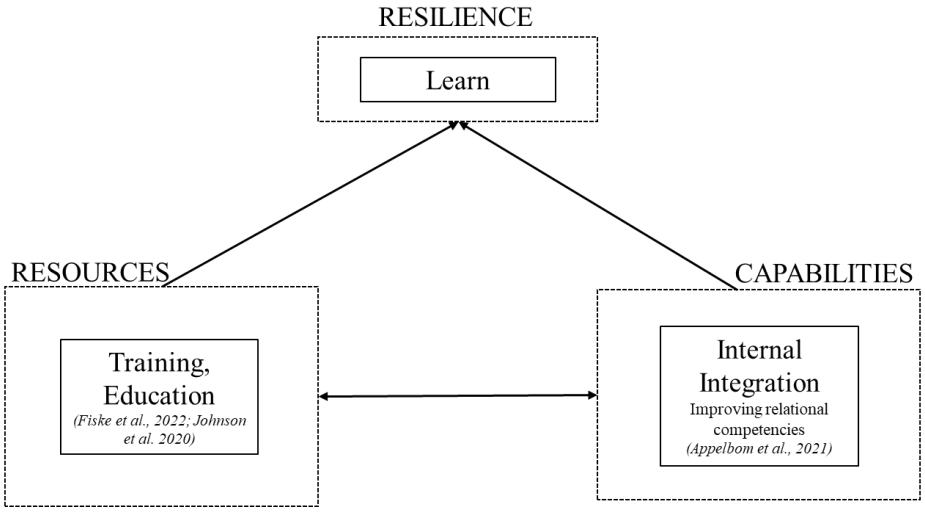


Figure 7. Resources and Capabilities for the ability to learn.

5. Discussion and research directions

This review represents an effort to aggregate the current body of knowledge on organisational characteristics, in the form of resources and capabilities, that support the hospital resilience in managing crises. Although the literature on healthcare resilience reveals an increasing interest in studying the resilience of healthcare organisations and what elements impact resilience of hospitals (Barasa *et al.*, 2018; Blanchet *et al.*, 2017; Gilson *et al.*, 2020), a critical aspect that emerges is the tendency to map linear relationships between organizational characteristics including structure, practices, and behaviours and hospital resilience. A further step would be to depict the complex set of configurations and combinations of these characteristics leading to resilience. In line with the operations management literature, which advocates for adoption of a resource-based perspective for exploring organizational resilience (Cheng and Lu, 2017; Ambulkar et al., 2016; Kamalahmadi and Parast, 2016), the study is grounded on the theoretical framework of the RBV. It formulates a framework delineating organizational characteristics in relation to resources and capabilities, illustrating the synergistic effects that emerge from their interplay.

The results reveal that even if there is no one-size-fits-all path to resilience (Lyng *et al.*, 2021), well-performing hospitals have implemented common resources and capabilities against disruptions. Existing research largely suggests that hospitals can differentiate from each other, in terms of resilience performance, by leveraging digital technologies, as property-based resources, along with technical skills and managerial competences, as knowledge-based resources. Specifically, the digital information infrastructure enables the collection of a vast quantity of relevant data that supports patient-cantered care, superior organizational knowledge, and synergies among hospital staff, medical personnel and patients, and hospital employees and supply partners (Rusinko et al., 2020; Marques da Rosa et al., 2021). As a result, digital technologies contribute to improved situational awareness, greater visibility and flexibility, namely resilience elements related to the ability to anticipate and adapt. However, while the adoption of digital technologies improves resilience, its

implementation is not without criticalities. The critical aspect lies in the development and cultivation of digital capabilities, which hinges on a deep understanding of how to effectively apply digital technologies and how to combine resources, such as information technology (IT) infrastructure and skills, to create superior applications (Garcia-Perez et al., 2022; Xu et al., 2022; Joyce et al., 2021). This knowledge must be integrated into organizational routines, leading to an enhancement in the IT skills base of hospitals (Bharadwaj, 2000). However, many studies found that improperly implemented digital technologies can cause time wastage and obstruct departmental activities (Austin *et al.*, 2022; McLeod *et al.*, 2019). Given these conflicting findings regarding the impact of digital technologies on hospital resilience, there is a pressing need for further research, including empirical investigations, specifically focused on unravelling the link between digital technology resources and digital capabilities to foster and nurture resilience dimensions.

Furthermore, despite the increasing interest in digital technologies within the healthcare sector, the existing studies predominantly concentrate on a restricted range of technologies, such as electronic health records or digital platforms and propose qualitative models of safe and trusted data-sharing (Hirano *et al.*, 2020; Milch et al., 2021; Kaleta et al., 2022).

These gaps underscore the need for additional research encompassing a wider array of Industry 4.0 technologies, including cloud computing, big data technologies, blockchain, cyber-physical systems and the Internet of Things (Ali and Kannan, 2022). Understanding how the latest frontier of Industry 5.0 regarding a comprehensive personalized healthcare services (CPHS) in modern healthcare Internet of Thing, scan be implemented in hospitals is just as essential as clarifying its role in hospital resilience (Taimoor and Rehman, 2022; Zhang et al., 2020). For hospitals at the forefront of implementing digital technologies in healthcare, there is a growing discussion about the potential adoption of Industry 5.0 to ensure an increasingly human-centred use of technology (Nayeri et al.,2023). This would enable more efficient management of operations within the hospital. For instance, intelligent healthcare devices assist in monitoring the expiration of equipment parts, alerting the responsible team. Furthermore, doctors can swiftly locate specific medical equipment, such as an

oxygen cylinder, when urgently needed, reducing the time spent searching and potentially contributing to saving the patient's life (Tonetto et al., 2021). Furthermore, this type of technology holds promise in the early diagnosis of serious illnesses, managing to correlate various health conditions.

The SLR revealed that both knowledge-based resources, encompassing administrative, organizational, and medical competences, and the related capabilities, namely the organizational capability, the internal and external integration ones, are significant contributors to the resilience dimensions, especially for the ability to adapt, respond, and recover (Jordan et al., 2022; Kazemi Mtin et al., 2021; Wang et al., 2022). Indeed, medical expertise empowered frontline staff to exhibit adaptive behaviours during emergencies, while the purchasing department competencies enhanced the ability to explore alternative sources for critical materials. Lastly, organizational competencies pertained the ability to adapt spaces, personnel, and delineate new roles in front of the crisis. In this context, issues related to department reorganisation, new job responsibilities, and altered work schedules were considerably more commonly reported (Litke et al., 2022). Implementing significant changes rapidly destabilised healthcare professionals who found themselves performing tasks outside their usual (Juvet *et al.*, 2021). A good hospital leadership can be considered as an essential competence not only for detecting early warning signs of a crisis, but also to effectively engage staff, facilitate collaborations within and among departments, help acquire new skills through education and training, boost staff well-being and self-care, resulting in better patient care and healthcare outcomes (Lim et al., 2020; Hodgins et al., 2022). Accordingly, hospital leadership style and behaviour is a key area to be explored further.

For successful hospital resilience, it is essential to address the availability of medical supplies, medications, drugs, and essential goods for patient care. This necessitates the improvement of the resilience of the healthcare supply chain. The purchasing department’s knowledge and skills, as well as the supply chain integration capability, have proven crucial in overcoming the barriers imposed by COVID-19. However, there is still a need to understand how the strategies of supply management

and collaboration between local authorities could influence the resilience of the healthcare supply chain (Harland *et al.*, 2021; Mervyn et al., 2019; Khuntia et al., 2022). Given the intricate complexity of the healthcare supply chain, involving actors in the upstream part such as medical device manufacturers, equipment producers, biotech firms, and pharmaceutical companies, in the central part including insurance companies, claims, administrators, and in the downstream part involving actors in healthcare delivery such as doctors, nurses, hospitals, and patients, it becomes essential to understand which coordination strategies prove most effective to ensure the most efficient delivery of services to the end patient. Moreover, the development of a digital infrastructure within the healthcare supply chain facilitates the real-time collection of data, fostering situational awareness and a proactive response to disruptive events. Despite the growing literature on the healthcare supply chain (Scala and Lindsay, 2021; Spieske *et al.*, 2022; Zamiela *et al.*, 2022), there is still room for understanding how the digital technology could influence resilience healthcare supply chain and what the related (either positive or negative) effects might be. Finally, a key aspect that emerges from the literature review concerns the need for collaborative and cooperative participation between hospitals (Koch et al., 2022; Ito and Aruga, 2022; Shahverdi et al., 2020). Further research is needed to investigate how healthcare organizations should be reorganised, individually and collectively.

The findings of this study are consistent with and validate previous frameworks that contain potential explanatory factors of resilience dimensions. Technology, for example, and the ability to establish effective internal and external integration are features present in Barasa *et al.* (2018). Blanchet *et al.* (2017) recognises the importance of knowledge as the ability to acquire, integrate, and evaluate many sources of information and competencies, as well as the ability to manage diverse interdependencies. This review identifies a lack of experimental studies in comparison to observational research. This aligns with recognition that resilience is not open to direct measurement or intervention (Ellis *et al.*, 2019). The lack of measurable indices suggests that there is still a gap between the concepts related to resilience and the following operationalisation in the context of the healthcare system and its organisations (Biddle *et al.*, 2020). An aspect closely connected to the theme of healthcare service

delivery and, consequently, a more resilient hospital system, is its increasing focus on the patient. As mentioned earlier, technological supports push in this direction, but it is not sufficient. Patient involvement is necessary in all stages of the supply chain, especially in the development of medical devices, to facilitate, support, and encourage usage not only by healthcare professionals but also by the patients themselves (Jiang et al., 2022). It would be worthy to investigate how empowering patients to identify the challenges ad co-design the best solutions (Garcia Martinez et al., 2022).

The future research perspective in this field is to enrich resilience operationalisation debates with new theoretical models and empirical studies. Analytical modelling approaches such as simulation, decision analysis, multi-criteria decision analysis, among others, and quantitative empirical research are relevant methods to understand in depth and consequently strengthen health resilience. With a more general-purpose key, the findings suggest that the following directions for future research should obtain a complete picture of resilience. This means that all the qualitative research emerged from this review must be integrated with quantitative research. It could be valuable to investigate with empirical studies the relationship between these resources and capabilities, figured out by this review, and resilience dimensions, catching, with cross-longitudinal studies, differences between hospitals.

6. Conclusions

Healthcare organisations and particularly hospitals have been severely affected by the pandemic that has undermined their primary goal of providing patient care. Such a crisis has put hospital resilience, namely, its ability to remain fully operational prior to, during, and following the disruption, at the centre of interest for researchers and practitioners. The findings of this study offer significant contributions to healthcare management researchers in advancing the current comprehension of hospital resilience. The SLR resulted in profiling the existing studies and identifying not only which

resources and capabilities could foster hospital resilience, but also which of these organisational characteristics are associated with specific dimensions of hospital resilience.

My research provides valuable insights to managers of service operations within hospitals highlighting those resources and capabilities to which managers should pay close attention to yield improvement in hospital resilience. A research approach based on resources and capabilities facilitates a greater comprehension of organizational dynamics and the development of structured and replicable resilience research (Alameddine *et al.*, 2019).

For an overall advantage in resilience performance, managers should promote integration in all its three forms, internal, external, and supply chain. Specifically, the findings of the study reveal that external integration has a greater impact on the four dimensions of resilience, anticipate, adapt, respond, recover, only having little impact on the ability to learn. To this end, managers must ensure that all activities of collaboration, cooperation, and coordination are implemented. Managers, thus, should cultivate relationships with external members, such as other healthcare facilities, local entities, and develop collaborative networking. Moreover, internal integration is a prerequisite for the successful implementation of external integration. In this regard, internal integration appears to have a significant impact on the four dimensions of resilience of adapt, respond, recover, and learn while having a lesser effect on the ability to anticipate. To this end, managers must ensure that activities of coordination, collaboration, and proper communication are properly implemented in the workplace within and across hospital departments. Lastly, the lessons learned from this review reveal that the integration of healthcare supply chains can facilitate the development of hospital response ability. Given the scarcity of resources resulting from the pandemic, managers must allocate resources judiciously in order to build a supply chain integration infrastructure that yields the greatest possible benefits.

In terms of organisational capabilities, particularly useful for the ability to anticipate and adapt, the study recommends that managers make concerted efforts to implement or redeploy appropriate management measures and develop various organizational aspects ranging from formal and informal

procedures and routines to new or changed tasks and roles. Also, they need to implement or redeploy appropriate management measures to boost adaptability in challenging situations and forging a closer link between services, staff, and patients. Hospitals are also suggested considering their resources and capabilities simultaneously. Utilizing the skills and experience of medical and administrative technical personnel, for instance, promotes the growth and the implementation of diverse capabilities, such as internal, external, and supply chain integration.

Despite using a recognised and scientifically rigorous research technique, the study presents certain limitations. The literature review sample was confined to a predefined set of inclusion-exclusion criteria. This means our final included body of knowledge has excluded book chapters, conference proceedings, non-peer reviewed articles and non-English articles. Incorporating more works might have resulted in extra relevant works and new insights. Similarly, the keywords used in the database search and the selection filters used in the literature search could have resulted in the omission of potentially relevant articles. Finally, while my literature analysis aims to collect findings from the past four years, my final included body of knowledge may have excluded significant publications on this topic, published prior to 2019. In this study, I employed the theoretical lens of RBV to examine the influence of resources and capabilities on hospital resilience. However, it is crucial to note that this perspective has a limitation known as "context insensitivity," neglecting contingencies that may impact this influence. To address this, in future studies, I will adopt the theoretical perspective of the Contingent Resource-Based View to delve deeper into environmental and organizational factors, aiming for a more comprehensive understanding of hospital resilience.

Chapter 2

The effect of digital technologies and staff skills on hospital resilience: The role of supply chain information integration

Abstract

In recent years, crises such as the COVID-19 pandemic have challenged hospitals, critical pillars of healthcare systems, revealing significant variations in their ability to respond effectively. Hospital resilience addresses the urgent need to understand how to enhance hospitals' capacity to respond effectively to crises. While numerous factors have been identified as critical to hospital resilience, they are often studied in isolation, overlooking the synergistic effects among them and lacking robust empirical validation. Grounded in the Resource-Based View, this paper investigates how key resources, namely digital technologies and staff skills, along with the capability of supply chain information integration (SCII), influence hospital resilience. Drawing on survey data from 130 Italian hospitals, the study examines the direct impact of these resources and capabilities on hospital resilience, as well as the mediating role of supply chain information integration, using structural equation modelling. The results reveal that digital technologies and external information integration capability directly affects hospital resilience. Moreover, the study underscores the importance of leveraging digital technologies and enhancing staff skills to foster supply chain information integration, which in turn mediates the relationship between these resources and hospital resilience. This research contributes significantly to theoretical and practical insights in hospital management and resilience strategies. The proposed theoretical framework enhances our understanding of hospital

resilience dynamics by elucidating the direct influence of resources and capabilities, while also highlighting the mediating effect of supply chain information integration. These findings offer actionable insights for hospital managers to optimize resource allocation and capabilities amidst uncertainties, thereby fortifying hospital resilience.

Keywords: *Hospital resilience-digital technologies-staff skills-supply chain information integration-hospital management*

1. Introduction

Hospitals are complex organizations that hold an apical position in the healthcare system, serving as a centre for the provision of high-level medical services and care, as well as functioning as centres for medical training and research (Fottler, 1987; Shaker Ardakani et al., 2023; Thune & Mina, 2016). Their dedication to delivering optimal medical care to patients faced challenges due to recent disruptive events that caused increased patient numbers, shortages of resources, insufficient staffing, and disruptions to normal operations (Gifford et al., 2022; Liu et al., 2020). Rethinking healthcare provision with a focus on developing and enhancing hospital resilience (HR) has now emerged as a priority for both researchers and practitioners (Barbash & Kahn, 2021; Ito & Aruga, 2022; Khademi Jolgehnejad et al., 2021). HR refers to the capacity to sustain critical healthcare operations and ensure the uninterrupted delivery of high-quality services to patients in need, even amidst disruptions or emergencies (Fallah-Aliabadi et al., 2022; Ridde et al., 2023; Zhong et al., 2015). Resilient hospitals have more flexibility, allowing them to explore various solutions to problems and adapt quickly when a predetermined strategy fails. This enables them to implement new solutions rapidly and effectively instead of being bound to existing plans that may not be suitable for the current situation.

The data published in official reports during the recent pandemic crisis have shown significant global disparity in hospital response. Some hospitals were able to manage the emergency while maintaining a high standard of care, whereas others faced greater challenges and difficulties (Bailey, 2021; LaPointe, 2021). According to Fitch Ratings, in United States, non-profit small hospitals have been

particularly affected. In these hospitals, elective procedure volumes have decreased as patients postponed scheduled surgeries due to the surge in COVID-19 cases, leading to a reduction in revenues (Kevin Holloran, 2021). Additionally, the scarcity of qualified medical and nursing staff has driven up costs, further straining smaller hospitals. This increased financial pressure has led to higher expenses, with available funds often falling short of covering the rising operational costs (LaPointe, 2021). Furthermore, data referring to the past few months underscores a critical issue: the challenges faced by hospitals are not limited to the crisis period but persist into the recovery phase. The uneven responses during the pandemic have translated into varied recovery rates, with some hospitals recovering more effectively than others (Owens, 2024). This disparity of hospital response to crisis has heightened the urgency of rethinking healthcare provision through the lens of hospital resilience (Barbash and Kahn, 2021; Ito and Aruga, 2022; Khademi Jolgehnejad et al., 2021). Hospital resilience refers to the capacity to maintain essential operations and deliver high-quality services to patients, even during disruptions or emergencies (Fallah-Aliabadi et al., 2022; Ridde et al., 2023; Zhong et al., 2015). Resilient hospitals explore various solutions to problems and adapt quickly when a predetermined strategy fails. This enables them to implement new solutions rapidly and effectively instead of being bound to existing plans that may not be suitable for the current situation. Hospital resilience is widely recognized as a multidimensional concept, meaning that its ability to effectively respond to crises depends on a combination of different organizational factors (Barzanji et al., 2024; Louise Biddle et al., 2020). The existing literature extensively examines how hospitals responded to the unprecedented challenges of the pandemic, the obstacles they faced, and the lessons learned, with a particular focus on the organizational resources mobilized during the crisis (Bai et al., 2024). These studies are often based on empirical qualitative studies, utilizing interviews with stakeholders directly involved in hospitals' crisis response, and emphasize the critical role of organizational factors in enhancing hospital resilience (Fallah-Aliabadi et al., 2020; Khademi Jolgehnejad et al., 2021).

Among these factors, while some studies highlight the pivotal importance of tangible resources, including advanced technological systems and robust infrastructure, other focus on intangible

resources, such as personnel competencies and efficient resource management (Bai et al., 2024). In particular, within the first category, great emphasis has been given to the role of digital technologies (DT) in enabling hospitals to adapt to a new normality in service delivery through remote monitoring and telemedicine (Ali & Kannan, 2022; Marques da Rosa et al., 2021). Hospitals equipped with digital applications, platforms, electronic devices, and wireless technology have demonstrated increased situational awareness, which allows for real-time identification of trends in materials, equipment, patient conditions, and processes (Tortorella et al., 2022).

Among intangible resources, several competencies and skills of hospital staff are perceived as potentially impacting hospital resilience, not only for effective job performance, but also for adapting in the face of challenges and difficulties (David et al., 2023; Juvet et al., 2021; Oliveira et al., 2023). Specifically, the clinical expertise and specialized knowledge of medical and nursing staff enhance the capacity to manage complex cases, make crucial decisions in high-stress situations, and improve hospitals' crisis preparedness and response (Fagerdal et al., 2022; Liu et al., 2020). Moreover, staff with solid communication and teamwork skills contribute to coordination and collaboration to address complex situations and develop unified response strategies (Chabrol et al., 2023; Gautier et al., 2023; Lyng et al., 2022).

Recent studies have also stressed the importance of the ability to manage information flows because it enables hospitals to improve the synchronization and coordination of processes among hospital departments and beyond hospital boundaries (Khalil et al., 2022; Mohtady Ali et al., 2021; Traverson et al., 2021; Veerapen & McKeown, 2021). The success of the collaborative culture within hospitals lies in the facilitated creation of multidisciplinary response committee among departments and operational units. This committee aims to foster the exchange of knowledge and information regarding changing conditions, enabling informed and timely decisions (Achour et al., 2022; Belhadi et al., 2021; Hales et al., 2020; Juvet et al., 2021; Sabateen et al., 2022; Tippong et al., 2022; Veerapen & McKeown, 2021). Hospitals that demonstrated cooperative behaviours at regional and local levels, collaborating with local authorities, central warehouses, external pharmacies, and other healthcare

organizations were better equipped to identify creative solutions together and achieve improved coordination of necessary resources (Kihlström et al., 2022; Spieske et al., 2022). Such an ability to manage the information flow, both internally and externally, is defined by scholars as supply chain information integration (SCII) and denotes the process by which an organization obtains, disseminates, and implements precise and timely information to facilitate the coordination of activities both internally, within internal hospital operational units, and externally across hospital partners (Flynn et al., 2010; Schoenherr & Swink, 2012).

However, despite the relevant contributions of previous works in studying the role of different organizational factors, i.e. resources and capabilities, in achieving hospital resilience, these factors have been examined in isolation, overlooking the potential synergistic effect of their utilization towards hospital resilience, whose complexity warrants an integrated analysis of its contributing factors (Bai et al., 2024). Few studies recognize the simultaneous contribution of resources and capabilities in achieving resilience outcomes. For example, studies by Traverson et al. (2021), Fagerdal et al. (2022), and Sabateen et al. (2022) recognize the key role of resources as digital technologies, communication and information systems, healthcare professionals' expertise, combined to capability as interdepartmental integration in fostering hospital resilience. Moreover, while acknowledging the importance of healthcare professionals' competencies and expertise, Oliveira et al. (2023), Chen et al. (2022), and Liu et al. (2020) emphasize the critical role of external integration, advocating for partnerships with stakeholders outside the hospital setting to strengthen resilience. However, the combined contributions of resources and capabilities to hospital resilience are largely confined to theoretical discussions (Biddle et al., 2020; Iflaifel et al., 2020; Lyng et al., 2022), without any empirical evidence about these relationships. Limited attention has been paid to empirically understand and demonstrate how key resources, as digital technologies and hospital staff skills, and key capabilities, as SCII, jointly contribute to achieve resilience (Arji et al., 2023).

Studies grounded in the Resource-Based View (RBV) theory—which posits that resources and capabilities enable organizations to achieve competitive advantage and that resources form the

foundation for developing valuable capabilities towards better outcome (Huo et al., 2016)— highlight the existence of an interaction effect between resources and capabilities which in turn may improve resilience (Brandon-Jones et al., 2014; Chahal et al., 2020), suggesting us that digital technologies and staff skills are key resources that can be leveraged to foster SCII capability in building resilience. Digital technologies in fact enable the collection, exchange, and integration of data from various sources (Tonetto et al., 2021), thereby improving the timeliness and accuracy of information flow across operational units and between hospitals and external partners, enhancing coordination and decision-making processes (Dobrzykowski et al., 2015; Li et al., 2009). This enhancement, in turn, strengthens the hospital's ability to respond effectively to crises. Similarly, the staff skills influence the quality of shared information (Schoenherr et al., 2015), foster relationships based on trust and teamwork, which in turn support the effective exchange and sharing of information, improving adaptation and response to crises (Cai et al., 2010; Chen et al., 2013; Zahoor and Gerged, 2021).

The lens of RBV may therefore inform our research exploring the complex interplay between key resources, such as digital technologies and hospital staff skills, and SCII capability in achieving hospital resilience (Figure 8).

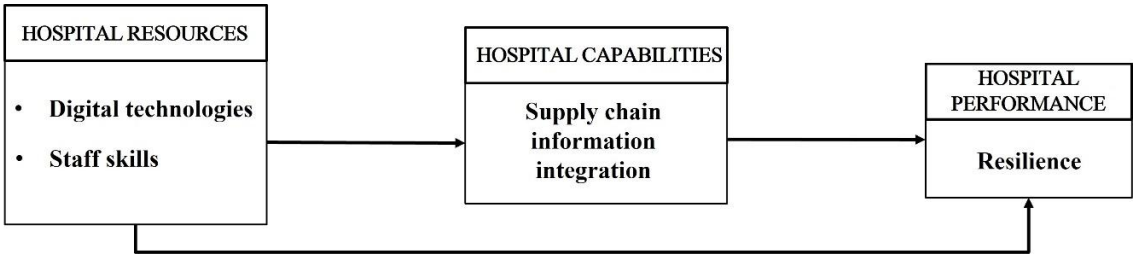


Figure 8. The broad research model.

Considering the gaps in the literature, this study addresses the following research questions (RQs):

RQ1: What is the direct impact of DT, staff skills, and the SCII on HR?

RQ2: What is the role of the SCII in the relationship between DT, staff skills, and HR?

To answer the two research questions, we conducted an empirical study on Italian hospitals, as Italy was one of the countries that were most severely and firstly impacted during the COVID-19 pandemic. Overall, the study contributes to theoretical and practical knowledge within the field of HR in several ways. From a theoretical perspective, in the light of the RBV, the study aims to enrich our understanding of the direct influence of hospital resources and capabilities on HR, as well as investigate how hospital resources shape capabilities that, subsequently, impact HR.

In addition, the study contributes to evaluating the mediating impact of SCII capability on the relationship between hospital resources and HR, elucidating the complete impact of DT and staff skills on HR. Hence, hospital managers and leaders will benefit from the findings of this study for managing resources and enhancing capabilities during uncertainties, thereby improving hospital resilience.

The remainder of the paper is structured as follows. The next section provides a theoretical background on HR, and a summary of the related literature adopting the RBV theory. The subsequent section develops the research model for this study. The following sections outline the methodology, covering sample selection, data collection techniques, and measurement approaches, as well as the analysis and findings, encompassing the assessment of both the measurement and structural models. The article concludes with a discussion of the findings, conclusions, limitations, and future directions.

2. Theoretical background

2.1 Hospital resilience

A hospital is considered as a combined or integrated part of the social and medical system. It is part of a broader network of institutions and services that work together to provide healthcare and social support to the community (Goldstein & Naor, 2005). In addition to providing comprehensive

healthcare services to the population, ranging from curative to preventive care, it plays a critical role as a training centre for healthcare professionals and as a dedicated venue for medical research (Fottler, 1987). In light of crises of various natures, including natural, humanitarian, ecological, and financial crises, and the concern for the significant impact these crises have on hospitals' response, the literature on healthcare resilience shows a growing interest in examining the role of resilience within hospitals. HR refers to the capacity of healthcare organizations to adapt their operations before, during, and after events to maintain necessary functions under anticipated and unforeseen circumstances (Barasa et al., 2018; Iflaifel et al., 2020). It is recognized as a critical capacity that enables hospitals to endure, absorb, and respond to the shock of disasters without disrupting essential healthcare functions and routine operations, ultimately returning to their original state or adapting to a new one (Zhong et al., 2015). HR is primarily conceptualized through four core capacities: absorptive, adaptive, transformative, and learning. These capacities are essential for hospitals to mitigate vulnerabilities before a crisis occurs and to swiftly react and recover post-disturbance (Khalil et al., 2022). They encompass the abilities of hospitals to uphold high-quality, patient-centred care using existing resources and capabilities, adjust internal structures (Donelli et al., 2022), and even transform functions and structures (Spieske et al., 2022) in response to changing environments. Moreover, learning capacity underscores the importance of reflecting on past actions and recognizing both failures and successes in developing improved solutions for future disturbances (Lyng et al., 2022).

2.2 Resource-based view theory

Hospital resilience significantly relies on organizational characteristics, resources and processes which collectively shape its capacity to adapt and recover in the face of challenges (Cimellaro et al., 2018; Duchek, 2020). Embracing a resource perspective deepens this understanding by framing resilience as an outcome of the strategic alignment and integration of resources and capabilities in achieving resilience (Brandon-Jones et al., 2014; Hussain et al., 2023; Wulandhari et al., 2023). According to the Resource-Based View (RBV) theory, resources are defined as assets or inputs owned

and controlled by an organization. These include tangible assets like infrastructure and technological devices, as well as intangible assets like knowledge and information sharing (Kim et al., 2015; Miller and Shamsie, 1996). Capabilities, on the other hand, refer to an organization's ability to effectively deploy resources, through specific formal and informal processes embedded in its routines (Amit and Schoemaker, 1993; Kraaijenbrink et al., 2010). The RBV posits that possessing heterogeneous resources alone is insufficient to achieve desired outcomes; this, instead, requires the efficient and synergistic utilization of these resources that, through organizational processes, develop capabilities (Teece et al., 1997; Xia and Zhang, 2010). Therefore, the study adopts the RBV as theoretical lens, as it provides a robust framework for examining the direct effects of resources and capabilities on hospital resilience as well as the mediating role of capabilities in the resources-resilience relationship.

2.3 Resources and capabilities for hospital resilience

In the hospital resilience literature there has been significant emphasis on digital technologies as key tangible resource enhancing hospital resilience, particularly in managing the growing complexity and unpredictability of healthcare (Garcia-Perez et al., 2023). Technologies such as electronic health records (EHRs), telemedicine platforms, predictive analytics, and interconnected communication systems play pivotal roles in enhancing the adaptive capacity of hospitals. These technologies enable real-time monitoring, streamlined information exchange, and data-driven decision-making, which are essential for maintaining operational continuity during crises (Khalil et al., 2022; Marques da Rosa et al., 2021; Tortorella et al., 2022). By reducing reliance on manual processes and improving data integration and analysis, they foster collaboration across departments and with external stakeholders (Ridde et al., 2023; Traverson et al., 2021).

Among intangible resources acting on hospital resilience, staff skills prove crucial being knowledge-based assets that comprise a combination of skills, competencies, abilities, knowledge, and experience that enable individuals to perform their roles effectively in adverse circumstances. Juvet et al. (2021) and Veerapen and McKeown (2021) underlined the importance of highly qualified

healthcare professionals, whose expertise was pivotal in adapting to rapidly changing conditions and addressing complex patient needs. Sabateen et al. (2022) illustrated the critical role of multidisciplinary skills among medical directors and front-line professionals in managing prolonged crises. Fagerdal et al. (2022) expanded on this by emphasizing how relational skills foster collaboration between nurses and physicians, proving essential for navigating high-pressure conditions and enhancing team-based problem-solving.

While these resources provide a critical foundation for hospital resilience, the literature increasingly underscores the importance of well-structured capabilities linked to coordination and collaborations both within and beyond hospital boundaries (Aldrighetti et al., 2019; Luke et al., 2023). In particular, this coordination capability is commonly referred to as supply chain information integration (SCII) defined in the hospital setting as the degree to which a hospital gathers, disseminates, and utilizes strategic knowledge and information, as well as fosters collaborative efforts both within internal departments and across organizational boundaries to establish inter-organizational cooperative arrangements (Flynn et al., 2010; Ralston et al., 2015). The idea behind information integration is to reap the benefits of integration in terms of effective cooperation and collaboration. It is essential to develop the process of combining data, knowledge, and information from multiple sources, such as data information systems and actors (Harland et al., 2007). Internally, strong cooperation between departments allows sharing real-time patient data and operational constraints, such as bed availability or staff schedules, allowing decision-makers to more swiftly reassign personnel to high-demand areas or coordinate medical equipment across units (Chabrol et al., 2023; David et al., 2023; Gautier et al., 2023; Lyng et al., 2022). Externally, partnerships with local authorities, neighbouring hospitals, and other regional stakeholders expand the hospital's capacity to manage surges in patient volume and overcome supply chain bottlenecks (Chen et al., 2022; Kihlström et al., 2022, 2022; Spieske et al., 2022). These collaborative efforts are particularly vital in challenging scenarios, including conflict-affected regions, where pooling resources and expertise becomes essential (Liu et al., 2020; Mohtady Ali et al., 2021; Oliveira et al., 2023; Sabateen et al., 2022).

Building on the notion of the RBV that capabilities transform resources into “actionable strengths”, namely, resources that can actively generate value and support strategic aims (Huo et al., 2016; Teece et al., 1997), this study posits that resources and capabilities do not operate in isolation, but rather interact in a complex, interdependent manner.

Table 2 provides a summary of the main resources and capabilities studied in relation to hospital resilience. Notably, none of the studies reported in Table 2 have examined all the identified resources and capabilities together or analysed the mediating effect of SCII capability in resource-hospital resilience relationship.

By examining how these elements integrate and reinforce one another towards resilience, we gain deeper insights into their role for hospital resilience as well as a new lens to interpret the disparity of hospital response to crisis.

Table 2. Review of existing research on hospital resilience, with aim, method, type of research, and main results.

Authors	Research question	Applied methodology	Research type	Organizational characteristics	
				Resources	**Capabilities**
(Khalil et al., 2022)	Lessons learnt from hospital responses to COVID-19 in the Eastern Mediterranean Region.	Empirical - Literature review	Qualitative	Teamwork; Information and communication systems; Digital technologies	Inter-organizational relationship; Collaboration
(David et al., 2023)	Operational strategies implemented by Quebec hospitals and their staff to contend with the COVID-19 crisis.	Empirical - Multiple case study approach	Qualitative	\	Internal collaboration for reorganizing human resources, tasks, and roles
(Gautier et al., 2023)	Governance strategies perceived by hospital staff in managing the COVID-19 response.	Empirical - Analysis of 177 qualitative interviews across six hospitals in Brazil, Canada, France, and Japan	Qualitative	Multidisciplinary Team; Integrated Information Systems	Inter-departmental cooperation
(Chabrol et al., 2023)	Identify the resilience capacity of a Parisian referral hospital in responding to the first three waves of COVID-19 cases.	Empirical - Observations, semi-structured interviews, focus groups, and lessons learned workshops	Qualitative	Multidisciplinary Team; Information sharing	Inter-departmental cooperation
(Oliveira et al., 2023)	Health services response to and preparation for sudden shocks and unexpected challenges during the COVID-19 health crisis.	Empirical - Single case study with data triangulation	Qualitative	Financial resources; Health professional experience	External collaboration and partnership
(Traverson et al., 2021)	Key strategies and recommendations for hospitals and professionals' resilience to the COVID-19 pandemic.	Theoretical-Scoping review of evidence on hospital and staff	Qualitative	Digital technologies (e-Health); Health professional experience;	Internal collaboration for reorganizing human resources, tasks, and roles

		resilience during the COVID-19 crisis		Information and communication system	
(Mohtady Ali et al., 2021)	Understand the construct of 'hospital resilience during disasters.	Theoretical - Systematic literature review	Qualitative	Information and communication	\
(Chen et al., 2022)	Experiences of health-care providers in Hubei, China during the early stages of the COVID-19 outbreak.	Empirical - Qualitative study using an empirical phenomenological approach	Qualitative	\	External collaboration among hospitals
(Liu et al., 2020)	Multi-objective optimization-based emergency response model enhance the resilience of the regional-level hospital network following earthquakes.	Empirical - Multi-objective optimization-based emergency response model	Quantitative	\	External collaboration and partnership; Inter-departmental cooperation
(Spieske et al., 2022)	Procurement strategies improve medical supplies availability and strengthen supply chain resilience in a pandemic.	Empirical - Multi-tier case study with semi-structured interviews	Qualitative	Digital platform	External coordination with other hospitals, pharmacies and laboratories, central warehouse
(Kihlström et al., 2022)	Facilitators and barriers to health system resilience and its responses at local and regional levels during the initial year of the COVID-19 pandemic in Finland.	Empirical - semi-structured interviews	Qualitative	\	External local collaboration and partnership; Internal collaboration for reorganizing human resources, tasks, and roles
(Marques da Rosa et al., 2021)	Explore the perceived contribution of ten digital technologies derived from Healthcare 4.0 (H4.0) to six healthcare services	Empirical - Multinational survey conducted with 109 experts, followed by follow-up interviews	Mixed	Digital technologies (Telemedicine, Digital non-invasive care)	\

(Tortorella et al., 2022)	To examine the contributions of digital applications, framed as Healthcare 4.0 (H4.0), to the resilience of healthcare organizations during the COVID-19 outbreak.	Empirical - Semi-structured interviews with senior managers from clinician and non-clinician departments	Qualitative	Digital Technologies (Telemedicine and Remote Consultations; Digital Platforms for Collaborative Sharing; Synthetic Medical Information Generation through Cloud Computing)	Inter-departmental cooperation
(Juvet et al., 2021)	To investigate the problematic real-world situations experienced by healthcare workers and their managers during the COVID-19 pandemic's first wave.	Empirical - quantitative and qualitative data collection (surveys, interviews)-thematic analysis	Mixed	Skills of extra qualified personnel; Information sharing	External collaboration and partnership; Inter-departmental cooperation
(Lyng et al., 2022)	To consolidate insights from diverse healthcare studies and contexts, aiming to offer a comprehensive understanding of resilience capacities within the healthcare sector.	Empirical – semi-structured interviews	Qualitative	Information sharing Digital Technologies	Internal collaboration for reorganizing human resources, tasks, and roles
(Veerapen & McKeown, 2021)	To explore the views and experiences of research healthcare professionals regarding their redeployment to frontline clinical roles during the COVID-19 pandemic.	Empirical – semi-structured interviews	Qualitative	Skills of extra qualified personnel	Internal collaboration for reorganizing human resources, tasks, and roles
(Fagerdal et al., 2022)	To explore and describe how leaders enable adaptive capacity in hospital teams, contributing to the overall resilience of healthcare systems.	Empirical– Case study	Qualitative	Nurse-physician skills; trust; Information sharing.	Inter-departmental cooperation
(Sabateen et al., 2022)	To assess the impact of the prolonged conflict in Palestine on managing the COVID-19 pandemic.	Empirical – Descriptive case study	Qualitative	Skills of Medical Directors, infectious disease specialists, pharmacists, front-liners, medical personnel	Internal collaboration for reorganizing human resources, tasks, and roles

3. Hypotheses development

3.1 Effects of digital technologies

Digital technologies describe a broad range of information and communication technologies that, built upon foundational pillar of IoT, big data, and cloud computing, facilitate the storage, processing, sharing, and managing data (Aceto et al., 2018). We draw from the RBV theory to explain the contribution of digital technologies to hospital resilience. All interconnected digital applications, electronics, and wireless devices are examples of digital technologies adopted and implemented in hospitals that allow for increased automation and enhanced interconnectivity among processes, products, services, and individuals (Brossard et al., 2022; Marques da Rosa et al., 2021). Employing electronic health records (EHR) is expected to enhance resilience capacity including adaptability and responsiveness to disruptions (Upadhyay et al., 2020). This improvement stems from the increased transparency, visibility, and flexibility in healthcare processes, ultimately ensuring the effectiveness of patient service delivery. A medical device traceability system facilitates the real-time monitoring of trends in materials, equipment, and processes, thereby enhancing situational awareness and improving a hospital's capacity to predict and address potential problems and disruptions (Malik et al., 2021). Moreover, digital platforms, electronic databases, and data-sharing systems for collaborative sharing of patient information promote different ways of interacting and disseminating health-related information (Tortorella et al., 2022). Similarly, digital technologies also play a connectivity role in facilitate inter-organizational communication and collaboration with external partners, such as other hospitals, suppliers, and pharmacies. For instance, supply chain applications enable transparent management of materials, products, and equipment (Zhang & Qi, 2021).

Hence, we propose:

H1. Digital technologies are positively related to hospital resilience.

H2. Digital technologies are positively related to (a) internal and (b) external information integration.

3.2 Effects of the staff skills

From an RBV perspective, a significant portion of the resources required for mitigating uncertainty and adapting to emergencies, is embedded in human resources such as employees' knowledge, skills, and behaviour, which result from complex social structures built over time and are therefore difficult to imitate (Colbert, 2004; Peng et al., 2008). The organizational resilience literature discusses staff skills in terms of the combination of capabilities, competencies, knowledge, and personal attributes that enable individuals to effectively execute their role even in adverse situations (Annarelli & Nonino, 2016; Iflaifel et al., 2020; Lengnick-Hall et al., 2011; Nyaupane et al., 2021; Shela et al., 2023). Among these staff competencies, the critical role of professional skills is recognized alongside relational skills. Professional skills encompass the specific knowledge and experience of medical staff in managing intensive care, as well as general competencies in critical thinking and problem-solving. Relational skills refer to the confidence of staff members in working in a team, along with related competencies, such as interdisciplinary collaboration and communication, and attitudes, such as emotional support and trust (Nzinga et al., 2021). Communication and teamworking enhance the contextual understanding of hospital processes by facilitating robust information exchange among different operational units within the hospital (Fagerdal et al., 2022; Juvet et al., 2021). This, in turn, can augment III, leading to the development of formal coordination mechanisms such as protocols and guidelines, and informal collaborative connections among hospital staff members (Forsgren et al., 2022; Keeley et al., 2020; Ree et al., 2021). Furthermore, a well-developed relational capacity facilitates interactions with external stakeholders such as community and local authorities, suppliers, and vendors, thereby optimizing the management of supplies and coordination of the supply network (Khuntia et al., 2022; Snowdon & Wright, 2022).

During emergencies, specific skills and experience of the medical staff are leveraged, creating teams of specialist nurses and physicians, for discussing the most effective way to assist and manage emergencies by combining their technical and leadership skills (Ladak et al., 2021; MacKinnon et al., 2022). Gupta et al. (2019) acknowledge skilled acute care nurses as a resource influencing care quality

and enhancing communication and coordination among operational units and various organizational resources, necessary for providing adequate patient care. The professionalism of medical staff significantly influences hospital decisions, often because the role of the physician extends beyond patient care to particularly affect choices and decisions regarding the selection of supplies, medications, surgical instruments, or medical implants (Falagara Sigala et al., 2022; Hannan et al., 2021; Winkelmann et al., 2022). This direct impact of physicians on procurement decisions can have significant implications for hospital resilience, as it affects resource management and the hospital's ability to adapt to unforeseen circumstances and emerging challenges (Abdulsalam et al., 2018).

Therefore, we propose the following hypotheses:

H3. Staff skills are positively related to hospital resilience.

H4. Staff skills are positively related to (a) internal and (b) external information integration.

3.3 Effects of supply chain information integration

In this study, the effects of SCII on resilience will be investigated from both internal and external perspectives, formulating hypotheses for direct relationships of both III and EII on hospital resilience. According to the RBV theory, internal and external information integration represents organizational capabilities linked to effective coordination and cooperation among critical functions within the hospital and with eternal entities (Das et al., 2006; Mandal & Jha, 2018; Peng et al., 2008). These interactions facilitate access to supplementary resources, as well as knowledge and information (Lai et al., 2013; Witter et al., 2023). The interdependence among operational units, as well as the interconnectedness between hospitals and supply chain actors, represents an integration factor that significantly influences resilience, ensuring rapid communication, and infusing agility into problem-solving processes (Ali et al., 2017; Poberschnigg et al., 2020; Scala & Lindsay, 2021). Building an integrated information system within hospitals enables improved situational awareness of operational processes, visibility of operations, and information sharing regarding different processes (Austin et al., 2022; Rubbio et al., 2019). Thus, all functions can appropriately allocate resources and maintain

comprehensive knowledge of inventory levels and patient demand. Hospitals are unable to manage complex crises when working in silos; instead, they rely on external network partners, such as other hospitals, local government, and organizations tasked with disaster response and coordination, to acquire valuable information, knowledge, and complementary resources (Gu et al., 2017; Scala & Lindsay, 2021; Zamiela et al., 2022). This external collaboration enhances the hospital's capacity to respond promptly to surges in patient demands. Collaboration contextualizes performance, enabling the monitoring of performance over time, understanding what works and what doesn't, distinguishing between high and low-performing outcomes (Howard et al., 2022). It also allows organizations to assess their positions relative to their peers. For example, cross-hospital partnerships and long-term relationships have been established not only for patient redistribution, but also to facilitate alternative sourcing through the creation of shared central warehouses for various medical products (Aldrighetti et al., 2019; Lyng et al., 2021; van den Berg et al., 2023).

Therefore, we propose:

H5. Internal (a) and external (b) information integration capabilities are positively related to hospital resilience.

3.4 The mediating effect of SCII capability in the relationship between digital technologies, staff skills and hospital resilience

The RBV underscores the need of effectively leveraging, processing and combining resources to create value and to develop capabilities (Brandon-Jones et al., 2014; Wang & Wei, 2007). Van De Wetering (2019) demonstrates that the information technology infrastructure can serve as a resource to strengthen clinical information exchange processes, enabling high levels of shareability and integration within hospitals. Digital technologies enable internal hospital operational units to engage in mutual interactions to share patient-related information and activities (Arji et al., 2023). While it is true that digital technologies can effectively facilitate the transfer of data, according to the RBV, it is equally plausible that without the presence and development of complementary coordination and

collaboration assets the digital technologies are not sufficient to enabling the exchange of clinical information. The adoption of digital technologies, thus, promotes the integration capabilities that foster a collaborative dimension which is crucial for achieving hospital resilience objectives in terms of enhancing situational awareness, transparency, and flexibility (Marques da Rosa et al., 2021; Tortorella et al., 2022). Similarly, research focusing on staff skills, in terms of relational behaviour, highlights the implications of this type of competency for hospital resilience, enabling staff timely communication, and consequently, a more rapid crisis response (Garcia-Perez et al., 2022; Upadhyay et al., 2020). Teamwork and collaboration exert a positive influence on hospital resilience within the context of relational competencies (Appelbom et al., 2021; Hines & Reid, 2021). This is because they enhance internal and external integration and coordination, thereby facilitating improved decision-making and responsiveness. Finally, the skills related to the problem-solving, finding unconventional solutions, and critical thinking, are vital for promptly responding to crises and minimizing their effects (McLeod et al., 2019). These skills are fully leveraged during multidisciplinary team meetings, that promote collaboration and knowledge exchange not only among hospital staff but also with external stakeholders such as local authorities, family doctors, external pharmacists, and suppliers (Hossain et al., 2022). The goal is to enhance awareness of hospital conditions and ensure well-informed decision-making to effectively manage crises and prevent service disruptions (Patel et al., 2021; Phattharapornjaroen et al., 2022). All these resources, both technological and related to staff skills are required to develop SCII capabilities within the hospital and to facilitate the achievement of resilience capacity. Thus, hospital resilience derives benefits in terms of enhanced adaptability and response.

In summary, we posit that hospitals that bundle digital technologies and staff skills can attain resilience performance thanks to SCII.

H6. Internal (a) and external (b) information integration mediates the relationship between digital technologies and hospital resilience.

H7. The relationship between staff skills and hospital resilience is mediated by internal (a) and external (b) information integration.

Figure 9 presents the theoretical framework that underpins this study.

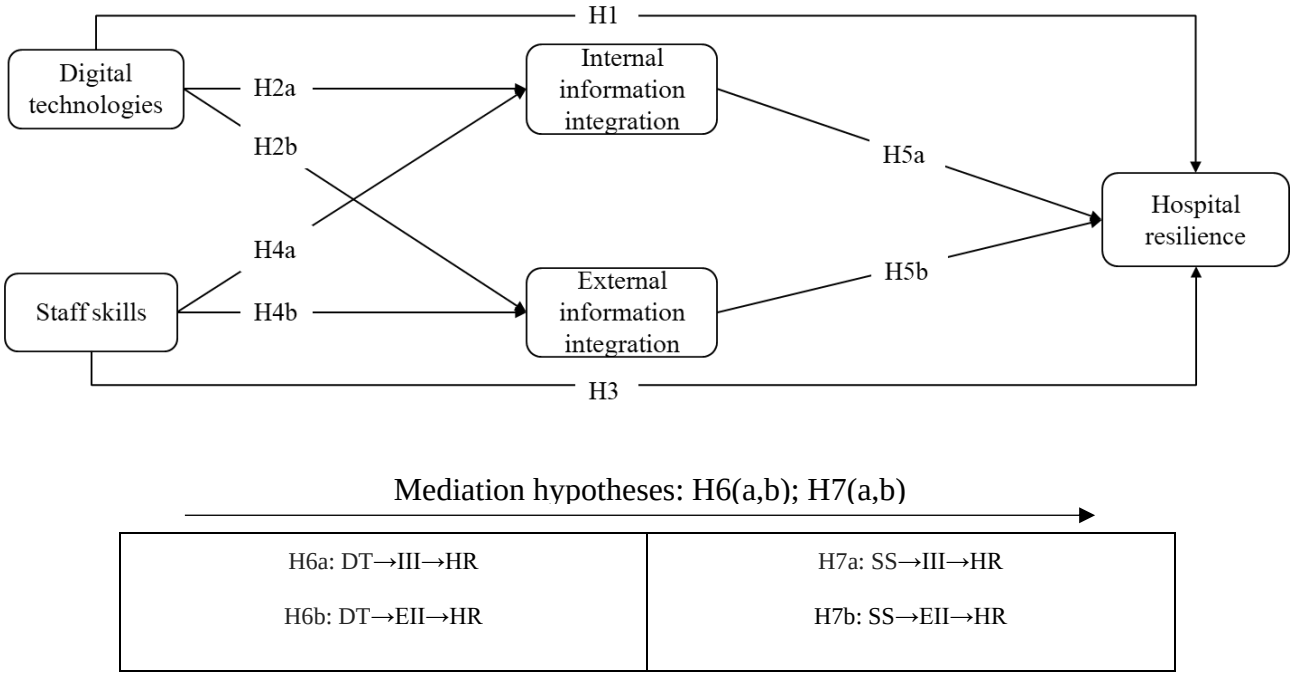


Figure 9. Research framework.

4. Methodology

4.1 Sample and Data Collection

To test the research model, we use an online survey as data collection instrument. The unit of analysis for this study was the Italian hospital. We focus on this country because it was one of the first and most affected by the pandemic at the European level, and we can test our model on the basis of a severe disruption as the Covid-19 pandemic. We selected a sample of 428 medium to large public and private hospitals across various classifications via a database hosted on the website of the Ministry of Health. In order to capture different perspectives on the hospital's organizational characteristics and their resilience we carried out a multiple informants survey (Damanpour et al.,

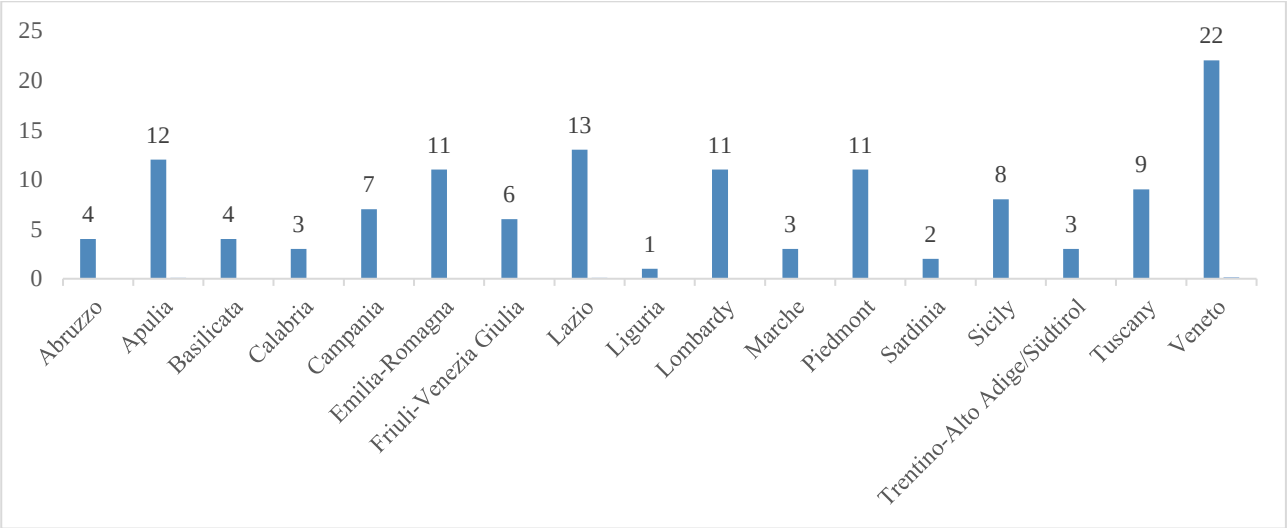
2009; Marsden et al., 2006). In particular, as key respondents we identified managers and directors at various levels within the hospital, from operational units or departments to hospital general management. These are appropriate respondents because they have in-depth knowledge about orchestrating hospital operations and wielding decision-making authority regarding hospital policies and procedures (Kakemam et al., 2020; Lee et al., 2011; Minvielle et al., 2008; Tasri & Tasri, 2020). They supervise and coordinate activities, allocate resources, manage personnel, and optimize workflow efficiency. We guaranteed anonymity and aggregated the data of respondents to ensure compliance with the privacy rules. The surveys were initially created in English and later translated into Italian, the native language of respondents. We adhered to the translation and back-translation protocols suggested by Lonner & Berry (1986). To ensure that the questions were clear and easily comprehensible to the respondents, the questionnaire underwent thorough pre-testing. Following a online mailing campaign conducted from September to October 2023, with a reminder sent after one month, 261 valid responses were collected. After the initial evaluation, the responses obtained from multiple respondents of 26 hospitals were aggregated by averaging each item (Dobrzykowski & Tarafdar, 2015). This resulted in a sample of 130 hospitals, representing nearly 30% (130/428) of the hospitals included in the sample. Table 3 presents the profiles and essential information of respondents, while Table 4 illustrates the geographical distribution of hospitals. Next, I describe the constructs' theoretical underpinnings and their operational definitions (measurement items).

Table 3. Characteristics of respondents (n=261).

Gender	Number
Male	107 (41.00%)
Female	147 (56.32%)
Not specified	7 (2.68%)
Respondent's age	
<= 30	3 (1.15%)
31-40	24 (9.29%)
41-50	58 (22.22%)
51-60	105 (40.23%)
>60	71 (27.20%)
Respondent's position	
Chief medical officer	6 (2.30%)
Department director	5 (1.92%)
Simple operational unit director	28 (10.73%)
Complex operational unit director	77 (29.50%)

Medical director	35 (13.41%)
Nurse manager	75 (28.74%)
Others	35 (13.41%)
Respondent's experience	
1-10	150 (57.47%)
11-20	48 (18.39%)
21-30	46 (17.62%)
31-40	16 (6.13%)
>40	1 (0.38%)

Table 4. Geographical distribution of hospitals (n1=130).



4.2 Measures of the variables

The questionnaire contains multi-item scales developed by prior research. To measure the constructs and variables of the research framework, we used previously validated scales, where all the items and responses appear on a five-point Likert scale to measure the questionnaire items, ranging from 1 (strongly disagree) to 5 (strongly agree). The scale for measuring digital technologies (DT) was adapted from a scale developed by (Zhang et al., 2023) and composed of 8 items. The scale for measuring the staff skills was adapted from Kakemam et al. (2020 and Kim (2020) with a total of 7 items. A total of 4 items was modelled from Li et al. (2023) for measuring the III while 3 items from Chen et al. (2013) and Li et al. (2023) were used to measure the EII. Furthermore, HR is considered to have a single dimension, as recommended by previous studies (Ambulkar et al., 2015; Brandon-Jones et al., 2014). This dimension encompasses items related to the organization's adaptability, speed of response to disruptions, and awareness of the external environment. Therefore, the scale for measuring hospital resilience (HR), adapted from Li et al. (2023), consists of 6 items.

5. Analyses and results

The research hypotheses were tested using covariance-based structural equation models (SEM) and AMOS 28 software was used for the analysis. SEM is used to simultaneously model multiple complex relationships between the observed and latent variables (Hair et al., 2021).

5.1 Measurement model

Regarding the measurement of the variables and dimensions of the research framework, DT, Staff Skills, III, EII, and HR were measured as reflective constructs. The evaluation of the measurement model by performing a confirmatory factor analysis (CFA) showed acceptable results. Our model showed good fit with the data ($\chi 2/df=1.529$; comparative fit index, CFI= 0.931; TLI= 0.917; GFI=

0.785; AGFI=0.725; NFI= 0.828; root mean square error of approximation, RMSEA= 0.064). The reliability and validity of the constructs were tested using a confirmatory analysis (Table 5). All the items had outer loadings greater than 0.60, as recommended by Hu & Bentler (1999). It is a commonly accepted value that does not affect the content validity of the scale. Second, all the constructs met the requisite of construct reliability, since their composite reliabilities, Cronbach's alpha, and convergent reliability (CR) values exceeded the 0.7 criteria. Third, the average variance extracted (AVE) values were higher than 0.5, indicating that the latent variables attained convergent validity. Finally, discriminant validity (Table 6) was tested using the Fornell-Larker criterion, where the root square of the AVE values of each construct was higher than the correlation coefficient between the latent variables. Control variables were selected to align with previous healthcare operations management studies (Dobrzykowski, 2019; Peng et al., 2020). The size of the hospital can impact economies of scale, the range of specialized services, the availability of resources, and the collaborative networks in which it is involved. The type of hospital, in terms of its teaching intensity, should be considered a control variable because teaching hospitals incur higher costs due to their educational mission. This distinction can affect resource allocation and operational complexity Ownership structure can influence various aspects, including the availability of financial resources, management of human resources, allocation of resources, and decision-making policies. Lastly, the number of physicians and nurses can impact the hospital's ability to deliver high-quality care and respond effectively to emergencies. Increased availability of healthcare staff can enhance resource management during crisis periods, allowing for better coordination of activities and more timely patient care. Moreover, the number of physicians and nurses can reflect the hospital's level of preparedness and capacity to handle critical situations, thus influencing its overall resilience.

Table 5. Measurement model results.

Construct	Factor loading	Cronbach's alpha	Composite reliability (rho_a)	Average variance extracted (AVE)
Digital technologies		0.921	0.920	0.589

DT1	0.699			
DT2	0.757			
DT3	0.828			
DT4	0.838			
DT5	0.827			
DT6	0.742			
DT7	0.684			
DT8	0.751			
Staff Skills		0.916	0.908	0.588
SS1	0.731			
SS2	0.706			
SS3	0.836			
SS4	0.867			
SS5	0.862			
SS2	0.643			
SS3	0.680			
Internal information integration		0.914	0.914	0.728
III1	0.832			
III2	0.892			
III3	0.818			
III4	0.868			
External information integration		0.882	0.894	0.741
EII1	0.865			
EII2	0.992			
EII3	0.700			
Hospital resilience		0.902	0.901	0.604
HR1	0.790			
HR2	0.857			
HR3	0.810			
HR4	0.815			
HR5	0.663			
HR6	0.709			

Table 6. Mean, standard deviation, and correlations.

	Mean	S.D.	1	2	3	4	5	6	7	8	9	10
Digital technologies (1)	3.3881	0.905	0,767									
Staff Skills (2)	3.7017	0.698	0.149	0.767								
Internal information integration (3)	3.9393	0.683	0.07	0,753	0.853							
External information integration (4)	3.5494	0.744	0.27	0.5	0,569	0.861						
Hospital resilience (5)	3.8772	0.712	0.408	0.307	0,315	0.515	0.777					
Hospital size (6)	540.68	413.22	-0.02	-0.058	-0,081	-0.033	0.02	1				
Hospital type (7)	0.10	0.301	0.018	-0.132	-0,105	-0.129	-0.024	0.416	1			
Hospital property (8)	0.16	0.369	0.156	0.197	0,121	0.154	0.173	-0.189	-0.146	1		
Number employed nurses (9)	764.59	658.15	0.03	-0.131	-0,178	-0.088	-0.04	0.922	-0.243	0.427	1	
Number employed physicians (10)	343.94	307.19	-0.051	-0.102	-0,154	-0.173	-0.07	0.838	-0.212	0.398	0.794	1

Note: The square root of AVE of the reflective constructs (DT, Skills, III, EIII, HR) is shown on the diagonal. Inter-construct correlations are shown off the diagonal.

5.2 Structural Model

The results shown in Table 7 suggest that most of the structural model's goodness-of-fit (GOF) values align with the recommended threshold values. This indicates the successful fit of the structural model (Hair, 2011). Figure 10 summarises the results of the direct hypotheses.

In Table 8, the findings of direct effects between the main constructs of the study show that the construct DT was strongly and positively linked to HR ($p<0.000$) supporting H1 as well as the EII, supporting H2b. In contrast, staff skills do not appear to have any significant effect on HR, but significantly impact III and EII, thus supporting hypothesis H4a and H4b. Differently from III, EII significantly influenced HR ($p < 0.000$). Regarding the indirect effects and mediation analysis, EII functions as a mediator, particularly as a partial mediator in the link between DT and HR, and as a full mediator in the connection between staff skills and HR. These findings support hypotheses H6b and H7b.

Table 7. Goodness of fit values of the structural model.

Mode	χ^2/df	P	GFI	AGFI	CFI	TLI	NFI	RMSEA
	<3.0	≥.0.5	≥.90	≥.80	≥.90	≥.90	≥.90	≤.08
Final structural model	1.552	.000	.782	.723	.928	.913	.824	.065

Table 8. Path coefficients of the structural equation model.

Relationship	Direct effects	T statistics	Indirect effects	Confidence interval	
				Lower bound	Upper bound
Direct effects					
H1. DT → HR	0.273 (0.000)***	3.330			
H3. Skills → HR	0.037 (0.814)	0.236			
H2a. DT → III	-0.006 (0.926)	-0.1			
H4a. Staff Skills → III	0.721 (<0.000)***	6.802			
H2b. DT → EII	0.191 (0.012)**	2.513			
H4b. Staff Skills → EII	0.488 (<0.000)***	4.88			
H5a. III → HR	0.019 (0.897)	0.126			
H5b. EII → HR	0.366 (<0.000)***	3.66			
Control variables					
Size→HR	0.001 (0.151)				
Type→HR	0.054 (0.716)				
Property→HR	0.102 (0.562)				
N° nurse→HR	0.000 (0.165)				
N° physicians→HR	0.000 (0.816)				
Indirect effects					
DT → III → HR		0.000	0.000 (0.960)	-0.027	0.022
Staff Skills → III → HR		0.001	0.014 (0.837)	-0.203	0.143
DT → EII → HR		1.25	0.070 (0.040)**	0.001	0.232
Staff Skills → EII → HR		2.29	0.179 (0.001)***	0.063	0.401

Note: n.s.= non-significant; DT=digital technologies; III=internal information integration; EII=external information integration; HR=hospital resilience. + p≤0.10; * p≤0.05; ** p≤0.01; *** p≤0.001.

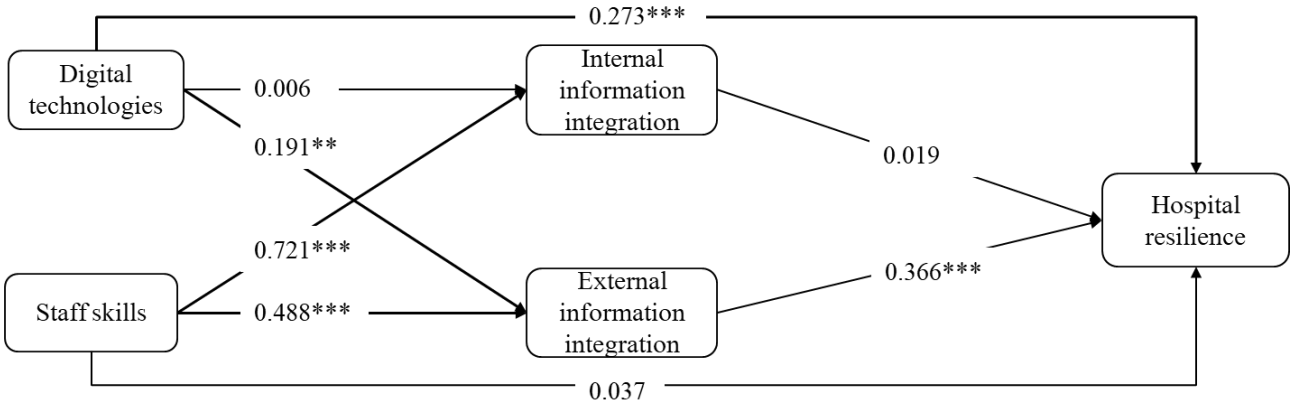


Figure 10. Summary of SEM results for direct hypotheses.

5.3 Common Method Bias

Common method bias assesses the correlation between observable variables. Typically, it is necessary to conduct this test when both dependent and independent variables are captured using the same response method. To address concerns about common method variance bias, we performed a Harman's single-factor test on the complete survey data set (Podsakoff et al., 2003). In line with the approach recommended by Lindell and Whitney (2001), we assessed common method bias within a structural equation modelling (SEM) framework using Amos 28. This involved creating a latent variable representing common method variance and regressing it onto all directly measured variables within the model. This confirmatory test serves to assess the fit of a one-factor model, whereby a worsening fit serves to refute CMB. The model fit of the one-factor model is χ^2=1426.151, df=334 and χ^2/df=8.30 compared with χ^2/df=4.270 of the measurement model. Also, an evaluation of the other fit indices reveals values much worse for the unidimensional model, suggesting that common method variance is not a concern in this study. Moreover, all the items are loaded on five different factors in the exploratory factor analysis (EFA). Furthermore, we address the potential for endogeneity both from the perspective of research design and through empirical testing. The endogeneity test assesses whether the independent variable is correlated with the error term of the dependent variable, in other words, it serves to determine whether the independent variable is actually

caused by the dependent variable or if there is another cause. From a theoretical perspective, we rely on the idea that previous research has highlighted the positive effects of the resources and capabilities considered in the study, such as the use of DT, the presence of a skills, and both internal (III) and external (EII) integration capabilities on organizational resilience in various contexts. To test endogeneity, we evaluated the risk of omitted variables bias and the simultaneity, namely the possibility of reverse causality. Regarding the first test for omitted variables bias, we incorporated a range of control variables that could potentially affect both the dependent and independent variables. Regarding reverse causality, we believe that a high level of adopted and implemented resources and developed capabilities, obtained over time, may lead to improvements in HR. However, it is unlikely that HR simultaneously determines such resources and capabilities, as they are influenced by various organizational factors such as corporate culture, personnel management policies, and investments in technology. In other words, a resilient hospital may not necessarily be effectively integrated in terms of information flow, communication, and coordination, nor may it have effectively implemented technological resources or utilized staff skills.

6. Discussion

Enhancing HR in the face of disruptions is a critical global challenge, particularly amid climate change and infectious health risks. This study developed and empirically tested the research framework depicting the relationship between resources, capabilities, and HR. Each subsection will examine the results and provide explanations for the support or lack of support for the hypotheses.

Our findings highlight that digital technologies serve as a critical resource for hospital resilience, exerting both a direct influence (H1 confirmed) and an indirect effect mediated by external information integration capabilities (H6b confirmed). This aligns with previous research that highlights the importance of digital technologies in enabling collaborative sharing of patient data, remote consultation, and enhanced information flow, all of which improve hospital capacity to adapt

and respond to crises (Fallah-Aliabadi et al., 2022; Sari et al., 2023; Tortorella et al., 2021). Moreover, our results address the calls in prior studies for further empirical investigations into the role of digital technologies in fostering hospital resilience, particularly in the context of the COVID-19 pandemic (Arji et al., 2023; Ignatowicz et al., 2023; Thirumalai and Devaraj, 2024; Wiig et al., 2023). Investigating the mediating role of SCII, the study offers an important mechanism through which the impacts of digital technologies on hospital resilience can be realized. In particular, confirming H6b, the results reinforce the notion that external information integration partially mediates the digital technologies-hospital resilience link, suggesting that the role of digital technologies in fostering hospital resilience emerges also through their ability of supporting coordination mechanisms with suppliers, other hospitals, and external stakeholders. During the pandemic, hospitals faced unprecedented uncertainty that extended beyond organizational boundaries, not only in managing surges in patient volume, but also addressing disruptions within the supply chains. In this vein, digital technologies played a crucial role in supporting collaboration with suppliers to secure new stock and establish alternative supplier relationships (Liu et al., 2020; Mervyn et al., 2019).

Interestingly, our results do not report a significant mediating role of internal information integration in the relationship between digital technologies and hospital resilience (H6a is not supported). This may be interpreted in light of the specific context of our analysis linked to an unpredictable disruption such as COVID-19 pandemic. In fact, although cross-functional coordination as well as the collection and exchange of information and data enabled by internal information integration capability can be expected a valid mechanism through which digital resources are used to cope with “normal” crisis (Benevento et al., 2024; Raimo et al., 2023), this was not so significant during crises or emergencies such as the pandemic. In this special time, instead, hospital needed to be well-integrated with external entities in order to better leverage digital technologies to enhance their ability to respond crisis or emergencies such as the pandemic.

In addition to the role of digital technologies, the study examines the relationship between staff skills and hospital resilience. We do not find a significant direct effect of staff skills on hospital resilience (H3 is not supported). This means that, while staff skills are essential for ensuring high-quality patient care (Boyer et al., 2012) and facilitating decision-making related to internal resource management (Fagerdal et al., 2022; Forsgren et al., 2022), their direct impact on resilience may be less pronounced due to several difficulties and stress experienced by staff during unpredictable crises as COVID-19 pandemic (Lou et al., 2022), which can hinder their ability to effectively contribute to broader organizational resilience (Achour et al., 2022). Interestingly, the confirmation of H7b demonstrates that staff skills impact on resilience becomes significant only in presence of external integration. This is an innovative result in the hospital resilience literature, which is enriched by the empirical evidence that staff skills represent a key resource for hospital resilience only in hospitals that are externally integrated. This means that cooperation and coordination with external stakeholders is a valid mechanism though which leverage staff skills to effectively manage crisis during special events such as the pandemic. The delivery of healthcare services is inherently complex, often chaotic, and frequently uncoordinated, involving numerous handoffs and transitions that can delay care, waste precious resources, and result in information asymmetries (Peng et al., 2023). These effects become even more pronounced during crisis. Achieving efficient synergies in quality management during crises requires staff skills, related to experience, expertise, mutual trust, and respect, that can drive seamless communication and coordination with external stakeholders (Vafaei-Zadeh et al., 2020b). This enables a higher level of information sharing among partners, fostering more targeted decisions regarding resource management, patient transfer needs, and care prioritization, thereby mitigating the impact of the crisis (Lin and Fan, 2024).

Lastly, the study sheds light on the relationship between information integration capabilities and hospital resilience. Specifically, our findings confirm the significant positive impact of external information integration on hospital resilience (H5b). Interestingly, however, the results did not indicate a significant direct impact of internal information integration on hospital resilience (H5a).

As previously explained, internal information integration represents operational capabilities that enable hospitals to perform basic functional activities, while external information integration represents a strategic capability that enable hospitals to improve activities by addressing the complexity of external environments that becomes amplified during crises. This highlights the limitations of internal integration in addressing the broader, system-level demands posed by crises.

The positive impact of external information integration on resilience suggests that, particularly in times of crisis, such as natural disasters and health emergencies, establishing collaborative networks, in order to cooperate sharing resources and information, represents a more effective governance structure. This approach of establishing collaborative network encompasses all organizations responsible of managing an emergency and involves mobilizing efforts in response to diverse crisis events by sharing information, financial and human resources, and expertise (Dobrzykowski, 2019; Pamucar et al., 2022). These efforts enable hospitals to enhance their responsiveness and adaptability during crises by ensuring the timely availability of resources and fostering more resilient supply chains (Nan and Tanriverdi, 2017; Shaker Ardakani et al., 2023; Spieske et al., 2022). These results are in line with the findings of the study developed by Dias and Escoval (2012) who emphasized that, during the economic crisis of 2008, hospitals responded most effectively non only by enhancing innovation through technological advancements, but also by implementing organizational changes aimed at fostering external collaboration with institutions and organizations possessing complementary expertise or addressing gaps within the hospital.

Finally, our findings show that digital technologies and external information integration play a crucial role in achieving resilience regardless of hospital size, teaching status, ownership and number of physicians and nurses employed (all the control variables considered in the study are not significant). This means that digital technologies adoption for enhancing resilience are consistent across small and large hospital, teaching and non-teaching, and public, private, and non-profit hospitals. This finding differs from Butkus et al. (2023), who reported that the benefits of resources for resilience tend to be greater in large hospitals compared to smaller ones. Instead, our results align

with the findings of Neupane et al. (2024), who assert that the ability to integrate with external entities to manage overcrowding and enhance resilience is consistent regardless of the hospital's type or ownership structure.

6.1 Contribute to theory

The study involves several theoretical implications to the literature. First, drawing from the theoretical framework of Resource-Based View (RBV), this study offers a novel perspective on the combined contributions of hospital resources and capabilities for achieving hospital resilience. We regard digital technologies and staff skills as resources, the supply chain information integration (SCII), in the form of internal and external information integration, as capabilities and hospital resilience as an outcome. We add empirical results to the discussion about the direct impact of resources and capabilities on hospital resilience, reporting the significant direct effect of digital technologies and external information integration (EII) towards hospital resilience. The lack of a significant result regarding the impact of internal information integration (III) capability on hospital resilience raises questions about the broader theory of information integration, which posits that both internal and external integration capabilities work to enhance resilience (Amoako et al., 2022; Chunsheng et al., 2019; Zhao et al., 2011). Specifically, III is theorized to play a crucial role in processing and disseminating information received from external sources within the hospital, thereby supporting organizational adaptation and response during crises (Schoenherr and Swink, 2012; Zhao et al., 2011).

Second, focusing on the RBV that posit that resources act as the foundation for developing valuable capabilities (Brandon-Jones et al., 2014; Huo et al., 2016; Teece et al., 1997), the study confirms that digital technologies serve as antecedents for the development of EII, while staff skills contribute to the development of both internal and external information integration capabilities. This result aligns with the findings of prior research (Amoako et al., 2022; Chen et al., 2013; Li et al., 2009) which suggest that the adoption of digital platform proved instrumental resources in facilitating the exchange

of information and coordination with external stakeholders, such as hospital managers, external pharmacists, local authorities.

Third, the study contributes to the literature by validating the role of SCII capability in the context of hospital resilience (Junaid et al., 2023; Scala and Lindsay, 2021; Senna et al., 2023). Specifically, the study empirically examines and confirms the resource-capability-resilience model within a hospital setting, highlighting the mediating role of EII in the relationship between digital technologies and hospital resilience, as well as between staff skills and hospital resilience. We, thus, emphasize the need for future studies to examine the role of different external actors for hospitals operating in challenging situations.

6.2 Contribute to practice

Given the financial strains on healthcare budgets in Europe and worldwide, resulting in reduced capital spending in healthcare systems, it is crucial to grasp the key resources affecting hospital resilience (Boeriu, 2018; Brende and Sternfels, 2023). First, our study shows relevant role of digital technologies for hospital resilience. Based on these results, hospital managers should direct their investments towards resources related to digital technologies in order to be better prepared to deal with disruptions. The recent pandemic crisis has ushered in a widespread acceptance of telemedicine and other digital innovations in medicine, changing the rules of the healthcare service. This study underscores the importance of pursuing this direction of digital transformation in healthcare to strengthen hospital resilience in future crises (Di Natale et al., 2024). The study also demonstrates that digital technologies contribute to hospital resilience through collaborative behaviours with external stakeholders. Considering that healthcare data is characterized by a large number of dimensions, a constantly changing set of attributes, and the need for near real-time data transmission (Calciolari and Buccoliero, 2010), hospital managers should consider that it is necessary for the digital technologies to be developed and well-aligned with external stakeholder to ensure efficient transmission of patient information during crisis (Raimo et al., 2023). Moreover, our findings suggest

that staff skills serve as antecedents for both internal and external information integration capabilities. These findings suggest that hospitals should invest in continuous training programs to enhance the skills of their staff, not only in clinical expertise but also in communication, collaboration, and decision-making. Hospital leadership should cultivate a culture of trust, teamwork, and mutual respect. Such a culture can amplify the impact of staff skills by promoting effective information sharing and coordination, which are critical for both internal and external integration. Finally, our findings reveal that external information integration positively impacts hospital resilience and serves as a mediating factor in the relationship between digital technologies, staff skills, and hospital resilience. External integration is a complex endeavour, and its benefits are best achieved when the risks are shared among interdependent actors (Titah et al., 2016). These results suggest that hospital managers need to develop strong collaborative capabilities with external stakeholders to effectively absorb shocks and respond to crises, replacing the fragmented and competitive nature it has always had (Ivankovic et al., 2023), and ensuring better coordination and resilience in challenging circumstances. By leveraging external networks, hospitals can tap into a wealth of knowledge, expertise, and innovative solutions that may not be readily available internally. Additionally, fostering external partnerships promotes a culture of openness, collaboration, and continuous learning within healthcare organizations, ultimately contributing to improved clinical quality and overall resilience. This approach of establishing collaborative network encompasses all organizations involved in managing an emergency and involves mobilizing efforts in response to diverse crisis events by sharing information, financial and human resources, and expertise (Dobrzykowski, 2019; Pamucar et al., 2022).

7. Future direction and conclusions

The purpose of the study was to explore how key resources, such as digital technologies and staff skills, alongside supply chain information integration (SCII) capabilities, directly impact hospital resilience Additionally, the study aimed to understand how resources contribute to the development

of capabilities to achieve resilience, framed within the Resource-Based View (RBV) theory. Despite the growing interest in hospital resilience, there remains a lack of empirical studies investigating the mechanisms through which resources influence resilience via internal and external information integration capabilities. Based on a sample of 130 Italian hospitals, the study empirically examined the impact of digital technologies staff skills, internal and external information integration on hospital resilience. Our results show a direct impact of digital technologies on hospital resilience, demonstrating the benefits of digital transformation in healthcare. Additionally, our results show staff skills are positively related to both internal and external information integration, suggesting the relevance of expertise and relational attitude of hospital staff in fostering integration withing the hospital and with external stakeholders. Crucially, the results of the study highlight the central role of external information integration capability that not only impact directly on hospital resilience but has a mediator role. External information integration partially mediates the relationship between digital technologies and hospital resilience as well as fully mediates the relationship between staff skills and hospital resilience.

As with any research endeavour, this study has its limitations. While this study focuses on constructs widely recognized in the literature as critical to hospital resilience, such as digital technologies, staff skills, and supply chain information integration, we acknowledge that other factors, including leadership, organizational culture, and emotional skills, may also significantly influence resilience. Future research should incorporate these dimensions to provide a more comprehensive understanding of the mechanisms underlying hospital resilience. Additionally, this study was conducted in Italy, one of the first and most heavily affected countries by the COVID-19 pandemic. Future research could extend these findings by examining hospital resilience in different national contexts to explore potential variations and generalizability across diverse healthcare systems and crisis scenarios. Another limitation of this study is the timing of data collection, which occurred during the pandemic. While this allowed us to capture unique perspectives and insights relevant to crisis scenarios, it may

also have influenced respondents' perceptions, potentially introducing bias related to the extraordinary circumstances of that period. Future research could address this limitation by employing longitudinal studies to track the evolution of hospital resilience over time and across different phases of crises. Based on the findings of this study, further investigations are needed to explore future directions in the field of hospital resilience. Considering that digital resources are crucial for transformation in the healthcare sector and that digitalization is the primary driver of long-term productivity growth, providing agility and speed to organizations, it is essential to examine when and how to manage this innovation to gain a better quality and efficiency in service delivery. Future research should also examine how the implementation of digital technologies affects patient outcomes, including recovery rates, patient satisfaction, and overall quality of care. Study the role of digital technologies in fostering patient-centric approaches to care, and how these approaches contribute to hospital resilience by improving patient engagement and self-management during crises.

This study explored the impact of organizational characteristics on hospital resilience, as such adopted the theoretical lens of the RBV that provides a solid foundation for understanding organizational factors influencing resilience and their interrelationships. Future research could extend the analysis accounting for the context or the condition that can influence how hospitals manage crises. For that, by adopting the lens of Contingency theory future research should delve into the effects of contingencies, such as hospital type, service complexity, and size, on the relationship between resources and capabilities and resilience. Given that the pandemic caused significant shifts in demand and supply also in the healthcare sector, altering resource dependencies within the supply chain, and considering the findings of this study demonstrates how hospitals rely on external resources acquired through transactional exchanges with other social actors (Tashman, 2021), future research could apply Resource Dependence theory to explore how resource dependencies and power dynamics evolve and intertwine with suppliers, government agencies, and other external actors during different stages of a crisis. Finally, considering that resilience is intrinsically linked to the acquisition and exchange of substantial volumes of information to mitigate the uncertainty in order to build

resilience, it is critical to improve information-related processes. Future studies could employ Organizational Information and Process theory to examine how hospitals can better manage the processes of acquiring, coordinating, and utilizing information. This would offer practical insights into optimizing information management to support resilience and ensure effective responses during times of crisis.

Chapter 3

Antecedents of hospital resilience: integrating resources, capabilities, and contingencies

Abstract

Hospitals play a crucial role in society, particularly during disruptive events like crises and emergencies. In the recent research programmes, hospital resilience is defined as the ability to maintain essential healthcare functions and to ensure the continuity of high-quality services to patients, even in the event of disruption. Efforts have been made to examine both successes and failures in achieving hospital resilience, particularly in response to recent crises. Hospital resources such as the utilization of information and communication technologies (ICTs) and digital skills, along with the enhancement of information integration capabilities, are identified as critical resources. However, the literature shows heterogeneous results on the relationships between these resources and capabilities, often due to contextual differences linked to both strategic and operational characteristics. The purpose of the paper extends beyond providing empirical validation of the relationships between these resources and capabilities and hospital resilience. From the perspective of the contingent resource-based view (CRBV), it also studied the moderating effects of operational contingencies in terms of service complexity (service variety and case mix index) and operational efficiency (average length of stay, bed occupancy rate, and turnover interval). Using a data set composed of primary survey data and secondary data, the study empirically tested and validated the research model employing hierarchical moderated regression analysis. The results confirm the direct relationship between all resources and capabilities and hospital resilience. Regarding moderating effects, the relationships between ICTs and digital skills, and hospital resilience are moderated by operational efficiency, while service complexity influences

only the relationship between internal information integration capabilities and hospital resilience. The results do not indicate a moderating effect of operational efficiency in the relationships between internal and external information integration capabilities and hospital resilience, suggesting that hospital managers should invest in practices that foster internal and external cooperation and collaboration to enhance resilience, regardless of operational efficiency levels. Furthermore, they should consider that the impact of ICTs on resilience varies depending on operational efficiency rather than service complexity. This highlights the importance of aligning ICT implementation with operational efficiency strategies to maximize their contribution to hospital resilience. Similarly, the relationship between digital skills and hospital resilience also varies depending on operational efficiency, while it is not influenced by service complexity.

Keywords: *hospital resilience, hospital contingencies, contingent resource-based view, information integration, information and communication technologies*

1. Introduction

During times of crises, hospitals assume a central role as the primary responders and especially in such times, their responsibility of ensuring the safeguarding and safety of public health remains more urgent than ever (Thune and Mina, 2016). The evolving healthcare landscape, marked by challenges such as pandemics, natural disasters, and increasing patient demands, poses increasing challenges for hospitals in ensuring timely and efficient healthcare services. Hospital resilience represents an emerging area of research properly aimed at understanding and improving the hospital functioning to address the numerous disruptions and risks that can compromise the effectiveness of healthcare delivery systems (Khademi Jolgehnejad et al., 2021; Ridde et al., 2023; Wiig et al., 2020). Drawing primarily from traditional concepts of safety management and resilience engineering, hospital resilience commonly refers to the ability of hospitals not only to withstand and absorb the challenges posed by unforeseen events but also to swiftly adapt and respond with effective strategies and

operations, ensuring the continuous delivery of essential patient care (Capolongo et al., 2020; Sari et al., 2023; Seyghalani Talab et al., 2024). The topic of resilience in healthcare has primarily focused on developing frameworks that provide a comprehensive representation of the concept within the healthcare context. These frameworks aim to capture factors, indicators, resources, capabilities, and elements that characterize organizational dimensions, including aspects related to the organization itself, personnel, environment, and behaviours (Barasa et al., 2018; Carbonara et al., 2024; Iflaifel et al., 2020; Lyng et al., 2022). Their implementation has driven advancements such as telemedicine, virtual consultations, and remote monitoring, which alleviate pressure and reduce congestion of hospital operational units, and enhance the flexibility and adaptability of service delivery, across geographical barriers (Benedictis et al., 2020; Cerchione et al., 2023; Nielsen et al., 2023; Tortorella et al., 2022; Chakraborty et al., 2021). Other studies suggested that hospital resilience is influenced not only by ICTs but also by the health literacy and digital skills of key hospital staff (Garrido-Moreno et al., 2024; Hansen et al., 2024; Nguyen et al., 2014). These competencies enable a shift in working methods from physical tasks to technical or technology-supported activities (Gu et al., 2023; He et al., 2022). Since the pandemic, interactions with patients through digital tools have significantly increased, making digital skills essential for optimizing patient data management. Digital skills equip hospital staff with the ability to identify potential issues and develop alternative and creative solutions to overcome such obstacles (Koebe and Bohnet-Joschko, 2023). Shifting the focus to the role of capabilities in enhancing hospital resilience, researchers have recognized the importance of internal and external information integration capabilities. These refer to the processes by which organizations obtain, disseminate, and implement accurate and timely information to facilitate the coordination of activities both internally, within internal hospital operational units, and externally across hospital partners (Flynn et al., 2010; Huo et al., 2016; Schoenherr and Swink, 2012). The role of III capability for resilience derives from the interdependence among operational units and the consequent necessity of using information sharing as a means to achieve coordination among physicians, nurses, and staff in order to absorb and quickly adapt to the crisis, delivering timely care (De La Garza and Lot, 2022;

Donelli et al., 2022; Gifford et al., 2022). Similarly, external information integration capability significantly enhances resilience through regional collaboration among hospitals, which has proven to be an effective strategy for mitigating crises. By facilitating patient transfer, resource sharing, and partnerships with external pharmacies, regional hospital collaborations have optimized resource allocation and improved response coordination (Bohnett et al., 2022; Chen et al., 2022; Shahverdi et al., 2020). Despite the acknowledged role of the aforementioned organizational resources and capabilities on hospital resilience, findings in this realm remain heterogeneous and sometimes contradictory (Grego et al., 2024; Hillmann, 2021), showing a variability in the effect of resources and capabilities on hospital resilience. In some cases, the adoption of mobile devices can generate operational inefficiencies, cause delays, and malfunctions that slow down the care process and increase the risk of adverse events (Austin et al., 2022; Roffia and Dabić, 2024). The rigidity of digital systems can prompt workers to bypass standard processes, increasing the risk of errors and reducing overall effect on resilience (Saurin et al., 2024). Similarly, the effects of information integration capability are equally heterogeneous, proving to be more critical in some contexts than others. Its contribution to resilience depends on how work is structured across various levels, disciplines, and departments, as well as on specific structural and operational constraints unique to each hospital (Tarifa-Fernandez and De Burgos-Jiménez, 2017). The variability in the impact of resources and capabilities on hospital resilience can be traced back to differences in contextual factors that shape the implementation of ICTs, the digital skills levels of staff, and the development of information integration capabilities for hospital resilience (Raimo et al., 2023; Rayburn and Gayle Rayburn, 1991; Tortorella et al., 2020).

Among these contextual factors, hospital size, age, bed capacity, ownership, geographic location, and teaching status, constitute strategic contextual factors, namely, characteristics that can be modified over the long term, while the complexity of services provided, the complexity of patients treated, and operational efficiency constitute operational contextual factors, namely, characteristics

related to daily routines, procedures and operations in the hospital setting which can be adjusted in the short term (Parast, 2022).

Whilst there is a rich body of literature on the role of key resources as ICTs and digital skills and internal and external information integration capabilities in enhancing hospital resilience (Atighechian et al., 2024; Khademi Jolgehnejad et al., 2021), studies on the role of contextual factors in building hospital resilience through resources and capabilities are rare, mainly focus on a specific set of contextual factors and remain only at a conceptual level. For example, in examining the relationship between ICTs and hospital resilience, Tortorella et al. (2021) suggested to consider hospital size, type, and geographic location, since they can act as moderators and impact on the strength of this relationship. Lyng et al. (2022) explained that the effect of several resource and capabilities, such as new technology, skills, and communication, on resilience highly depend on the hospital context. These few contributions, however, focus on a set of strategic contextual factors, highlighting the need to take an additional step by investigating the impact that others contextual factors (Contandriopoulos et al., 2018; Cristian, 2018; Ignatowicz et al., 2023; Sari et al., 2023; Parast, 2022), acting on a more operational level, such as operational efficiency and service complexity, may have on the relationship between hospital resources and capabilities and resilience (Agostini et al., 2023; Chakraborty et al., 2021; Foroughi et al., 2022; Ignatowicz et al., 2023). Investigating the role of operational contextual factors in organizing resources and capabilities towards resilience in the hospital setting remains crucial because it can provide valuable insights onto the dynamics of hospital operations and how they influence hospital resilience (Donelli et al., 2022; Foroughi et al., 2022). Among these, hospital operational efficiency, which involves ensuring timely access to care and reducing waiting times, all while providing high-quality services and appropriate treatments at the lowest possible cost (Yaduvanshi & Sharma, 2017), can in fact significantly influence the availability and readiness of resources and capabilities during times of crisis (Essuman et al., 2020).

While the optimization of resources may provide immediate advantages under normal conditions (Wikner et al., 2017), excessive operational efficiency can limit a hospital's ability to adapt swiftly to disruptions. Resources, such as ICT systems and healthcare staff, are often utilized to their maximum capacity, leaving little room for reallocation during crises or emergencies. This rigid allocation of resources leaves little operational margin available, thereby hindering the hospital's ability to absorb shocks or respond dynamically to unexpected challenges (Frangeskou et al., 2024). Moreover, service complexity, which characterizes hospitals providing complex services often depend on standardized care protocols and strict procedures to ensure patient safety and uphold high-quality treatment outcomes, may also influence of resources and capabilities on hospital resilience. In fact, although these structured approaches are essential under normal operating conditions, they can limit the flexibility of leveraging resources and capabilities during crises in order to achieve resilience (de Arquer et al., 2022).

Hence, we argue that examining the effects of operational contextual factors, as operational efficiency and service complexity, on the relationship between resource and capabilities and hospital resilience, is a critical area of inquiry and gaining a deeper understanding of these contextual factors can effectively guide and support the targeted implementation of resilience practices, ensuring their successful application (Hodgins et al., 2021).

In light of the above motivation, the study aims to answer the following research question (RQ): What is the influence of operational contextual factors on the relationship between resources, capabilities and hospital resilience?

In addressing this research question, the study adopts the Contingent Resource-Based View (CRBV) theory, which properly explains why organizations may achieve different value for resilience even if employing the same resources and capabilities (Hick et al., 2022), linking these different outcomes to contextual factors, i.e., contingencies.

The study contributes to the literature by addressing the need for further empirical research on hospital resilience. It is innovative in its application of the CRBV theory to hospital management

and hospital resilience literature as it extends the analysis of the RBV to hospital resources and capabilities, considering the contingent effects of service complexity and operational efficiency.

These contributions have significant practical implications for hospital administrators and policy-makers. Conducting detailed analyses of specific needs and contingencies allows hospitals to better investments, facilitating effective resource allocation, and thereby enhancing overall preparedness and response for future crises. The remainder of the paper is structured as follows. The next section provides a theoretical background on hospital resilience and CRBV theory. In the subsequent section, the framework inspired by the CRBV is presented along with the research model and hypotheses. Following this, we describe the methodology, with insights into sample and data collection and measurement methods. Next, we present the main findings. Finally, the conclusions and implications deriving from the study are discussed in the last session.

2. Theoretical background

2.1 Hospital resilience

The concept of hospital resilience has gained increased prominence in the global healthcare sector in recent years, driven by a series of shock events that have significantly affected the overriding goal of maintaining the continuous delivery of healthcare services to patients (Sari et al., 2023). Many definitions of resilience in healthcare and hospital settings have been adapted from previous studies, borrowing concepts and approaches of resilience from other disciplines such as psychology, ecology, safety management and resilience engineering (Turenne et al., 2019). This cross-disciplinary integration has resulted in a widespread use of terminology and a proliferation of varying definitions (Wiig et al., 2020), see Table 9 below.

Table 9. Definitions of hospital resilience in previous studies.

Authors	Resilience definitions
(Seyghalani Talab et al., 2024)	Hospital resilience is the *capacity* of hospitals to *withstand, assimilate, and respond* to the impacts of critical situations, while ensuring the continuous delivery of essential healthcare services.
(Ignatowicz et al., 2023)	Resilience describes the *intrinsic ability* of a system to *adjust* its functioning before, during, or after disruptions and changes, allowing it to maintain essential operations in both anticipated and unforeseen circumstances.
(Barbash and Kahn, 2021)	Resilient hospital can provide high-quality care for infected patients while also preserving care standards for oncological and chronic patients. These hospitals *anticipate* and *mitigate* the impact of challenges, *adapt* and *absorb* unexpected shocks despite thorough planning, and *explore multiple solutions and quickly modify strategies* when initial plans prove insufficient.
(Ridde et al., 2023); (Traverson et al., 2021)	Resilience refers to the *capacities* of a hospital *facing* shocks, stress or chronic destabilizing tensions, to *absorb, adapt and/or transform* as necessary to maintain and/or improve universal access to comprehensive, relevant and quality health care.
(Pishnamazzadeh et al., 2020)	Hospital resilience refers to the *bounce back* of a *system or an entity* following a disaster, in order to *rapid response* to unfavourable events, and *system ability* to reduce failures.
(Blanchet et al., 2017)	Resilience of a health system refers to the capacity to *absorb, adapt and transform* when faced with a shock like a pandemic, natural disaster, armed conflict, or financial crisis, while still maintaining control over its structure and functions.
(Foroughi et al., 2022)	Hospitals are resilient if they can *absorb* and recover from shocks in the short term while positively *adapting* and *transforming* its structure over the long term to adapt to changes and sustain its peak performance.
(Ali et al., 2022)	Hospitals are disaster-resilient when they can *withstand* the effects of disasters, reduce mortality and morbidity, and *maintain* the same level of patient services in terms of quality and frequency as they do under normal conditions.
(Cimellaro et al., 2018)	Hospital disaster resilience is the capacity to *prepare* and *plan* for, *absorb* and *recover* from catastrophic events, and maintain essential operations under both anticipated and unforeseen conditions.

Building on the taxonomy of safety science resilience, which identifies the capacities to anticipate, monitor, respond, and learn (Hollnagel et al., 2006), definitions of hospital resilience encompass a broader range of capacities (see Table 10). While the most common, among these, involve the abilities to absorb, adapt, and reactive ability to transform, Barbash and Kahn (2021) and Cimellaro et al. (2018) also highlights the proactive anticipatory ability. These capacities enable hospitals to maintain high-quality, patient-centred care using the same level of resources and capabilities, adjust their internal structure, or transform functions and structure in response to a changing environment. In this chapter, the focus is on examining the impact of contingencies on relationship between resources and capabilities and resilience during and immediately following a crisis. Consequently, my interest lies not in the level of preparedness that hospitals achieved prior to the crisis, but in what becomes essential once the crisis has occurred, and so their capacity to absorb, adapt to, and respond to crises effectively. To define, operationalize, and apply the concept of resilience within healthcare research, it is crucial to address a set of core questions that help in delimiting the research on this topic (Wiig et al., 2020). First of all, it is crucial to define what a hospital needs to be resilient against. Crises can refer to adverse events such as failures, chronic diseases, or errors (Anderson and Watt, 2020; Ellis et al., 2019), as well as disruptive crises like pandemics (Kontogiannis, 2021). In this chapter, I focus on the pandemic crisis as it offers valuable insights for preparing for future disruptive crises, not only epidemiological but also climatic, geopolitical, and natural disasters. Furthermore, studying the resilience of hospitals to disruptive crises provides benefits for improving responses to chronic crises and addressing everyday errors (Kruk et al., 2017). In addition to the type of crisis considered, it is also required clarify the levels of analysis and contexts, which in terms of resilience can span from individual, organizational, and systemic level (Alameddine et al., 2019; Hillmann and Guenther, 2021). My research aims to focus on hospitals, by adopting the perspective of organizational resilience (Agostini et al., 2023; Seyghalani Talab et al., 2024). This perspective suggests viewing the organization as composed of tangible and intangible assets that provide value and are essential for

executing its processes (Galaitsi et al., 2023). Studying organizational resilience, therefore, involves examining the resources and capabilities, and their combinations, that enable the organization to prevent, mitigate, and respond to crises (Barasa et al., 2018; Iflaifel et al., 2020; Lyng et al., 2022; Wiig et al., 2020). This chapter aims to clarify what is essential for explaining and understanding how resilience is supported in hospitals. To achieve this, I consider ICTs and digital skills as resources, and identify III and EII as capabilities highlighted in the literature as most impactful in addressing crises, with the goal of providing empirical validation.

2.2 Contingent Resource-Based View

The CRBV has drawn from the traditional RBV theory which posits that in challenging situations, resilient organizations can utilize their resources, capabilities or their bundles to enable a successful response (Chahal et al., 2020; Gupta et al., 2018; Su and Junge, 2023). To address the criticism of context insensitivity of the RBV, where the effectiveness of resources and capabilities for resilience outcome varies depending on specific conditions (Brandon-Jones et al., 2014), researchers in healthcare management are increasingly considering the specific context and conditions in which the relationships between resources, capabilities and resilience occur (Agostini et al., 2023; Burnard and Bhamra, 2011; Chakraborty et al., 2021; Foroughi et al., 2022; Ignatowicz et al., 2023; Senna et al., 2023; Tortorella et al., 2021). Previous studies adopting the CRBV theory have approached resilience in two primary ways. On one hand, it has been operationalized as a resource that can improve performance, due to the fact that various type of resilience can be classified as resources within the RBV framework, such as agility, flexibility, integration (Liu et al., 2018; Yang and Hsu, 2018; Yuan et al., 2022). On the other hand, resilience has been conceived as an outcome, a measure of operational performance during a crisis, achievable through bundle of resources and capabilities (Brandon-Jones et al., 2014; Huang et al., 2023; Li et al., 2023). Aligned with the second perspective, this study considers hospital resilience as an outcome, since this approach allows me to examine which forms of resources and capabilities enhance hospital resilience (Acquaah et al., 2011; Beuren et al., 2022;

Yu et al., 2019; Huemer and Wang, 2021). The ICTs are considered strategic resources that are highly beneficial during disruptions, as they can enhance clinical quality, improve service efficiency, increase patient satisfaction, and reduce costs (Gupta et al., 2018; Senna et al., 2023; Wetering and Versendaal, 2020). Closely linked to this, digital skills complement the use of ICTs, together forming essential assets that should be developed across various departments (Carbonara et al., 2024; Nuccio and Mogno, 2023). These resources enable the timely exchange of data and information and ensure effective interfacing among various stakeholders, including patients as a primary group (Carbonara et al., 2024; van de Wetering et al., 2018). Furthermore, information integration capabilities are regarded by resilience literature as strategic resources to be implemented and developed to mitigate disruptions, enhance response, and improve the ability to anticipate and recover from such events (Ayadi, 2024; Huo et al., 2016; Piprani et al., 2020). By focusing on operational contingencies, I can obtain a more detailed understanding of how internal practices and dynamics within hospitals influence their ability to absorb, adapt and respond to challenges. Considering operational contingencies described by Parast (2020), namely elements that can be adjusted in the short term, the literature examines the moderating role of service complexity and operational efficiency. Service complexity, which refers to the number of services offered and the severity of patient conditions treated, is considered a 'contextual moderator' because it affects the need for diverse materials, resources, and processes depending on specific patient conditions (Peng et al., 2020, 2023; Vitikainen et al., 2009). This can make the adaptation and rapid response of hospitals more challenging in the face of a crisis. The approach to operational efficiency relates to how hospitals modify their operations, processes, and management programs to cope with adversity, aiming to optimize their inputs to generate outputs (Androutsou et al., 2022; Ramanathan, 2010).

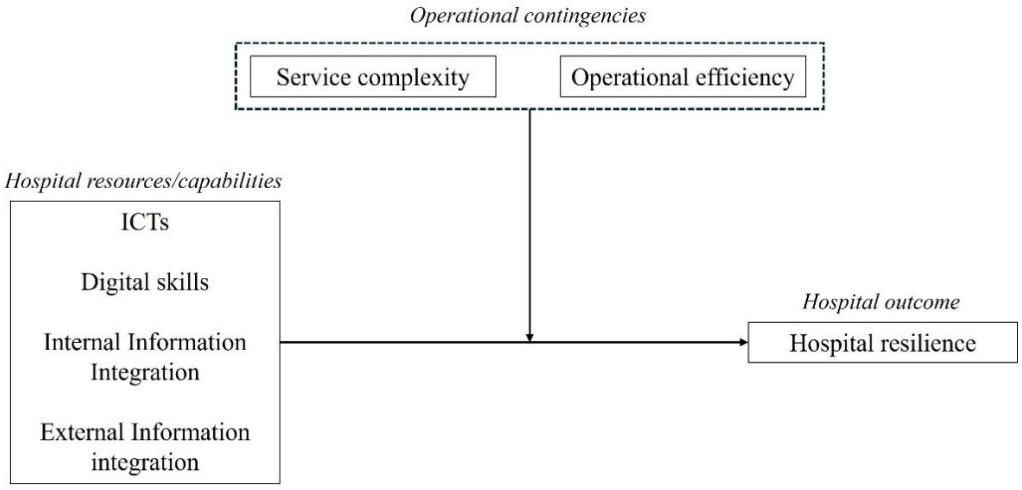


Figure 11. Research framework.

2. Hypotheses development

The earlier sections have highlighted a significant gap in the literature concerning the interplay between hospital resources and capabilities and hospital resilience in light of contingencies (Figure 11). Below, hypotheses are developed regarding the direct impacts of ICTs, digital skills, internal and external information integration on hospital resilience. Subsequently, hypotheses pertaining to the impacts of service complexity and operational efficiency on the relationship between resources and capabilities considered in the study and hospital resilience are presented.

3.1 The impact of hospital resources and capabilities on hospital resilience

All interconnected digital applications and platforms, electronics databases, and microstructure technologies are examples of ICTs that have been adopted and implemented in hospitals, enabling higher levels of automation and interconnectivity of processes, products, services, and people (Marques da Rosa et al., 2021). This kind of technology, like electronic health records, patient monitoring systems, alert and notification systems, telemedicine facilitate collaborative sharing of patient information within and among different operational units, as well as enabling inter-organizational communication and collaboration with external partners such as other hospitals,

suppliers, and pharmacies (Tortorella et al., 2022). By fostering seamless communication and collaboration, ICTs ensure that critical information reaches the right individuals promptly, enable swift responses to emerging challenges, and enhance overall resilience (Tonetto et al., 2021). Additionally, ICTs improve the adaptability of hospitals through the implementation of remote monitoring systems and telemedicine solutions, enabling healthcare providers to deliver care to patients outside traditional clinical settings, reducing the burden on physical healthcare facilities, and ensuring continuity of care (Garcia-Perez et al., 2023). Moreover, ICTs can improve the responsiveness of hospitals, facilitating the implementation of redundancy measures. For examples, sensor and software utilized for monitoring the status of principal power sources can provide immediate alerts to staff or automatically activate backup systems in the event of malfunctions or maintenance needs (Tortorella et al., 2022). Moreover, thanks to digital platforms hospital can build redundant network connections, to minimize downtime and maintain essential services during disruptions (Spieske et al., 2022). By enabling hospitals to adapt and respond to disruptions effectively, ICTs strengthen organizational resilience and ensure the continuity of essential healthcare services.

Hence, we propose the following hypothesis:

H1. Information and communication technologies have a positive impact on hospital resilience.

Effective communication via technological devices within hospitals and with external partners requires the staff to possess the requisite skills and proficiency in using these digital tools (Dichter et al., 2022). Digital skills, in essence, involve the combination of digital knowledge and practical know-how in recognizing, retrieving, storing, arranging, and examining digital data (European Commission. Joint Research Centre. Institute for Prospective Technological Studies., 2013). Digital skills are represented as key determinants of other competencies, including problem-solving abilities (van Laar et al., 2020). A hospital staff with advanced digital skills is capable of using essential technological tools and understanding how and where digital resources can be applied to manage crises effectively (Gu et al., 2023). During crises, hospitals often face rapidly evolving circumstances and may be

required to swiftly implement or adapt new technologies to meet emerging needs. Staff with advanced digital skills can manage such changes more effectively, ensuring greater flexibility in the face of unforeseen challenges (Shela et al., 2023). Moreover, during crises, it is crucial to ensure efficient communication and collaboration to coordinate response actions, including the reorganization of resources and the dissemination of critical information. Staff with advanced digital skills can make the most of available communication tools, facilitating coordination both within and outside the hospital. Staff with advanced digital skills can expedite the data analysis process, enabling timely decisions that optimize resource utilization and enhance the hospital's ability to respond effectively to crises, thus strengthening the overall resilience of the healthcare institution (Nzinga et al., 2021). Low level of digital skill among key hospital staff can influence patient safety and increase the incidence of errors, representing significant barriers to the rapid and effective response for patients (Bastone et al., 2024).

Thus, it can be hypothesized that:

H2. Digital skills have a positive impact on hospital resilience.

The interdependence of medical practices in hospitals, as well as between hospitals and external stakeholders, reveals that integration strategies are necessary for ensuring rapid communication, and infusing agility into problem-solving processes (Poberschnigg et al., 2020; Scala and Lindsay, 2021). Internal integration refers to shared information processing among an organization’s internal operational units based on mutual alignment resulting from interaction, information sharing, and joint planning (Peng et al., 2023). Developing collaborative behaviours and information sharing within hospitals facilitates the timely acquisition of accurate information, leading to improved situational awareness of operational processes and greater visibility of operations (Mitchell and Boyle, 2021; Rubbio et al., 2019). Consequently, it ensures that relevant information is readily available to frontline staff and decision-makers, enabling swift action and minimizing response times. Similarly, exchanging strategic information with external stakeholders, including suppliers of medical devices, other hospitals, external pharmacies, and government authorities, enables greater situational

awareness and visibility. Consequently, all operational units can effectively allocate resources and maintain comprehensive knowledge of inventory levels and patient demands. Cross-hospital partnerships and long-term relationships have been established not only for patients' redistribution but also for enabling efficient resource sharing and mutual support during crises and facilitating alternative sourcing through the creation of shared central warehouses for various medical products (Aldrighetti et al., 2019; van den Berg et al., 2023).

Therefore, we propose the following hypotheses:

H3. Internal information integration is positively related to hospital resilience.

H4. External information integration is positively related to hospital resilience.

3.2 Moderating effect of service complexity

The hospital, as one of the most complex organizations, constantly faces the challenging task of providing effective and efficient care. Unlike industrial operations, which often deal with standardized products and processes with uniform inputs, hospitals must navigate a wide range of complexities, including patients with heterogeneous characteristics, a variety of diagnoses, treatment interconnections, and comorbidities (Thirumalai and Devaraj, 2024).

Hospital service complexity represents the number and variety of services provided by the hospital and the seriousness and diversity of patients admitted to a hospital (Peng et al., 2020). The wide range of services offered in a hospital, across multiple operational units, each with distinct operational needs and workflows, introduces complexity into the hospital's operational environment and impacts the effectiveness of resources and capabilities deployed to enhance resilience (Thirumalai and Devaraj, 2024). In particular, hospital delivering complex services often rely on standardized care protocols and rigid procedures to ensure patient safety and maintain high-quality treatment outcomes (Gifford et al., 2022; Thirumalai & Devaraj, 2024). While these structured approaches are critical under normal operating conditions (Bertsimas & Pauphilet, 2024), they may

constrain the flexibility needed to utilize resources and capabilities effectively during crises (Kuntz et al., 2019; Van Heel et al., 2024).

In relation to ICTs which have proven effective for resilience in remote monitoring, facilitating communication, and establishing network connections, their utility diminishes in hospitals providing highly complex healthcare services since they often necessitate direct, personalized care, therapeutic interventions, and extensive human interactions, requiring the patient's physical presence within the hospital (Peng et al., 2020). As a results, the reliance on hands-on care and specialized therapeutic processes limits the adaptability and effectiveness of ICTs in addressing crises and ensuring the continuity of patient care (McCrum et al., 2014). Similarly, the complexity of the hospital environment can significantly influence the relationship between digital skills and hospital resilience. The effectiveness of ICTs and associated digital skills in enhancing resilience is significantly hindered by the rigidity of care pathways and the necessity to administer treatments within the hospital setting rather than remotely. Hence, clinical staff working in hospitals with highly complex structures may not fully leverage digital tools like telemedicine to manage crises effectively and achieve resilience (Thirumalai and Devaraj, 2024).

Hence, we propose:

H5: Hospital service complexity negatively moderates the relationship between ICTs and hospital resilience.

H6: Hospital service complexity negatively moderates the relationship between digital skills and hospital resilience.

During crises, hospitals often face uncertainties primarily concerning the availability of resources, emergency logistics, and protocol adherence. In situations like these, complexity can exacerbate the uncertainty, making it more challenging for staff to effectively manage the situation and respond promptly to patient needs (Iflaifel et al., 2020).

In a complex hospital setting with numerous specialty units and multidisciplinary care teams, the effectiveness of internal information integration in enhancing hospital resilience is significantly

influenced by the complexity of services offered. As the variety and volume of information to be managed increase due to diverse patient flows and specialized care pathways, relying on seamless communication and coordination to adapt to changing environment and continue to provide the complex services becomes increasingly challenging (Davis et al., 2013; Drupsteen et al., 2013). In a similar way, the complexity of the patients' cases in hospital limits the positive impact of external information integration on resilience. Hospitals with high service complexity often require highly specialized equipment, pharmaceuticals, and other critical resources tailored to their unique care pathways (Bilici et al., 2018; De Jonge et al., 2001; Junaid et al., 2023). However, during crises, relying on effective collaborations and partnerships with suppliers to secure these specific resources and continue to provide complex services can be challenging (Senot et al., 2016; Spieske et al., 2022). Furthermore, in cases involving patients requiring highly specialized treatments, transferring such patients to less-equipped facilities external information integration is less effective due to the specific and advanced nature of the care required for these patients (Aitken et al., 2020; Nugus et al., 2010; Wan et al., 2002). Hence, we hypothesize:

H7: Hospital service complexity negatively moderates the relationship between internal information integration and hospital resilience.

H8: Hospital service complexity negatively moderates the relationship between external information integration and hospital resilience.

3.3 Moderating effect of operational efficiency

In the hospital setting, operational efficiency represents an objective measure of how the hospital organizes and utilizes its resources and refers to ensuring timely access to care, minimizing waiting times, and delivering high-quality services and appropriate treatments at the lowest possible cost (Yaduvanshi & Sharma, 2017).,

It is tied to managerial competencies, routines, tasks, and processes that improve the organization's effectiveness in converting inputs into outputs (Parast, 2022; Yang et al., 2017).

While such optimization of resources may provide immediate advantages under normal conditions maintaining operational stability of the organization, excessive efficiency can limit a hospital's ability to adapt swiftly to disruptions (Ataburo et al., 2024; Hybinette et al., 2021; Jakovljevic et al., 2024). In a highly efficient system, resources such as ICT systems and healthcare staff are often utilized to their maximum capacity and configured to manage standardized workflows for ensuring high bed occupancy rate and low turnover interval. During the pandemic crisis, many hospitals reported difficulties in adapting ICT systems to the rapidly evolving clinical priorities. This lack of flexibility in the systems often resulted in delays in updating patient information, highlighting the trade-off between operational efficiency and adaptability. In a similar way, the level of operational efficiency influences how digital skills are utilized and their impact on resilience. In a highly efficient context, the digital skills are often used to their full capacity to optimize performance and minimize waste (Bidoli et al., 2023). In a highly efficient hospital, staff with digital skills are entirely allocated to specific tasks, leaving little room for rapid reorganization during emergencies (Bastone et al., 2024; Fornes-Romero et al., 2020; Jimenez et al., 2020).

Hence, we propose:

H9: Operational efficiency negatively moderates the relationship between ICTs and hospital resilience

H10: Operational efficiency negatively moderates the relationship between digital skills and hospital resilience.

When a hospital maintains a high level of operational efficiency, often implies well-structured processes with limited redundant capacity. While this structure supports routine operations, it can reduce flexibility and leave little room for adapting processes during crises. For example, when greater patient coordination is required to manage emergencies, the rigid and optimized systems may limit the effectiveness of internal information integration as a mechanism for enhancing resilience (Dobrzykowski et al., 2015; Kim and Swink, 2021). Conversely, in hospitals with lower operational efficiency, internal information integration becomes more critical, as it compensates for

inefficiencies and supports adaptive responses to crises (Milch et al., 2021; Peng et al., 2020). Similarly, when operational efficiency is high, the incremental value of external information integration for resilience decreases. In highly efficient hospitals, existing processes and resources are optimized for routine operations, leaving limited capacity to leverage external collaborations effectively during crises. The lack of flexibility and room for structural adjustments reduces the impact of external information integration on resilience (Kim and Swink, 2021; Mascia and Di Vincenzo, 2011). In contrast, hospitals with lower operational efficiency benefit more from external collaborations, as these partnerships provide critical resources, knowledge, and support to address internal weaknesses and enhance resilience. We propose the following hypotheses:

H11: Operational efficiency negatively moderates the relationship between internal information integration and hospital resilience.

H12: Operational efficiency negatively moderates the relationship between external information integration and hospital resilience.

3. Methodology

To test the hypotheses, a data set composed of primary survey data and secondary data was utilized (Dobrzykowski et al., 2015; Hofer et al., 2012; Schmidt et al., 2017). Utilizing multiple data sources enables a higher level of validity and insights that cannot be obtained from single data sources (Gardner et al., 2015). If the use of secondary data is unambiguous and objective, helping to reduce common method bias, subjective data can provide meaningful comparisons between hospitals (Hsu and Sabherwal, 2012). Primary data were collected to measure independent variables, namely the ICTs, digital skills, internal and external information integration, and the hospital resilience, whereas secondary data were obtained to measure the hospital operational contingencies of service complexity, and operational efficiency, and control variables (hospital size and type).

4.1 Survey data

The questionnaire contains multi-item scales developed by prior management and information system research. To measure the constructs and the variables of the research framework, I use scales previously validated, where all the items and responses appear on a five-point Likert scale to measure the questionnaire items, ranging from 1 (strongly disagree) to 5 (strongly agree). The concept of resilience is a latent construct that cannot be directly measured or observed (Essuman et al., 2022, 2020; Ignatowicz et al., 2023). In the healthcare context, the concept of resilience has been addressed across various levels, including system-wide and individual level, however, empirical assessments of resilience are most frequently conducted at the organizational level. Seyghalani Talab et al. (2024) and Zhong et al. (2015) have developed sets of indicators for measuring resilience as latent construct, grounded in comprehensive literature reviews and subsequently validated through expert panels. These tools encompass a broader range of dimensions, extending beyond just the preparation phase to include, among others, aspects such as vulnerability, safety, responsiveness, and post-disaster recovery. Others developed diverse indicators based on the toolkit of the World Health Organization's Hospital Safety Index (WHO HSI), which assesses healthcare facilities' preparedness for crises from structural, functional, and human resources perspectives including structural integrity, resource availability, and adequate staffing levels (Dewar et al., 2014; Hosseini et al., 2019; Mulyasari et al., 2013; Shalhoub et al., 2017). Given the absence of these measures in existing empirical studies evaluating of hospital resilience and that our study aims to measure the level of resilience achieved during and immediately after the shock of the pandemic crisis, we have extended our research by incorporating tools from the organizational resilience literature that assess resilience during these critical phases and treat it as an outcome measure (see Table 10). In our study, we adopted the scale developed by Li et al., (2022) for measuring resilience during the pandemic, due to its foundation in well-established and extensively used scales in the literature for assessing resilience.

Table 10. Measures of resilience in organizational management literature.

Authors	Description of dimensions of resilience

(Kantur and Say, 2015)	9-item organizational resilience scale developed to measure: Robustness (resistance capacity); Agility (easily and rapidly adaptation to circumstances); Integrity (the extent to which employees are integrate in the organization).
(Ambulkar et al., 2015)	4- items firm resilience scale developed to measure: ability of the firm to cope with changes due to a supply chain disruption, the ability to adapt to a supply chain disruption and provide a quick response, the ability to maintain high situational awareness.
(Parker and Ameen, 2018)	4-item scale adapted from Ambulkar et al., (2015) measure the degree to which the firm could cope with disruptions and how well the firm was able to adapt to the power supply disruptions.
(Do et al., 2022)	9-item scale adopted by Kantur and Say (2015).
(L. Li et al., 2022)	3-items scale adapted from Ambulkar et al., (2015).
(Cui et al., 2022)	4-item scales adapted from Ali et al., (2017), Ambulkar et al., (2015) and Parker & Ameen (2018) to measure: The ability to adapt to supply chain disruptions and manage the changes caused by them. The ability of firms to respond to interruptions and grasp the overall situation and development trend of supply chain operations.
(Y. Li et al., 2022)	9-item scale adopted by Kantur and Say (2015) to measure the successful of organizations in facing COVID-19 pandemic.
(Q. Li et al., 2023)	9-items adopted from Kantur and Say (2015) for measuring organizational resilience.

The constructs, along with their respective items and the literature references, are shown in Table 11. I conducted the survey in Italian hospitals due to their significant exposure during the recent COVID-19 pandemic crisis. To maximise the applicability of the findings, I selected the hospital population based on contextual and organizational factors, including size, type, and region. Specifically, we employed a regional approach to sample selection, ensuring thorough geographical coverage across Italy and identifying key hospital facilities in each area. We selected a sample of 428 medium to large public and private hospitals across various classifications via a database hosted on the website of the Ministry of Health. The recipients, including medical directors, nurse managers, and operational unit directors, were selected for their critical decision-making roles in hospital operations. Throughout the pandemic, these individuals were key figures in managing hospital activities and coordinating

personnel. They played a vital role in improving healthcare services and fostering teamwork through collaboration with hospital leaders and external partners.

Following a online mailing campaign conducted from September to October 2023 in which we contacted a sample of 2,521 recipients, with a reminder sent after one month, 261 valid responses were collected. This yielded a response rate of 10,35%, which is comparable to the response rates and sample sizes of similar studies (Chen et al., 2013; Peng et al., 2023). After the initial evaluation, the responses obtained from multiple respondents of 26 hospitals were aggregated by averaging each item (Dobrzykowski and Tarafdar, 2015). This resulted in a sample of 130 hospitals, representing nearly 30% (130/428) of the hospitals included in the sample. I guaranteed the anonymity and aggregate data usage of respondents to ensure compliance with privacy rules. I developed, pre-tested, and refined the survey in collaboration with experts who have been working in hospitals for many years. The survey questions specifically referred to the period between 2020 and 2022—the years of the pandemic. Respondents were clearly instructed to consider their experiences and responses in the context of the pandemic years when providing their answers.

For this study, the translation-back-translation procedure from English to Italian and back to English was used.

Table 11. Constructs and items.

Construct	Item	Indicator	References
Information and communication technologies (ICTs)	ICTs has been widely utilized in the operational units of the hospital where you work.	ICTs1	Zhang et al. (2023)
	ICTs has been used for connection and integration among departments of the hospital.	ICTs2	
	ICTs has been used in knowledge and resource sharing among the departments of the hospital.	ICTs3	
	ICTs has been used to share data, information and resources with partnering organizations in a timely manner.	ICTs4	
	ICTs has been used to create effective interfaces in collaborative businesses with partners.	ICTs5	
	ICTs has been used to share key information and data with key suppliers.	ICTs6	
	ICTs has been used to share key information and data with key patients.	ICTs7	

	ICTs has been used in integration with major suppliers and patients.	ICTs8	
Digital skills (DS)	The staff is able to save useful data files directly to the right folder.	DS1	Blaique et al. (2023); Barbosa et al. (2023)
	The staff is able to create a new patient record.	DS2	
	The staff is able to add clinical data (e.g. treatment side effects, occurrences).	DS3	
	The staff is able to organize digital files via a hierarchical folder structure (organize information to be able to find it later).	DS4	
Internal information integration (III)	The work performed requires that staff maintains close cooperation within hospital.	III2	Ma and Zhang (2022); Li et al. (2019)
	The work performed requires that staff cooperates with each other within hospital to solve problems.	III3	
	The work performed requires that staff establishes trustful relationships within the hospital.	III4	
	The work performed requires that staff frequently, informally, and in a timely manner shares information.	III5	
External information integration (EII)	The work performed requires that staff engages in active communication between our hospital and external partners (such as customers, suppliers, distributors, and alliance partners).	EII1	Li et al. (2023); Chen et al. (2013)
	The work performed requires that staff cooperate with external partners to solve problems.	EII2	
	The work performed requires that staff trusts external partners.	EII4	
Hospital resilience (HR)	In the face of emergencies, our hospital can persist and maintain the critical health care functions.	HR1	Li et al. (2023)
	In the face of emergencies, our hospital produces a variety of effective solutions to problems.	HR2	
	In the face of emergencies, our hospital does not give up and continues the path.	HR3	
	In the face of emergencies, our hospital responds and acts quickly.	HR4	
	In the face of emergencies, in order to benefit from the negative circumstances, our hospital has developed alternatives.	HR5	
	In the face of emergencies, our hospital is a place where all the employees engaged to do what is required from them.	HR7	

4.2 Secondary data

Besides the data resulting from the survey, operational contingency data were acquired from the online database managed by the Italian Ministry of Health. These data originate from the Ministry of Health's Open Data website and the National Outcomes Program (PNE) website, made available by the National Agency for Health Services (AGENAS). The agency aims to evaluate the practical

effectiveness, appropriateness, equity of access, and safety of care provided by the National Health Service (SSN), focusing on the Essential Levels of Assistance (LEA). These databases have a strong reputation and garner significant interest and appreciation from healthcare professionals and the scientific community alike, who widely use their indicators in scientific studies (Angelo et al., 2023; Marino and Quattrone, 2019; Pecoraro et al., 2021). As regard the variables related to service complexity, they are calculated considering the service variety in terms of number of clinical operational units, and the Case Mix Index (CMI) (Peng et al., 2008). The CMI is a measure of the severity of illness of patients admitted to hospital (Sharma et al., 2016). It is a metric used to gauge resource utilization within a hospital, derived from the diagnosis-related group of patients treated, reflecting the clinical complexity and the medical care needs of all the patients admitted to the hospital. Since operational efficiency is defined as the extent to which resources are used to generate output, in this context, operational efficiency was assessed through resource productivity, with particular emphasis on hospital beds, considered a fundamental resource within a hospital (Keegan, 2010; Salge and Vera, 2013). We have adapted the variables identified by Aloh et al. (2020), analysing the productivity associated with the number of beds, suggesting that operational efficiency should be evaluated using three indicators: average length of stay, bed occupancy rate, and turnover interval. The average length of stay of a patient in hospital, measured in days occupying a bed. The bed occupancy rate is an efficiency measure that indicates the percentage of hospital bed that are occupied by patients over a certain period of time, relative to the total number of available beds. The turnover interval refers to the period of time during which the turnover of a hospital bed occurs, measured from when a patient is discharged until the next inpatient arrives. Secondary data refer to the crisis period related to the pandemic, so each indicator is obtained as the average value for the years from 2020 to 2022. To complement the data collection, we also utilized ministerial databases to gather information on control variables. In order to measure the control variables, we have considered the sum of the number of beds per department for measuring hospital size (Macinati and Anessi-Pessina, 2014), the teaching status for hospital type (Peng et al., 2020; Salge and Vera, 2013).

These variables are considered to potentially impact the availability of resources and capabilities. For instance, size is often associated with efficiency, conceived as a variable that can undermine hospital operational effectiveness. Variations in size may influence economies of scale, thereby impacting the quality of patient services and the hospital's ability to manage crises effectively (Giancotti et al., 2017). According to Al-Amin et al. (2018), hospital size exhibits a negative correlation with efficiency. Similarly, the type of hospital may influence the extent of resource adoption and capability development (Burke et al., 2002). For example, hospitals that provide acute care often exhibit a high adoption rate of ICTs. Furthermore, control variables related to size and type can dramatically influence the level of resilience. For instance, number of beds reflects the hospital's capacity to accommodate patients seeking treatment. Moreover, these control variables implicitly indicate the quantity and usage of resources and capabilities implemented in the hospital, thus affecting the achievable level of resilience for that hospital (Pishnamazzadeh et al., 2020).

4.3 Combined data set

The survey responses of 130 hospitals were matched with corresponding secondary data using the hospital name and its unique identification code to prevent errors resulting from cases of homonymy. Of course, this operation was feasible only in those instances where the survey response specified the hospital name and relevant information was available. As such, the final sample used for analysis comprises 121 hospitals, representing 25.21% (121/480) of the initial sample, which remains an acceptable proportion and is consistent with comparable studies in the literature. Table 12 presents a summary of geographic distribution of hospitals.

Table 12. Sample geographics distribution (N=121).

Characteristics	**Number of respondents**	**Percentage of respondents**
Region		
Abruzzo	4	3.31%
Apulia	12	9.92%
Basilicata	4	3.31%

Calabria	3	2.48%
Campania	7	5.79%
Emilia-Romagna	11	9.09%
Friuli-Venezia Giulia	7	5.79%
Lazio	13	10.74%
Liguria	1	0.83%
Lombardy	11	9.09%
Marche	3	2.48%
Piedmont	10	8.26%
Sardinia	2	1.65%
Sicily	8	6.61%
Trentino-Alto Adige	3	2.48%
Tuscany	7	5.79%
Veneto	15	12.40%

4. Empirical analysis and results

5.1 Construct validity

The evaluation of the measurement model by performing a confirmatory factor analysis (CFA), using SPSS AMOS 26, showed acceptable results. Our model showed good fit with the data ($\chi2$= 444,023; degrees of freedom=303; $\chi2$/df=1,465; CFI= 0,942; TLI= 0,932; GFI= 0,807; AGFI=0,759; NFI= 0,840; RMSEA= 0,062).

An exploratory factor analysis was conducted employing principal component analysis with varimax rotation on the constructs pertaining to ICTs, digital skills, internal and external information integration, and hospital resilience, aimed at elucidating the underlying dimensions of these constructs (Yu et al., 2017). The analysis affirmed the categorization of items into predefined constructs, yielding an explained variance of 74.742%.

The reliability and validity of the constructs were tested using a confirmatory analysis, as indicated in Table 13. All the items had outer loadings greater than 0.60, as recommended by Hu and Bentler (1999). It is a commonly accepted value that does not affect the content validity of the scale. Second, all the constructs met the requisite of construct reliability, since their composite reliabilities, Cronbach's alpha, and convergent reliability (CR) values exceeded the 0.7 criteria. Third, the average

variance extracted (AVE) values were higher than 0.5, indicating that the latent variables attained convergent validity. Table 15 presents descriptive statistics and Spearman correlation matrix between variables. We operationalized the dummy variable in the regression analysis as a binary variable, where 1 represents "non-teaching" and 2 represents "teaching." According to the Central Limit Theorem, normality of the data is less of a concern with larger sample sizes, as the theorem suggests that the sampling distribution of the mean will approach normality regardless of the population distribution (Mishra et al., 2019).

Table 13. Measurement model results.

Construct	**Factor loading**	**Cronbach's alpha**	**Composite reliability (rho_a)**	**Average variance extracted (AVE)**
Information and communication technologies		0.917	0.914	0.572
ICTs1	0.677			
ICTs2	0.753			
ICTs3	0.845			
ICTs4	0.837			
ICTs5	0.817			
ICTs6	0.728			
ICTs7	0.653			
ICTs8	0.720			
Digital skills		0.866	0.870	0.632
DS1	0.708			
DS2	0.878			
DS3	0.920			
DS4	0.640			
Internal information integration		0.911	0.904	0.657
III1	0.637			
III2	0.830			
III3	0.871			
III4	0.799			
III5	0.893			
External information integration		0.880	0.894	0.742
EII1	0.871			
EII2	0.991			
EII4	0.697			
Hospital resilience		0.905	0.903	0.573
HR1	0.625			
HR2	0.803			
HR3	0.856			
HR4	0.809			
HR5	0.805			

HR6	0.674
HR7	0.700

5.2 Findings

This research adopts hierarchical moderated regression analysis to test the hypotheses, using IBM SPSS 28 software. This study utilizes the variance partitioning procedure introduced by Jaccard et al. (1990) and employed in prior studies (Hong and Hartley, 2011; Peng et al., 2023; Tatikonda and Rosenthal, 2000; Wu, 2013; Wu et al., 2012). The variance partitioning procedure comprises four steps.

Step 1: Control variables, such as the hospital size and type, are entered into the regression.

Step 2: One of the hospital resources, such as the ICTs, is entered into the regression. The aim of this stage is to investigate the main single impacts of hospital resources and capabilities.

Step 3: Five moderators of the operational contingencies are entered as a block.

Step 4: Five interaction terms of moderators are entered as a block. This step is used to test the moderating effects. Here, the significance test for the incremental F-statistic is used to determine significant moderating effects. In the moderated regression analysis, this research uses “centering” reduce multicollinearity (Jaccard et al., 1990). Furthermore, we assessed the presence of collinearity issues by examining variance inflation factors (VIF). Our analysis revealed no significant VIF values in any of the equations (VIF < 10.00), suggesting that multicollinearity was not a major concern (Hair, 2011; Wu et al., 2012).

The hypotheses H1-H4 state that ICTs, DS, III, and EII have a positive relationship with HR. Hypotheses H5-H8 propose that ICTs, DS, III, and EII are moderated by service complexity, while H9-H12 suggest they are moderated by operational efficiency. The results for all hypotheses are shown in Tables 16-18. Control variables such as size and type (teaching status), introduced in Step 1 of the multivariate regression analysis, show no significant impact on hospital resilience (Tables 16-18). In Step 2 of the multivariate analysis (Tables 16-18), the results indicate that ICTs, DS, III,

and EII have main effects on resilience, supporting hypotheses H1-H4. When considered together all resources and capabilities, ICTs and EII remain the variables with main effects on resilience. Moving to the moderating effects of the relationship between ICTs and HR (Table 16), Step 4 of the multivariate regression analysis shows that the incremental F-value for the block of interaction items is significant, with the interaction terms related to operational efficiency being significant, thus supporting H9. However, H5, related to the moderating effect of service complexity, is not supported. In Table 17, the incremental F-value is significant, and the interaction terms between operational efficiency and DS are slightly significant, supporting H10. However, as with H5, the moderating effect of service complexity is not significant, meaning H6 is not supported. Table 18 shows that the incremental F-value in Step 4 for the block of interaction items of III and the case mix index is significant, supporting H7, while the moderating effect of operational efficiency is not significant, so H11 is not supported.

Table 14. Descriptive statistics and bivariate correlation matrix of variables.

	N	Mean	S.D.	1	2	3	4	5	6	7	8	9	10	11	12
1. ICTs	121	3.3922	.89183	1.000											
2. DS	121	3.6231	.92357	.492**	1.000										
3. III	121	3.9847	.62970	.193*	.308**	1.000									
4. EII	121	3.5195	.75018	.380**	.422**	.461**	1.000								
5. HR	121	3.9091	.68381	.326**	.414**	.268**	.408**	1.000							
6. Average Length of stay	121	9.9981	9.76098	-.132	-.141	-.128	-.065	-.185*	1.000						
7. Bed occupancy rate	121	74.36	12.8697	.039	.066	-.285**	-.124	.003	.300**	1.000					
8. Turnover interval	121	6.31	13.1625	.034	-.019	.205*	.202*	-.041	.235**	-.370**	1.000				
9. Service variety	121	20.64	10.914	-.029	.033	-.258**	-.138	-.004	.220*	.371**	-.275**	1.000			
10. Case Mix Index	121	.9737	.15763	.058	.094	-.132	.053	.052	.030	.262**	-.107	.485**	1.000		
11. Hospital size	121	573.11	434.329	-.054	.012	-.187*	-.075	-.022	.339**	.352**	-.004	.849**	.381**	1.000	
12. Teaching status	121	1.17	.380	.007	.097	-.098	-.048	.045	.154	.329**	-.207*	.456**	.226*	.371**	1.000

Table 15. Hierarchical moderated regression analysis of ICTs/contingencies on hospital resilience.

Variable entered (N=121)	Dependent variable: Hospital resilience											
	Step 1			Step 2			Step 3			Step 4		
	Stand. Beta	Stand. Errors	VIF	Stand. Beta	Stand. Errors	VIF	Stand. Beta	Stand. Errors	VIF	Stand. Beta	Stand. Errors	VIF
Hospital size	-.024	.000	1.168	-.011	.000	1.169	.007	.000	2.919	.096	.000	3.021
Teaching status	.018	.179	1.168	.003	.167	1.170	.005	.177	1.302	.00	.166	1.308
ICTs				.372***	.066	1.002	.368***	.067	1.039	.370***	.065	1.120
ALS							.095	.007	1.341	-.056	.008	1.886
BOR							-.081	.005	1.351	-.098	.005	1.451
TI							-.163+	.005	1.175	-.308**	.005	1.643
CMI							-.015	.011	3.899	-.161	.010	4.181
Service variety							.066	.448	1.430	.101	.443	1.609
ICTs x ALS										.344*	.011	3.105
ICTs x BOR										-.273*	.007	1.882
ICTs x TI										-.631***	.010	4.097
ICTs x CMI										-.093	.008	1.927
ICTs x Service variety										-.009	.490	2.102
F for the step	0.034			18.777***			0.712			4.321***		
F for the regression	0.034			6.285***			2.773**			3.621***		

Adjusted R^2	-0.016	0.117	0.106	0.221

Table 16. Hierarchical moderated regression analysis of digital skills/contingencies on hospital resilience.

Variable entered (N=121)	Dependent variable: Hospital resilience											
	Step 1			Step 2			Step 3			Step 4		
	Stand. Beta	Stand. Errors	VIF	Stand. Beta	Stand. Errors	VIF	Stand. Beta	Stand. Errors	VIF	Stand. Beta	Stand. Errors	VIF
Hospital size	-.024	.000	1.168	-.018	.000	1.169	-.007	.000	2.919	-.022	.000	2.948
Teaching status	.018	.179	1.168	-.024	.165	1.178	-.024	.176	1.311	-.014	.177	1.329
Digital skills				.412***	.063	1.178	.395***	.065	1.058	.450***	.072	1.304
ALS							.064	.007	1.311	-.198	.011	3.377
BOR							-.042	.005	1.345	-.007	.005	1.442
TI							-.123	.005	1.343	.003**	.006	1.833
Service variety							-.013	.011	3.897	.020	.011	4.172
CMI							.045	.446	1.449	.007	.477	1.659
Digital skills x ALS										.423+	.014	6.722
Digital skills x BOR										-.075	.008	3.108
Digital skills x TI										-.431+	.011	6.806
Digital skills x Service variety										-.069	.008	2.098
Digital skills x CMI										.129	.604	2.891
F for the step	0.034			23.658***			0.382			1.011		
F for the regression	0.034			7.922***			3.131***			2.316**		

Adjusted R^2	-0.016	0.148	0.124	0.125

+ p≤0.10; * p≤0.05; ** p≤0.01; *** p≤0.001.

Table 17. Hierarchical moderated regression analysis of internal information integration /contingencies on hospital resilience.

Variable entered (N=121)	Dependent variable: Hospital resilience											
	Step 1			Step 2			Step 3			Step 4		
	Stand. Beta	Stand. Errors	VIF	Stand. Beta	Stand. Errors	VIF	Stand. Beta	Stand. Errors	VIF	Stand. Beta	Stand. Errors	VIF
Hospital size	-.024	.000	1.168	.001	.000	1.175	-.071	.000	2.919	-.077	.000	2.973
Teaching status	.018	.179	1.168	.037	.171	1.172	-.002	.180	1.311	.033	.176	1.329
III				.313***	.096	1.014	.339***	.102	1.058	.318***	.102	1.304
ALS							.076	.007	1.311	.086	.009	1.140
BOR							.041	.006	1.345	-.006	.006	1.423
TI							-.134	.005	1.343	-.191**	.008	1.184
Service variety							.048	.011	3.897	.043	.011	4.007
CMI							.0124	.450	1.449	.056	.477	1.397
III x ALS										.095	.020	6.722
III x BOR										.094	.008	3.108
III x TI										.122	.010	6.806
III x Service variety										.070	.011	2.098
III x CMI										.262*	.866	2.891
F for the step	0.034			12.534***			1.000			2.504*		

F for the regression	0.034	4.203**	2.201**	2.409**
Adjusted R^2	-0.016	0.074	0.074	0.132

+ p≤0.10; * p≤0.05; ** p≤0.01; *** p≤0.001.

Table 18. Hierarchical moderated regression analysis of external information integration /contingencies on hospital resilience.

Variable entered (N=121)	Dependent variable: Hospital resilience											
	Step 1			Step 2			Step 3			Step 4		
	Stand. Beta	Stand. Errors	VIF	Stand. Beta	Stand. Errors	VIF	Stand. Beta	Stand. Errors	VIF	Stand. Beta	Stand. Errors	VIF
Hospital size	-.024	.000	1.168	-.026	.000	1.168	-.104	.000	2.919	-.101	.000	3.027
Teaching status	.018	.179	1.168	.051	.159	1.173	.013	.165	1.311	.022	.166	1.322
EII				.475***	.074	1.005	.515***	.077	1.058	.550***	.081	1.221
ALS							.037	.007	1.311	-.116	.009	2.827
BOR							.055	.005	1.345	.043	.006	1.678
TI							-.194**	.005	1.343	-.054	.008	3.626
Service variety							.081	.010	3.897	.093	.010	4.229
CMI							.024	.420	1.449	.000	.443	1.615
EII x ALS										.327	.020	6.546
EII x BOR										.117	.008	2.667
EII x TI										-.305	.013	9.793
EII x Service variety										-.154	.009	2.445
EII x CMI										.045	.608	2.416

F for the step	0.034	33.841***	1.486	1.108
F for the regression	0.034	11.309***	5.258***	3.677***
Adjusted R^2	-0.016	0.205	0.221	0.225

+ p≤0.10; * p≤0.05; ** p≤0.01; *** p≤0.001.

4. Discussion and implications

4.1 Discussion of results

This study provides empirical validation of previous research, confirming a positive association between hospital resources and capabilities, specifically ICTs and digital skills, and hospital resilience during the recent pandemic crisis (Bhaskar et al., 2020; Cui et al., 2022; Foroughi et al., 2022; Furstenau et al., 2022; Khalil et al., 2022; Tonetto et al., 2021). In response to the requests from various researchers (Agostini et al., 2023; Chakraborty et al., 2021; Foroughi et al., 2022; Ignatowicz et al., 2023; Tortorella et al., 2022), I aimed to add a significant contribution to the study of hospital resilience by examining the moderating effects of hospital contingencies related to service complexity and operational efficiency, on the relationship between hospital resources/capabilities and resilience (Donelli et al., 2022; Foroughi et al., 2022; Tonetto et al., 2021). This research is crucial for deepening the understanding of quality in modern healthcare systems and for developing a robust, evidence-based framework for enhancing healthcare resilience (Lyng et al., 2022). Despite recent studies emphasizing their role in hospital resilience, our research stands out as one of the first to utilize surveys for testing hypothesized relationships in this specific context.

I confirm the positive impact of ICTs and digital skills in enhancing the responsiveness and adaptability of patient care processes (He et al., 2022; Marques da Rosa et al., 2021). Additionally, I validate the positive effect of information integration capabilities, both within and beyond hospital boundaries. Sharing information allows hospitals to acquire data, knowledge, and insights, which accelerates adaptation and decision-making during and immediately after crises. This finding aligns with the conclusions drawn by Peng et al. (2023), who also highlight the relevance of establishing internal integration, whose dynamics encompass processes such as acquiring missing or damaged resources from nearby operational units and facilitating expertise and knowledge exchange beyond individual units. These processes enable the identification of root causes associated with material and

resource shortages, leading to a deeper understanding and response to challenges encountered by hospitals. Resilience can be strengthened as hospitals gain access to additional resources such as specialized medical equipment, additional staff, and external funding (Benzidia et al., 2021; Spieske et al., 2022). Furthermore, the sharing of knowledge and experiences enables hospitals to address operational and clinical challenges more effectively, facilitating coordinated responses. Access to crucial information from external sources, such as governmental regulations and patient data, is essential for informing hospital decisions and strategies (Donelli et al., 2022). Establishing collaborative relationships with suppliers and other external entities expands the hospital's support network and reduces isolation, ultimately enhancing the overall ability to respond to emergencies and maintain continuity of care (Ridde et al., 2023).

Moreover, when considering moderating effects, we observe that hospital operational efficiency has a positive influence on the relationship between ICTs, digital skills, and hospital resilience. Notably, all three measures of operational efficiency—average length of stay, bed occupancy rate, and turnover interval—are significant moderators.

In particular, we found that the shorter patient stays, reflecting higher operational efficiency, the lower the impact of resources and hospital resilience. This can be explained by the fact that longer patient stays provide more opportunities for ICTs to be leveraged in patient care processes, facilitating the exchange of information across departments and various information systems (McDermott and Stock, 2007; Pham et al., 2024). Longer stays give hospital staff the time to utilize digital tools, share knowledge, and find innovative solutions, thus fostering resilience. In this case, inefficiencies, represented by longer patient stays, can actually increase the benefits of ICTs and digital skills, as these tools are more fully utilized in supporting care delivery. Regarding the bed occupancy rate, the results suggest that a higher turnover of beds—indicative of greater bed utilization—weakens the positive effect of ICTs on resilience. This can be explained by the fact that hospitals with a high bed occupancy rate are likely already demonstrating resilience by efficiently managing patient inflow without overwhelming bed capacity. Consequently, the marginal utility of ICTs in enhancing

resilience decreases, as these hospitals are already capable of handling patient turnover effectively without relying heavily on technological interventions. Differently, in the case of turnover interval, the findings show that lower efficiency, reflected by a longer time between discharging one patient and admitting the next, reduces the utility of resources as ICTs and digital skills in enhancing hospital resilience. It seems that ICTs and digital skills do not thrive in this scenario of reduced efficiency during crises. This may be because the hospital is not adapting effectively to provide care to a high volume of patients within a short timeframe. The longer turnover intervals lead to fewer patients being treated, which limits the opportunities for hospital staff to fully utilize ICTs and digital skills (Hansen and Baroody, 2023; Wani and Malhotra, 2018). Additionally, with fewer patients moving through the system, there are fewer demands on the hospital's information-sharing and decision-making processes, meaning that the potential benefits of technology are underutilized (Pecoraro et al., 2021). Essentially, in such cases, the hospital's operational inefficiency diminishes the role of these digital tools in supporting patient care and overall resilience (Cunningham et al., 2006).

The results regarding the moderating effect of service complexity show non-significant findings for the relationships between resources, specifically ICTs and digital skills, and hospital resilience (H5 and H6 not supported). Similarly, no moderating effect of service complexity on the relationship between external information integration and hospital resilience was found (H8 is not supported). Conversely, an interesting result that emerges from the study is the significant moderating effect of service complexity, as measured by the CMI, on the relationship between internal information integration and hospital resilience (H7 confirmed).

A higher CMI indicates that a hospital is dealing with more complex, resource-intensive cases (Mendez et al., 2014). This result suggests that during crises, such as the pandemic, the more complex the patient profiles, meaning that hospitals are treating a greater variety of severe and challenging cases, the more the internal integration of information positively contributes to hospital resilience (Chuang et al., 2020). In such scenarios, the ability to efficiently share and coordinate information across departments is crucial for adapting to rapidly changing patient needs and ensuring that all

teams are aligned in their response. The complex nature of care required for high-CMI patients demands precise and timely information sharing to make informed decisions, allocate resources appropriately, and ensure continuity of care (Dobrzykowski et al., 2016). As a result, hospitals with strong internal information integration are better equipped to handle the operational stress caused by treating complex cases, thus enhancing their overall resilience during disruptive events. Finally, our findings reveal that neither internal nor external information integration is moderated by the two contingency variables of service complexity and operational efficiency. These results show that regardless of the complexity of services offered, and patients treated, as well as the level of efficiency achieved by the hospital, the integration initiatives, not only between operational units but also with external entities, commonly prove beneficial for all categories of hospitals. Addressing current and future uncertainty can be achieved by encouraging some staff members to participate in training courses and job rotations, thereby maintaining a broader base of general knowledge and skills. This approach enables easier redistribution of personnel during crises. Additionally, it may help mitigate challenges associated with increasing staff specialization, such as poor collaboration, fragmentation, and organizational rigidity (Gifford et al., 2022).

4.2 Contributions to theory

The theoretical contributions of this study are manifold and reflect an innovative approach in the field of hospital resilience to understanding the linkage between resources and capabilities and resilience through the paradigm of the CRBV. In particular, this study contributes to the literature by offering a new and comprehensive perspective in analysing hospital resilience. ICTs, digital skills and information integration capabilities are considered as enablers, while service variety and operational efficiency are considered moderators. In the first place, I established that the resources considered in the study, namely ICTs, digital skills, and internal and external information integration, all have a direct and positive effect on resilience. While the literature extensively discusses the role of ICTs in hospital resilience (Marques da Rosa et al., 2021; Tortorella et al., 2022), less attention has been given

to the role of information integration capabilities. Therefore, my study makes a valuable contribution in this regard. Moreover, having demonstrated an active role in achieving resilience through internal and external information integration, these results provide a potential theoretical basis for analysing and addressing the operational issues arising from the intrinsic interdependencies in healthcare delivery processes during crises (Barasa et al., 2018). From the perspective of CRBV (Brandon-Jones et al., 2014; Parast, 2022), this study proposed service complexity and operational complexity as moderator variables, providing a useful conceptual framework for understanding how digital resources and integration capabilities translate into hospital resilience in contexts characterized by different levels of service complexity and operational efficiency. While these contingencies have been previously explored in relation to patient satisfaction, quality of care, and hospital performance, their impact on resilience has not yet been examined, marking a novel contribution to the existing literature. Through the analysis of the contingent effect of service complexity and operational complexity, this study provides a deeper understanding of the conditions under which digital resources and integration capabilities can play a significant role in promoting hospital resilience.

4.3 Implications for practice

Given the complexity and novelty surrounding the concept of hospital resilience, hospital managers should strengthen resilience capacity through digital resources, the skills to use them, and integration capabilities (De La Garza and Lot, 2022; Donelli et al., 2022). Firstly, to improve the hospital's ability to respond to crises and ensure preparedness, managers should invest in advanced information systems that enable efficient collection, management, and analysis of clinical and administrative data. These systems should be designed to facilitate easy access and sharing of information across various hospital departments and units. Consequently, investments should also be directed towards improving staff training in digital skills. This would equip the staff with the appropriate training to develop new ways of delivering services, even in times of crisis (Fornes-Romero et al., 2020). In addition, a practical implication of this study could be the institutionalization of investments in professionals

with digital and technological skills. This involves the adoption of new technologies and the creation of digital profiles capable of managing these innovations (Bastone et al., 2024).

Establishing a collaborative culture within the hospital, through regular meetings, team-building activities, and online communication platforms, is crucial for fostering effective communication and collaboration among different operational units. This becomes even more important in the case of hospitals with a high case mix. Furthermore, hospital managers should actively engage the hospital in the healthcare network by establishing partnerships and collaborations with other healthcare organizations, including other hospitals, medical centres, diagnostic laboratories, and healthcare service providers. These partnerships can facilitate the exchange of information and knowledge, enabling a more integrated approach to patient management and emergency response. Additionally, the results highlight that investments in ICTs and digital skills may have varying impacts depending on the operating context.

Finally, since no contingent effects were found between internal and external integration capabilities, hospital managers can focus on investing in the development of these capabilities regardless of the specific context. This suggests that these integration capabilities can positively influence hospital resilience, irrespective of specific circumstances, providing a solid foundation for improvement efforts. The smart use of technologies, streamlining processes, continuous training, and prioritizing safety and privacy all converge towards a single objective: placing the patient at the centre of attention.

4.4 Research limitations

This research has limitations that need to be considered. Firstly, operational efficiency was assessed by looking at bed productivity, overlooking the productivity of nursing and medical staff. Therefore, future research could further explore this aspect, including broader measures of operational efficiency. Moreover, the research only considered two types of control variables: size based on the number of beds and whether the hospital is a teaching hospital or not. However, there are other strategic variables, such as hospital ownership, location (e.g., whether it is located in rural or urban

areas), and the age of the hospital, which could affect hospital resilience. Therefore, future research could examine the effect of these strategic variables to gain a more comprehensive understanding of the factors influencing hospital resilience. This study focuses solely on the effects of contingencies on the relationship between resources, capabilities, and hospital resilience. Future studies could broaden the scope and investigate the relationship between resilience and hospital performance. The survey received a response rate of just over 10%, aligning with similar studies employing a comparable methodology. Nevertheless, a higher response rate would have been advantageous. Although our dataset was sufficient for hypothesis testing, aligning primary and secondary data posed challenges and resulted in a reduction in sample size due to missing data and information on hospitals. Moreover, our study addressed external integration among all stakeholders indiscriminately. Future research could delve into the various relationships and understand which one's impact hospital resilience more than others. A potential avenue for future research could focus on understanding the financial impact of implementing digital resources, given their positive effect on resilience. Since one of the primary concerns regarding the adoption of such technologies is the investment cost, future studies could explore whether, following the initial investment, an effective implementation of these digital tools can help reduce or contain costs over time. Moreover, our study focuses on the pandemic crisis during and immediately after its occurrence. It would be interesting to investigate whether the impact of resources and capabilities on resilience, as well as the moderating contingent effects, persist in a post-crisis phase. A longitudinal study could be particularly valuable in exploring these dynamics over an extended period, offering deeper insights into the lasting effects of such resources.

An interesting finding concerns the direct effect of turnover interval on hospital resilience. Among all the moderators, this variable represents a form of efficiency that directly impacts resilience outcomes. This open up a reflection on whether resilience may depend on measures of efficiency as well as other performance indicators. This provides room to investigate the relationships between hospital resilience and hospital performance.

Conclusions

This thesis aims to expand our understanding of resilience within the healthcare context by examining factors that can enhance the ability of hospitals to respond effectively to increasingly unpredictable and impactful crises. Given the critical importance of resilience in healthcare systems, particularly within hospital settings (Bai et al., 2024), I focused on identifying key organizational characteristics that may support hospitals in building resilience. To achieve this, I conducted three studies presented across the three main chapters of this thesis. In the first chapter, I conducted a systematic literature review to identify organizational characteristics that influence hospital resilience, with a focus on insights gained from the COVID-19 pandemic. The second chapter builds on these insights and presents a quantitative study conducted across a sample of Italian hospitals, aimed at empirically testing and validating key organizational characteristics highlighted in the literature as enhancers for resilience, specifically within the phases of adaptation and response. Finally, the third chapter presents a second quantitative study also focusing on Italian hospitals, to further investigate resilience mechanisms during the pandemic crisis. This study examines the moderating effects of hospital-specific contingencies on the relationship between organizational characteristics and resilience, providing a nuanced understanding of the adaptive and responsive abilities of hospitals in crisis contexts. The first chapter presents a systematic literature review conducted following PRISMA guidelines (Moher et al., 2009). This review addresses which organizational characteristics influence specific resilience dimensions, including hospital's ability to anticipate, adapt, respond, recover, and learn. Guided by the resource-based view (RBV) as a theoretical framework, I categorized key organizational characteristics into resources and capabilities, analyzing their synergistic impacts and systematically mapping how each contributes to different resilience dimensions. Indeed, while recent literature reviews (Biddle et al., 2020; Jolgenhejad et al., 2020; Iflaifel et al., 2020; Barasa et al., 2018; Arji et al., 2023; Khalil et al., 2022) have been valuable, they have frequently overlooked the intricate ways in which resources and capabilities integrate with one another. Instead, these reviews have typically provided linear and indiscriminate classifications of organizational factors related to

hospital resilience. In contrast, this study is the first to establish a categorization of hospital factors through a theoretical lens, derived from management field, which has been traditionally used to examine organizational resilience (Ambulkar *et al.*, 2015; Blackhurst *et al.*, 2011; Gupta *et al.*, 2018), but not yet systematically applied in healthcare context. Indeed, although the RBV is widely recognized in strategic management and resilience literature (Brandon-Jones et al., 2014), its application to the healthcare sector is relatively limited. I believe this work offers significant contributions to the field of hospital resilience. First, this research contributes to the healthcare management domain by providing a new perspective on the interplay between resources, capabilities, and hospital resilience, offering a structured, replicable framework for studying resilience of hospitals. By demonstrating that digital technologies enhance hospitals' abilities to anticipate and adapt to disruptions, this study establishes its relevance at the intersection of healthcare management and information systems research (Rubbio and Bruccoleri, 2023; Arji et al., 2023; Bamel et al., 2023). It underscores the imperative for healthcare organizations to strategically leverage digital innovations as integral components of their resilience-building efforts. This contribution enriches the existing literature on technology adoption in healthcare, particularly in light of the ongoing transformations driven by rapid technological advancements. In light of the global challenge posed by acute hospital bed shortages and constrained hospital capacity, there is an increasing focus on exploring alternative healthcare models designed to minimize hospital stays (Karlsen et al., 2024). By emphasizing the critical roles of internal, external, and supply chain integration, it provides empirical evidence that these integration forms significantly enhance hospitals' abilities to anticipate, adapt, respond, and recover from crises. This finding aligns with and enriches research streams focused on collaborative practices and inter-organizational relationships in healthcare (Bergami et al., 2024). Finally, I use the literature review as a springboard to outline opportunities for future research.

In the second chapter, I focused on the resources and capabilities identified as impactful for hospitals' adaptive and responsive capacities. Specifically, I conducted a study with three primary objectives: to test the direct impact of digital technologies, staff skills, and information integration capabilities

on hospital resilience, particularly concerning the dimensions of absorbing, adapting, and responding; to investigate the relationships between digital technologies, staff skills and both internal and external information integration capabilities; and to test the mediating effect of information integration capabilities in the relationships between digital technologies, staff skills, and hospital resilience. Consistent with the hypotheses developed, I found that digital technologies and external information integration have a direct impact on hospital resilience. Additionally, while staff skills positively influence internal information integration, the findings further indicate that both digital technologies and staff skills significantly enhance external information integration. Notably, external information integration acts as a complete mediator in the relationship between staff skills and hospital resilience and serves as a partial mediator in the relationship between digital technologies and hospital resilience. My research, thus, makes relevant contributions. First, it represents, to my knowledge, the first quantitative study that utilizes original survey data collected from Italian hospitals to investigate the emerging literature on hospital resilience. By providing empirical evidence of the pivotal role digital technologies play in enhancing hospitals' ability to adapt and respond to global health challenges, this study confirms and reinforces the importance of digital transformation in the healthcare and hospital context (Kraus et al., 2021; Dal Mas et al., 2023). It highlights the necessity for integrating insights from digital innovation literature in healthcare, emphasizing the transformative potential of technology of reshape healthcare delivery, optimize processes (Cannavacciuolo et al., 2023), as well as its capacity to improve decision-making and enable more agile responses during crises (Juvet et al., 2021; Veerapen and McKeown, 2021). Furthermore, by showing that staff skills, including relational, professional, and technical competencies, significantly enhance internal information integration, this research enriches both healthcare human resource management and organizational learning literature (Ambrose et al., 2021; Do et al., 2022; Haraldseid-Driftland et al., 2021). It illustrates that skilled staff foster a continuous learning environment within hospitals, where information is not only shared but also retained and effectively applied across departments. In doing so, the finding also adds value of knowledge management within healthcare

organizations (Barasa et al., 2018; Myllärniemi et al., 2012). Skilled personnel facilitate the transfer of both explicit and tacit knowledge, an essential process for effective internal integration, especially under crisis conditions when rapid, accurate communication of complex information is critical (Cruz-Cunha et al., 2010; Alajmi et al., 2016). Additionally, this study intersects with the literature on inter-organizational knowledge sharing, providing empirical evidence that hospitals achieve greater resilience by accessing diverse knowledge sources beyond organizational boundaries. By emphasizing the role of external information integration (EII), the research offers empirical support to the concept that resilience strategies increasingly depend on external information flows (Lai et al., 2013; Witter et al., 2023). By empirically demonstrating how hospitals benefit from integrating external information sources, the research highlights the interdependence of people, technology, and organizational processes in building healthcare resilience. This insight supports the concept that resilience can be systematically developed through strategic integration practices across socio-technical networks (Lyng et al., 2021; van den Berg et al., 2023; Alameddine et al., 2019). This research also contributes to offer valuable insights into the potential of public-private partnerships (PPPs) in enhancing healthcare resilience. External information integration often entails collaboration between public health systems and private entities, including suppliers, technology providers, and community organizations (Scala & Lindsay, 2021; Zamiela et al., 2022). By emphasizing the resilience benefits of external integration, the study lends empirical support to the literature on PPPs as facilitators of resilience in healthcare, suggesting that hospitals can enhance resilience through strategic partnerships that pool resources and knowledge across sectors, thus extending the applicability of PPP frameworks in crisis management (Foroughi et al., 2022). Finally, the study implicitly contributes to the literature on leadership in healthcare resilience (Lyng et al., 2022). Effective external information integration frequently depends on strong leadership that prioritizes collaborative networks, agile response mechanisms, and the adoption of innovations. By highlighting the strategic importance of external information flows, the research suggests that leadership practices focused on fostering external collaboration are integral to resilience. This aligns with the literature on

transformational leadership in healthcare (Perez, 2021; Barbash & Kahn, 2021; Mohtady Ali et al., 2021), which posits that resilient outcomes are driven by leaders who champion inter-organizational collaboration, knowledge-sharing, and a culture of adaptability. The study further contributes to theoretical models of resilience by demonstrating that EII is a critical mechanism that transforms internal resources, such as staff skills, into resilience outcomes. This underscores the idea that while skilled personnel are essential, their impact on resilience may be constrained without established an effective EII processes. In doing so, the study provides empirical grounding to theories in resilience engineering and healthcare information systems, which advocate for EII as a bridge linking internal strengths with enhanced resilience capabilities. It suggests that hospitals, rather than being isolated entities, are interdependent with broader systems, and their resilience is thus partly shaped by the quality of information and resources flowing from outside (Peng et al., 2023).

Finally, in the third chapter, through an empirical investigation conducted across Italian hospital, I shed new light on the role of key contingencies, namely the service complexity and the operational efficiency, in the relationship between resources, capabilities and hospital resilience, specifically in the dimension of absorb, adapt and respond. This study responds to the calls in healthcare resilience literature for a deeper exploration of how hospital conditions linked to the typology of care provided and patients treated, alongside the capacity to transform inputs into outputs (i.e., operational efficiency) influence the relationships between ICTs, digital skills, internal and external information integration, and hospital resilience (Agostini et al., 2023; Chakraborty et al., 2021; Foroughi et al., 2022; Ignatowicz et al., 2023; Tortorella et al., 2022). This study not only deepens our understanding of quality in modern healthcare systems but also aids in developing robust, evidence-based frameworks for enhancing healthcare resilience (Lyng et al., 2022). By demonstrating that even when operational efficiency decreases during crises, hospitals can still adapt, and respond effectively, provided they implement and leverage ICTs and digital skills among their staff. This insight extends beyond traditional views of operational efficiency by highlighting that technology adoption and digital competencies play a critical role in maintaining hospital resilience, especially in times of crisis.

The study offers valuable insights for healthcare management and advances the discourse on quality of care in healthcare systems (Dobrzykowski et al., 2016; McDermott and Stock, 2007; Hansen and Baroody, 2023). It suggests that hospitals can prioritize digital innovation and staff training in ICTs as a strategic response to enhance resilience, since these efforts can make a significant difference in maintaining hospital operations and ensuring continuity of care when traditional operational processes are disrupted. In other words, the study demonstrates how operational efficiencies can amplify the benefits of digital resources, thereby improving overall care quality and patient outcomes. Moreover, by confirming the impact of interna and external information integration for hospital resilience, the study demonstrates that fostering a collaborative culture characterized by open communication and proactive information sharing can significantly enhance decision-making processes and improve the overall responsiveness of healthcare organizations, contributing to organizational behavior literature. These insights are particularly valuable for managers aiming to cultivate agile organizational cultures that can swiftly adapt to dynamic circumstances, thereby ensuring sustained operational effectiveness. The study also addresses the impact of service complexity, as measured by the Case Mix Index (CMI), on resilience and information integration. The findings indicate that hospitals managing more complex and resource-intensive cases benefit significantly from strong internal information integration, particularly during crises like the pandemic. This contribution adds to the literature on complexity in healthcare delivery, providing a framework for understanding how hospitals can better manage information flow and coordination in the face of operational stress (Chuang et al., 2020). Since the capabilities for information integration—both internal and external—are not moderated by any hospital contingencies, their role in enhancing resilience is essential for every hospital, regardless of the complexity of services provided or the levels of operational efficiency achieved. They highlight the need for supportive policies that encourage hospitals to invest in information integration capabilities as a means to enhance resilience. This contribution informs strategic decision-making by advocating for collaborative frameworks among hospitals, suppliers, and governmental entities to ensure continuity

of care during emergencies (Ridde et al., 2023). From an operations management perspective, this insight emphasizes that effective integration of information is a fundamental requirement for all healthcare institutions seeking to improve their resilience, particularly in crisis situations. This contributes to the discourse on operational design, indicating that hospitals should invest in systems that facilitate information flow and coordination to bolster their responsiveness during crises. It suggests a shift in focus towards the foundational role of information systems in operational strategy. This contributes to the discourse on operational design, indicating that hospitals should invest in systems that facilitate information flow and coordination to bolster their responsiveness during crises. It suggests a shift in focus towards the foundational role of information systems in operational strategy.

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Appendix A - Descriptive findings of the articles included in the review

Figure A1 shows the distribution per year of the reviewed papers across the study time frame. Looking at the resulting sample, over the past four years, the increasing number of articles published emphasises the higher level of relevance of the topic that has drawn attention from more researchers.

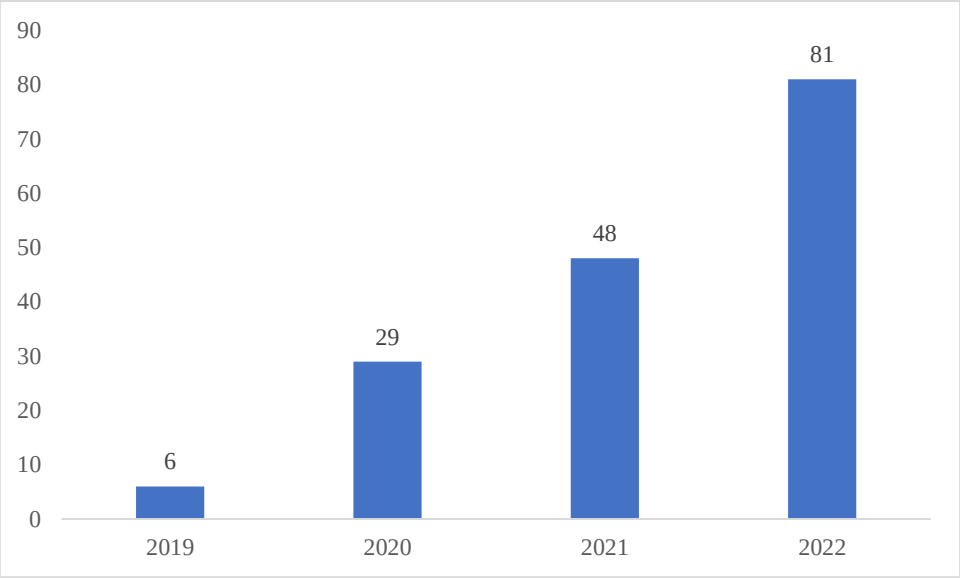

Figure A1. Distribution of the reviewed papers across the period 2019-2022.

Table A1 reports the journals that published hospital resilience related articles from 2019 to 2022, citing only the journals publishing at least two papers on the topic. The top contributor is BMC Health Services Research (8 papers), followed by IEEE Access (7 papers) and PLoS ONE (6 papers). Disaster Medicine and Public Health Preparedness, BMJ Leader, Frontiers in Public Health published 4 papers on the topic, while International Journal of Lean Six Sigma, International Journal of Environmental Research and Public Health, International Journal of Disaster Risk Reduction, IEEE Transactions on Industrial Informatics and International Journal of Operations & Production Management contributed publishing 3 papers on the topic. The journals publishing 2 papers will follow: Safety Science, Multimedia Tools and Applications, International Journal of Logistics Management, BMJ Open, Applied Ergonomics, Annals of Operations Research, IEEE Internet of Things Journal, Supply Chain Management: An International Journal, International Journal of Health Policy and Management.

Table A1. Number of papers by journal.

Journal title	***Number of articles***
BMC Health Services Research	*8*
IEEE Access	*7*
PLoS ONE	*6*
Disaster Medicine and Public Health Preparedness	*4*

BMJ Leader	*4*
Frontiers in Public Health	*4*
International Journal of Lean Six Sigma	*3*
International Journal of Environmental Research and Public Health	*3*
International Journal of Disaster Risk Reduction	*3*
International Journal of Operations & Production Management	*3*
IEEE Transactions on Industrial Informatics	*3*
Safety Science	*2*
Multimedia Tools and Applications	*2*
International Journal of Logistics Management	*2*
BMJ Open	*2*
Applied Ergonomics	*2*
Annals of Operations Research	*2*
IEEE Internet of Things Journal	*2*
Supply Chain Management: An International Journal	*2*
International Journal of Health Policy and Management	*2*
Others	*98*
Grand Total	***164***

Table A2 reports the articles according to the geographical context which they focus on. As challenges are progressively taking on a global scale, the analysis of the national context provides an essential perspective to understand which states are addressing these challenges and how they responding to them. Among the 164 papers, 19 specifically addressed the United States, 12 concentrated on the United Kingdom (UK), and 6 delved into Italy. In addition, 5 studies considered multiple countries across different continents: Brazil, Chile, Argentina, Australia, the UK (Tonetto et al., 2021); Brazil, Mexico, Chile, Argentina, USA, Australia, the UK, and Canada (Marques da Rosa et al., 202; and Tortorella et al. 2021); and a global investigation conducted by Bhaskar et al. (2020a), Harland et al. (2021), Zhang & Qi (2021); Sanford et al. (2022) and Capolongo et al. (2020). Furthermore, three studies exclusively concentrated on European countries: Winkelmann et al. (2022) investigated different European countries, Papalexi et al. (2021) focused on the UK and Greece, and Spieske et al. (2022) on Austria, Switzerland, and Germany. Ravaghi et al., (2022), on the other hand, detail the states bordering the eastern coast of the Mediterranean.

Table A2. Geographical distribution of the reviewed papers.

Country of the study	**Number of articles**	**References**

Australia	5	*Austin et al. (2022); Shaw et al. (2022); Hodgins et al. (2022); Ziser et al. (2021); Pomare et al. 2022*
Brazil	3	*Alemsan et al. (2022); Furstenau et al. (2022), Tortorella et al. (2022)*
Canada	2	*Tremblay et al. (2022); Snowdown and Wright (2022)*
China	6	*Lim et al. (2020); Liu et al. (2020); Chen et al. (2022a); Jiang et al. (2022); Wong et al. (2022); Xu et al. (2022)*
Eastern Mediterranean Region (EMR)	1	*Ravaghi et al. (2022)*
Finland	1	*Kihlström et al. (2022)*
France	3	*de La Garza and Lot (2022); Bessis et al. (2022); Minka et al. (2021)*
Global	5	*Zhang and Qi (2021); Sanford et al. (2022); Capolongo et al. (2020); Harland et al. (2021); Bhaskar et al. (2020a);*
Italy	6	*Rubbio et al. (2019); Casiraghi et al. (2020); Trucco et al. (2022); Donelli et al. (2022); Ferorelli et al. (2020); Aldrighetti et al. (2022)*
Japan	2	*Hirano et al. (2020); Chen et al. (2022b)*
Kenya	1	*Kagwanja et al. (2020)*
Nepal	1	*Moitinho de Almeida et al. (2021)*
Netherlands	2	*Gifford et al. (2022); Kuiper et al. (2022)*
Norway	4	*Ree et al. (2021); Barrett (2022); Lyng et al. (2021); Fagerdal et al. (2022)*
Palestine	1	*Sabateen et al. (2022)*
Peru	1	*Ceferino et al. (2020)*
Scotland	1	*Scala and Lindsay (2021)*
Sweden	2	*Appelbom et al. (2021); Hybinette et al. (2021)*
Switzerland	1	*Juvet et al. (2021)*
Turkey	3	*Ortiz-Barrios et al. (2020); Turan (2021); Pamucar et al. (2022)*
United Kingdom	12	*Ballantyne and Achour (2022); Borek et al. (2022); MacKinnon et al. (2022); McLeod et al. (2019); Sacoor et al. (2020); Shah et al. (2021); Till and McGivern (2020); Veerapen and McKeown (2021); Garcia-Perez et al. (2022); Grailey et al. (2022); Pandit et al. (2021); Mervyn et al. (2019)*
United States	19	*Cimellaro et al. (2019); Hassan and Hussam (2020); Rusinko (2020); Shahverdi et al. (2020); Hines & Reid (2021); Mandel-Ricci and Belfi (2022); Bohnett et al. (2022); Sawyerr and Harrison (2022); Chiu et al. (2021); Hannan et al. (2021); Moss et al. (2021); Spiva et al. (2020); Wei et al. (2019); Croghan et al. (2022); Khalil et al. (2022); Khuntia et al. (2022); Koch et al. (2022); Ladak et al. (2021); Jordan et al. (2022)*
Germany	2	*Ölcer et al. (2021); Litke et al. (2022)*
Pakistan	2	*Hussain et al. (2022); Malik et al. (2021)*
Multiple countries from various continents	3	*Tortorella et al. (2021); Marques da Rosa et al. (2021); Tonetto et al. (2021)*
Multiple European Countries	3	*Papalexi et al. (2021); Spieske et al. (2022); Winkelmann et al. (2022)*
Poland	1	*Łukasik andPorębska (2022)*
Taiwan	1	*Wang et al. (2022)*
Austria	1	*Kaleta et al. (2022)*
Iran	1	*Kazemi Matin et al. (2021)*

Figure A2 provides an overview of the research methodologies employed in the sample of selected articles. Four different categories of research methodologies are found: quantitative including analytical and mathematical model and simulation; empirical concerning case studies (exploratory, longitudinal, multiple, single), and involving data collection through observations, interviews, and surveys to obtain descriptive findings or test hypotheses using regression analysis; review including systematic literature review, topic modelling, review synthesis; and finally, researchers' perspectives including commentary and conceptual framework. The analysis reveals that the majority of articles (84 out of 164) relied on empirical studies as the primary method of investigation. Most of these papers (77/84) employ the case study method for data collection and analysis. These articles share the common objective of collecting direct testimonies from hospitals regarding the strategies implemented to mitigate the effects of the crisis. Data collection involves interviews with healthcare professionals and hospital managers, as well as observational studies (McLeod et al., 2019; Rubbio et al., 2019; Liu et al., 2020). The nature of these works is highly exploratory, indicating a still nascent stage of research in this field. The remaining 12 papers among the 84 empirical ones use survey methodology for data collection, with six papers conducting regression analyses in order to test hypotheses (Papalexi et al., 2021; Lim et al., 2020), while the other six used survey as collecting data with the aim of performing descriptive analyses such as factor analysis for ranking (Cimellaro et al., 2019), hierarchical clustering (Tortorella et al., 2021). The second most commonly employed methodology category is quantitative (39 papers), with 32 adopting an integrated mathematical and simulation model. This approach aims to enhance safety, transparency, and promptness in the transmission of hospital data both within the hospital and externally. This is achieved by addressing cybersecurity through blockchain, crypto system fog-based communication architecture, and edge computing. Among the remaining, seven papers develop simulations with the aim of examining the most effective patient management solution among local and regional hospital networks during natural disaster (Ceferino et al., 2020; Shahverdi et al., 2020; Hassan and Hussam, 2020, Kazemi Matin et al. 2021, Hossain et al., 2022), and with the goal of defining effective resource allocation

during mass casualty incident (Trucco et al., 2022, Patrone et al., 2020). The third category pertains to the 29 papers that utilized researchers' perspective. Among these, six are conceptual, leading to the definition of a theoretical framework regarding healthcare resilience (Behrens et al.,2022; Ito and Aruga, 2022; Lyng et al., 2022a; Lyng et al., 2022b; Phattharapornjaroen et al., 2022; Zamiela et al., 2022). The remaining 23, on the other hand, present viewpoints and expert comments on the events that occurred. Literature reviews represent the least employed methodology category in the analysed studies, numbering 12, and among them, only 3 employ a systematic research method of analysis (Chowdhuri et al., 2021; Angelopoulou and Panagopoulou, 2022; Friday et al., 2021).

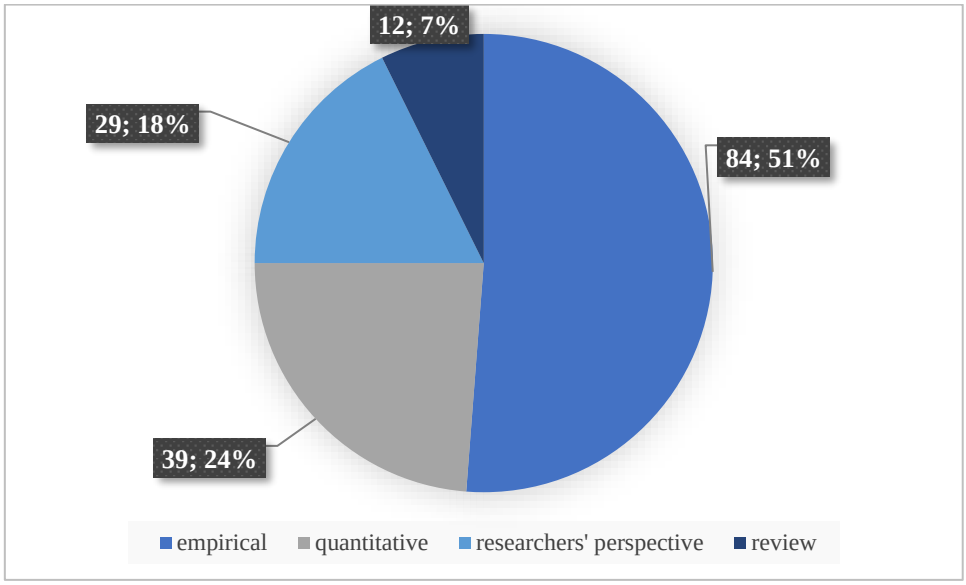

Figure A2. Employed research methodologies.

Appendix B - Detailed overview of resilience dimensions, resources, capabilities of retrieved papers.

Authors	Year	Resilience Dimension	Resources	Capabilities	Methodology	Specific methodology/technique/method applied
Appelbom et al.	2021	Learn	Training for hospital leaders on how to manage crisis, transfer of new knowledge; teamwork, interpersonal skills, effective educational interventions		Empirical	Case study
Awan et al.	2021	Anticipate	Digital technologies (cybersecurity)		Quantitative	Mathematical model and simulation
Baxter & Casady	2020	Respond Recover		Externa integration (Public-private partnership: institutional cooperation, long term infrastructure contracts, short-medium and long term projects)	Researchers' perspectives	Commentary
Bhaskar et al.	2020b	Adapt	Digital technologies (Telemedicine, communication infrastructure)	Technological capability	Researchers' perspectives	Commentary/viewpoint

Casiraghi et al.	2020	Adapt Learn	Skills of medical and nursing staff Training for staff	Organizational capability (after cancelling elective surgeries, re-employment of medical and nursing staff in covid wards); External integration (Formal national and intrahospital protocols)	Empirical	Case study
Chowdhury et al.	2021	Adapt Respond Recover	Digital technologies (3-D printing technology, artificial intelligence and mobile service operation)	Organizational capability (redefinition of roles and tasks; scaling capacity) External integration (partnership)	Review	Systematic literature review
Cimellaro et al.	2019	Respond	Information sharing, emergency training and drills	Internal integration (coordination within and across departments)	Empirical	Survey, factor analysis for ranking
Domadiya & Rao	2021	Anticipate	Digital technologies (Data mining central service)		Quantitative	Mathematical model and simulation
Ejaz et al.	2021	Anticipate	Digital technologies (cybersecurity: combination of edge computing and blockchain)		Quantitative	Mathematical model and simulation

Fiske et al.	2021	Anticipate	Educational training (for students on stress management, trauma-informed care, develop resilience skills)	Internal integration (collaborate with other disciplines to provide care)	Empirical	Case study (educational course)
Guo et al.	2021	Anticipate	Digital technologies (cryptosystem and fog-based communication architecture)		Quantitative	Mathematical model and simulation
Hines & Reid	2021	Anticipate Respond	Skills and competence of nurses, physicians, doctors and technician (expert team)	Organizational capability (Establishing protocols and guidelines); External integration (collaboration with local authority, agencies)	Empirical	Case study (survey, interviews, secondary data)
Hirano et al.	2020	Anticipate	Digital technologies (cybersecurity)		Empirical	Case study
Huey and Palaganas	2020	Learn	Training for hospital leaders (on how to manage crisis, transfer of new knowledge); teamwork, interpersonal skills, effective educational interventions		Review	Review synthesis
Hundal et al.	2021(a)	Anticipate	Quality culture (Lean six sigma programs and practices)		Empirical	Interviews + new model

Hybinette et al.	2021	Adapt	Information sharing	Internal integration (coordination among managers such as clinical coordinators, head nurses, physicians); organizational capability (reorganising tasks, defining clearly new role)	Empirical	Case study (observation)
Jan et al.	2022	Anticipate	Digital technologies (cybersecurity)		Quantitative	Mathematical model
Juvet et al.	2021	Adapt Respond	Skills of extra qualified personnel; Information sharing	Organizational capability (Reorganisation of tasks, services and spaces; staff increases and reassignments; new rules and protocols); Internal and external integration (interdisciplinary collaboration and collaboration with families)	Empirical	Longitudinal study
Kagwanja et al.	2020	Adapt		Organizational capability (Reorganisation of tasks, services and spaces; staff increases and	Empirical	Learning site: interviews, observations, secondary data

				reassignments; new rules and protocols); Collaboration (external integration)		
Marques da Rosa et al.	2021	Anticipate Adapt	Digital technologies (Telemedicine, Digital non-invasive care)	External integration (project for design of digital collaborative platforms)	Empirical	Case study (survey, interviews)
McLeod et al.	2019	Anticipate Adapt	Pharmacist competence in using electronic prescribing and medication administration (epa) systems;	Technological capability	Empirical	Case study (observation, interviews)
Milch et al.	2021	Anticipate Adapt	Digital technologies (telemedicine)		Review	Literature review
Ölcer et al.	2021	Adapt	Digital technologies (Web site for sharing information, Telemedicine)		Empirical	Case study (qualitative document analysis, qualitative content analysis)
Plagg et al.	2021	Adapt		External integration with primary care specialist (helpful in identifing outbreaks in a timely manner and take immediate action to avoid going to hospital)	Researchers' perspectives	Perspective/opinion piece/ commentary/ viewpoint
Ree et al.	2021	Adapt	Managerial skills	Organizational capability (Prioritizing and	Empirical	Longitudinal case study

				allocation of resources); internal integration (interdisciplinary collaboration); external integration (networks or collaboration with external actors)		
Rubbio et al.	2019	Anticipate Adapt	Digital technologies (electronic medical records, digital platforms)	Internal integration (multidisciplinary collaboration) Flexibility	Empirical	Case study (on hospital ward, semi structured interviews)
Rusinko	2020	Adapt	Digital technologies (telemedicine, communication infrastructure; Additive manufacturing)		Empirical	Case study
Sacoor et al.	2020	Adapt	Medical skills (incorporating dentists in the emergency workforce)		Researchers' perspectives	Commentary/ viewpoint
Scala & Lindsay	2021	Respond		External integration (local authority, suppliers)	Empirical	Exploratory case study
Shahverdi et al.	2020			External integration (coordination with other hospitals for patient transfer, coalition policy)	Quantitative	Simulation of hospital interconnections, shared resources.

Tonetto et al.	2021	Adapt	Digital technologies (ICT's for remote consultation, digital platforms, digital non-invasive devices; interconnected medical emergency support)	Internal and external information integration (collaborative sharing)	Empirical	Exploratory case study
Turan	2021	Learn	Psychoeducational training for intensive care workers		Empirical	Case study
Ullah et al.	2020	Anticipate	Digital technologies (cybersecurity)		Quantitative	Mathematical model+simulation
Wiig et al.	2021	Recover Learn	Digital technologies (digital platform) communication skills of regulators and hospital managers	Internal and external integration (reflective spaces, dialogic practice for gaining understanding about the organization)	Researchers' perspectives	Commentary/viewpoint
Agrahari et al.	2022	Anticipate	Digital technologies (cybersecurity)		Quantitative	Mathematical model
Alemsan et al.	2022	Anticipate	Quality culture (Lean principles)		Review	Scoping review
Ali and Kannan	2022	Adapt	Digital technologies (Iot, big data, blockchain, Ai)		Review	Topic modelling
Austin et al.	2022	Adapt	Digital technologies (computerised clinical support systems, telecommunication, health medical records)	Technological capability External integration (distal specialist consultation, and integrated patient-centred care)	Empirical	Cwa modelling+case study

Ballantyne and Achour	2022	Adapt	Nurses skills leaders competencies	Organizational capability (Reorganisation of tasks, services and spaces; staff increases and reassignments; new rules and protocols)	Empirical	Case study (interview)
Barrett	2022	Anticipate		External integration with suppliers and HIT designer	Empirical	Case study (interview)
Behrens et al.	2022	Adapt Respond	Backup suppliers	Organizational capability (Reorganisation of tasks, services and spaces; staff increases and reassignments; new rules and protocols); Increasing capacity of staff	Researchers' perspectives	Conceptual
Bessis et al.	2022	Adapt		Organizational capability (Reorganisation of tasks, services and spaces; staff increases and reassignments; new rules and protocols);	Empirical	Case study (description)
Bhaskar et al.	2020a	Adapt	Digital technologies (telemedicine,	External integration	Researchers' perspectives	Commentary based on case-based approach literature review, website, media sources

			communication infrastructure)			
Bohnett et al.	2022	Respond		External integration (inter-organizational collaboration)	Empirical	Case study (survey+monte carlo simulation)
Borek et al.	2022	Adapt		Organizational capability (shifting responsibilities and redeployment)	Empirical	Longitudinal case study (interview)
Ceferino et al.	2020	Respond		Organizational capability (reorganisation of tasks, services and spaces; staff increases and reassignments; new rules and protocols); External integration (collaboration between groups of interdependent hospitals, social networks, coordination)	Quantitative	Simulation of earthquakes response at national level
Chen et al.	2022(a)	Adapt Respond		External integration (hospital networking, cooperation between hospitals through the ambulance deviation)	Quantitative	Mathematical model, case study (comparative study between different strategies)

Chen et al.	2022(b)	Adapt	Digital technologies (telemedicine) skills of the NCIS GO service (multidisciplinary team comprising geriatricians, oncologists, advanced nurse practitioner, nurses, care coordinators, pharmacists, medical social workers, physiotherapists, occupational therapists, and dietitians)		Empirical	Case study
de La Garza and Lot	2022	Adapt Respond	Knowledge, competencies and expertise of hospital crisis unit made up by critical care, surgery, medicine, administrative skills, epidemiologist, surgeons, infectologists, virlogists information sharing and communication	Internal and external integration (coordination mechanisms, working groups) Organizational capability (reconfigurations of roles and tasks, change protocols, simplification of administrative procedure)	Empirical	Interview
Dichter et al.	2022	Adapt	Interpersonal skills	Internal integration	Researchers' perspectives	Perspective/opinion piece/commmentary/viewpoint
Donelli et al.	2022			Organizational capability (reorganization of roles, rules and tasks)	Empirical	Case study

Furstenau et al.	2022	Adapt	Digital technologies	External integration	Empirical	Multiple case study
Gifford et al.	2022	Adapt	Skills of crisis team crisis unit (board members, departmental managers (e.g., hr, capacity planning) and medical leaders); digital technologies	Organizational capability (scaling capacity, increasing ICU and emergency care capacity; change of destination of use about spaces); redeployment of staff; expansion of role (after short training)	Empirical	Exploratory case study
Harland et al.	2021	Respond	Skills and competencies of managers and administrative staff (to identify new suppliers); Digital technologies	External information integration (coordination with suppliers)	Empirical	Interview
Hassan and Mahmoud	2020	Anticipate Respond	Skills and competencies of managers and administrative staff	Organizational capability (reorganisation of tasks, services and spaces; staff increases and reassignments; new rules and protocols); External integration (collaboration through interdependent hospital groups, redistribution of patients and reduction of waiting times)	Quantitative	Definition of functionality model and simulation in a case study

Hussain et al.	2022	Anticipate	Quality culture (lean tools for eliminating redundant activities and designing useful interventions for achieving operational resilience through better responsiveness)		Empirical	Case study (interview and observation)
Ito and Aruga	2022	Respond		External integration (healthcare coalition)	Researchers' perspectives	Conceptual
Kihlström et al.	2022	Anticipate Recover Learn	 Information sharing Educational program (how to stay updated) Training	External integration (networks of cooperation local and regional level for identifying creative solutions together, for ensuring access to PPE, setting up covid testing infrastructure)	Empirical	Case study
Kuiper et al.	2022	Anticipate	Quality culture (Lean 6 sigma programs and practices)		Researchers' perspectives	Commentary/viewpoint (abductive reasoning)
Li	2022	Anticipate	Digital technologies (cybersecurity		Quantitative	Mathematical model

			Blockchain)			
Lim et al.	2020	Anticipate Adapt Learn	Backup, emergency stockpiles Managerial and medical skills Training and drills for staff	Organizational capability for technical response plan (reorganisation of tasks, services and spaces; staff increases and reassignments; new rules and protocols); Internal integration (interdisciplinary communication) External integration with authority or emergency agencies and public	Empirical	Survey for data collecting and regression analysis
Liu et al.	2020	Adapt Respond	Nurse-physician skills to communicate, trust, information sharing.	Internal and external integration	Empirical	Case study (interview)
Lotfi et al.	2022	Anticipate	Digital technologies (blockchain technology for VMI to manage the medicine inventory) Information sharing	External integration (communication between suppliers and resellers)	Quantitative	Mathematical model

Lyng et al.	2022a	Adapt		Organizational capability (reframing practices, adjustment as short term adaptation; re-prioritizing resources)	Researchers' perspectives	Conceptual
Lyng et al.	2022b	Adapt	Skills and competencies of healthcare operators (as mediators between hospitals and community, transferring knowledge between departments) Information sharing Digital Technologies	Internal and external integration (multidisciplinary coordination and between hospitals and community)	Researchers' perspectives	Conceptual
MacKinnon et al.	2022	Adapt	Managerial skills (preparing areas) Interpersonal skills (teamworking, support for decision making about patients)	Internal integration (multidisciplinary coordination) organizational capability (scaling capacity)	Empirical	Case study (interview)
Mandel-Ricci and Belfi	2022	Adapt Respond		External integration (cooperation between hospitals, routine coordination meetings with governors 'office)	Empirical	Case study

Moitinho de Almeida et al.	2021	Adapt	Educational training (psychological support) Interpersonal skills	Internal integration (staff meeting) Organizational capability (reorganisation of tasks, services and spaces; staff increases and reassignments; new rules and protocols)	Empirical	Case study, interview
Musamih et al.	2022	Anticipate	Digital technologies (cybersecurity through NFT: transparency and security of products in the healthcare supply chain, with benefits such as verification of product propriety, transferability, authenticity, and blocking of new entry flows)		Quantitative	Mathematical model
Ortiz-Barrios et al.	2020	Anticipate	Backup, Emergency equipment, training and drills	Internal integration (multidisciplinary communication)	Quantitative	Analytical model
Pamucar et al.	2022	Anticipate	Digital technologies for Healthcare supply chain using fuzzy rough numbers (FRN)		Quantitative	Mathematical model+case study

Papalexi et al.	2021	Anticipate	Quality culture (Lean principles)		Empirical	Multi group regression
Phattharapornjaroen et al.	2022	Adapt		Internal and external integration; organizational capability (reorganisation of tasks, services and spaces; staff increases and reassignments; new rules and protocols)	Researchers' perspectives	Conceptual
Pu et al.	2022	Anticipate	Digital technologies (cybersecurity)		Quantitative	Mathematical model
Ravaghi et al.	2022	Anticipate Adapt Respond	Experience of multi-sectorial and multi-speciality emergency operating centres (teaching role); Skills and experience of hospital directors, members of hospitals management teams Information sharing digital technologies	External integration (multisectoral collaboration involving private sector, educational institutions, military, national and international NGOs); organizational capability (increasing capacity, staff, increasing spaces, reorganization of resources) Internal integration (meeting)	Empirical	Descriptive analysis

Rehman and Ali	2022	Anticipate Adapt	Digital technologies (augmented reality, blockchain, iot, tatus and identification, radio-frequency identification (RFID), cybersecurity and business intelligence in the supply chains for timely sharing of data and information)		Quantitative	Mathematical model+multi-criteria decision-making (mcdm) techniques for analysis.
Sabateen et al.	2022	Adapt Respond	Skills of procurement department in increasing backup of PPE, Skills of multidisciplinary response committee (comprised of Chief Executive and Operations Officers (CEO, COO), Medical Director, infectious disease specialists, members of the infection control committee, pharmacy/supply services, front-liners, and support services like cleaners)	Internal integration (daily briefing); organizational capability (reorganizing spaces and tasks)	Empirical	Case study
Sawyerr and Harrison	2022	Learn	Training and education interpersonal skills	Internal integration	Empirical	Case study (implementation of psychoeducational program)

Shakil	2020	Anticipate	Cloud technologies for privacy and security		Quantitative	Mathematical model + simulation biometric security, experiment to validate the authentication
Shaw et al.	2022	Adapt	Virtual assistance of rpavirtual	Internal and external integration (interprofessional collaboration and team working)	Empirical	Case study
Sigala et al.	2022	Respond	Skills of procurement department increasing in-house production (PPE, disinfectants), digital platform	External integration (coordination with other hospitals, pharmacies and laboratories, central warehouse)	Empirical	Review, interview, modelling
Singh and Chaurasiya	2022	Anticipate	Digital technologies (cybersecurity)		Quantitative	Mathematical model
Spieske et al.	2022	Respond	Skills of procurement department increasing in-house production (PPE, disinfectants), digital platform	External integration (coordination with other hospitals, pharmacies and laboratories, central warehouse)	Empirical	Multiple case study
Taimoor and Rehman	2022	Anticipate Adapt	Digital technologies (healthcare 5.0)		Researchers' perspectives	Commentary/viewpoint

Tortorella et al.	2021	Anticipate Adapt	Digital technologies (Telemedicine, wireless devices; information and communication technologies (such as platform) for collaborative sharing)	Technological capability; Internal and external integration (with patients)	Empirical	Exploratory survey, hierarchical clustering
Tortorella et al.	2022	Anticipate, Adapt	Digital technologies (digital platform, ERP, ICT, RFID, Interconnected and real-time electronic medical record of patients, Augmented reality as clinical decision support, Remote diagnosis through mobile applications, Wireless body area network)		Empirical	Multiple case study
Tremblay et al.	2022	Respond		External integration (on-site collaboration with clinicians, managers, policymakers, people)	Empirical	Multiple case study
Trucco et al.	2022	Adapt	Skills of dedicated team of specialists	Organizational capability (Reorganization of resources)	Quantitative	Discrete event simulation
Vanderwerf et al.	2022	Adapt Respond	Digital technologies (telemedicine) managerial and medical skills	Internal and external integration	Researchers' perspectives	Commentary/viewpoint
Winkelmann et al.	2022	Adapt Respond	Experience of final year medical and nursing students,	Organizational capability (increasing capacity	Researchers' perspectives	Commentary/viewpoint

			inactive professionals to return to work Managerial skills	(with other spaces, mobilising final year medical and nursing students, inactive professionals to return to work) External integration with regional cross-border collaborations (redistribution of patients)		
Zamiela et al.	2022	Adapt	Digital technologies	External integration	Researchers' perspectives	Conceptual
Chiu et al.	2021	Anticipate Adapt	Digital technologies (telemedicine) residents' competencies (to expand the available staff)		Empirical	Single case study (survey+descriptive findings)
Ferorelli et al.	2020	Anticipate	Quality culture (incident reporting system)		Empirical	Case study
Garg et al.	2020	Anticipate	Digital technologies (cybersecurity)		Quantitative	Analytical model
Hannan et al.	2021	Respond		External integration (Communication with external pharmacies)	Researchers' opinions	Commentary

Islam et al.	2021	Anticipate	Digital technologies (cybersecurity through fog/edge computing)		Quantitative	Analytical model
Johnson et al.	2020	Learn	Training and drills for staff		Empirical	Case study
Lyng et al.	2021	Adapt Respond	Digital technologies (telemedicine, platform) nursing homes experience	External collaboration (patients and families)	Empirical	Case study (exploratory)
Malik et al.	2021	Anticipate Adapt	Digital technologies (Health information system)		Empirical	Case study (cross-sectional study)
Mayer et al.	2021	Anticipate	Digital technologies (Fog/edge computing, internet of things)		Quantitative	Mathematical model and simulation
Minka et al.	2021	Adapt	Backup, emergency stockpiles Digital technologies (telemedicine) managerial and medical skills	Organizational capability technical response plan (reorganisation of tasks, services and spaces; staff increases and reassignments; new rules and protocols); Internal integration (interdepartmental communication)	Empirical	Case study (descriptive observational study)

		Learn	training and drills for staff	external integration with authority or emergency agencies and public.		
Moss et al.	2021	Anticipate	Staff experience (prevent drug shortage)		Researchers' opinions	Commentary
Reyes et al.	2021	Adapt	Nurse-physician skills to communicate, trust. Information sharing.	Internal integration	Researchers' opinions	Commentary
Shah et al.	2021	Adapt	Digital technologies (digital platform) hospital's improvement team	Internal integration	Empirical	Case study (observation)
Spiva et al.	2020	Learn	Training and education, interpersonal skills	Internal integration	Empirical	Case study (observation)
Suresh et al.	2021	Adapt	Extra qualified personnel, information sharing	Organizational capability (reorganisation of tasks, services and spaces; staff increases and reassignments; new rules and protocols); internal and external integration interdisciplinary collaboration and collaboration with families	Review	Total interpretive structural modelling (tism)

T. de Oliveira et al.	2021	Anticipate	Digital technologies (cybersecurity)		Quantitative	Mathematical model and simulation
Till and McGivern	2020	Adapt	Information sharing	Internal integration (leadership)	Empirical	Case study (interview)
Uhl-Bien et al.	2020	Adapt	Information sharing, skills of nurses	Internal integration (leadership)	Researchers' opinions	Commentary
Veerapen and McKeown	2021	Adapt Respond	Competences of final year medical and nursing students, inactive professionals (return to work)	Organizational capability (reorganisation of tasks, services and spaces; staff increases and reassignments; new rules and protocols); internal and external integration	Empirical	Case study (interview)
Wei et al.	2019	Adapt		Internal integration among staff members	Empirical	Interview
Xu et al.	2020	Anticipate	Digital technologies (cybersecurity with ntru lattice)		Quantitative	Analytical model
Zhang & Qi	2021	Adapt	Digital technologies (ITC)		Empirical	Regression to test hypotheses
Zhang et al.	2020	Anticipate Adapt	Digital technologies (healthcare 5.0 and digital twin)		Quantitative	Mathematical model and simulation
Angelopoulou and Panagopoulou	2022	Anticipate	Implementation of psychoeducational program		Review	Systematic literature review and meta-analysis
Bozorgmehr et al.	2022	Recover	Information sharing	External integration (governmental authority)	Researchers' opinions	Commentary

Croghan et al.	2022	Adapt Learn	Nurse and physicians skills psychoeducational program	Internal integration	Empirical	Survey+multiple linear regression
Fagerdal et al.	2022	Adapt	Nurse-physician skills, communication, trust. Information sharing.	Internal integration	Empirical	Case study
Fernandes et al.	2022	Adapt	Nurse-physician skills, interpersonal skills (trust), Information sharing.	Internal integration; organizational capability (Reorganisation of tasks, services and spaces; staff increases and reassignments; new rules and protocols)	Researchers' opinions	Commentary
Forsgren et al.	2022	Respond	Information sharing; interpersonal skills, managerial skills	External integration (local authority)	Review	Scoping review
Förster et al.	2022	Adapt	Information sharing, interpersonal skills, hospital manager's skills	Internal and external integration (networking)	Empirical	Interview
Garcia-Perez et al.	2022	Anticipate Adapt	Digital technologies (cybersecurity) digital skills		Empirical	Survey+multiple linear regression
Garg et al.	2022	Anticipate	Digital technologies (cybersecurity)		Quantitative	Mathematical model
Grailey et al.	2022	Adapt	Manager's skills	Internal integration	Empirical	Interview

Haraldseid-Driftland et al.	2022	Learn	Interpersonal skills	Internal integration (collaborative learning)	Review	Literature review
Hodgins et al.	2022	Adapt	Interpersonal skills	Internal integration (non-hierarchical governance)	Empirical	Case study
Hossain et al.	2022	Recover	Hospital manager's skills	External integration (stakeholder coordination private non-private players; integration with pharmacies)	Quantitative	Grey clustering method
Hundal et al. (b)	2021	Anticipate (Risk Mitigation)	Digital technologies (big data analysis) quality culture (lean six sigma: failure mode and effects analysis)	Organizational capability (resource reconfiguration)	Review	Content analysis
Jagatheesaperumal et al.	2022	Anticipating Adapt	Digital technologies (5G remote surgery, 5G enabled iot services: more reliable and trustworthy services among medical services, machine learning algorithms; iot pill bottle)		Researchers' opinions	Commentary
Jeet et al.	2022	Anticipate	Digital technologies (cybersecurity)		Quantitative	Mathematical model and simulation
Jiang et al.	2022	Respond	Interpersonal skills	External integration (community, families)	Empirical	Survey for data collecting and descriptive analysis

Khalil et al.	2022	Anticipate Adapt	Backup, information sharing, expert team	Internal integration (communication and collaboration in decision making)	Empirical	Focus group (grounded theory)
Khuntia et al.	2022	Respond Recover	Manager's skills, skills of procurement department	External integration (supply chain stakeholders)	Empirical	Survey+regression analysis
Litke et al.	2022	Adapt	Interpersonal skills	Organizational capability (reorganisation of tasks services and spaces; staff increases and reassignments; new rules and protocols); internal integration	Empirical	Observations and interview
Lowry et al.	2022	Learn	Training for hospital leaders on how to manage crisis, transfer of new knowledge; teamwork, interpersonal skills, effective educational interventions		Empirical	Survey and descriptive findings
Łukasik andPorębska	2022	Adapt Respond		Organizational capability (reorganisation of tasks services and spaces)	Empirical	Scenarios
Nimmy et al.	2022	Anticipate	Digital technologies (cybersecurity)		Quantitative	Mathematical model and simulation

Sanford et al.	2022	Adapt	Training for staff	Organizational capability (reorganisation of tasks services and spaces); internal integration	Empirical	Observations and interview
Snowdown and Wright	2021	Respond	Skills of procurement department (diversifying suppliers); digital platform	External integration (coordination with other hospitals, pharmacies and laboratories, central warehouse, local manufacturer)	Empirical	Case study
Wang	2022	Respond	Digital technologies	External collaboration with local authority (institutional cooperation)	Researchers' opinions	Commentary
Wazid et al.	2022	Anticipate	Digital technologies (cybersecurity through blockchain)		Quantitative	Mathematical model and simulation
Wong et al.	2022	Adapt	Interpersonal skills	Organizational capability (reorganisation of tasks services and spaces); internal integration	Empirical	Case study (cross-sectonal study)
Xu et al.	2022	Adapt	Digital technologies (e-health), digital skills		Empirical	Case study (cross-sectonal study)
Ziser et al.	2021	Adapt	Digital technologies, digital skills, pharmacist's experience	Internal integration, organizational capability	Empirical	Observations

				(defining new roles and tasks)		
Joyce et al.	2021	Anticipate	Digital technologies (cybersecurity), digital skills, digital education and training		Review	Literature review
Singh and Chaurasiya	2021	Anticipate	Digital technologies (cybersecurity)		Quantitative	Mathematical model and simulation
Abraham et al.	2019	Anticipate	Digital technologies (cybersecurity)		Quantitative	Mathematical model and simulation
Aldrighetti et al.	2022	Respond	Skills of procurement department	External integration (lateral transshipment, central logistics hub, collaboration with other hospitals)	Empirical	Case study (simulation model)
Franco and Christie	2022	Learn	Psychoeducational program nurse's experience		Empirical	Observation
Friday et al.	2021	Respond		External integration (collaborative planning, forecasting and replenishment practices)	Review	Systematic literature review
Capolongo et al.	2020	Adapt Respond	Digital technologies (IT systems, smartphones, wearable devices, telemedicine)	External integration (hub and spoke model avoiding overflow of users in the hospitals)	Researchers' opinions	Commentary
Guo et al.	2021	Anticipate	Digital technologies (cybersecurity)		Quantitative	Mathematical model and simulation

Jordan et al.	2022	Adapt Learn	Interpersonal skills, information sharing psychoeducational support	Internal integration (interprofessional teamwork) external integration (with external pharmacists and care coordinators and patients) organizational capability (reconfiguration of tasks and roles)	Empirical	Interview
Kaleta et al.	2022	Adapt Respond	Digital technologies (telemedicine remote technologies)		Quantitative	Mathematical model and simulation
Kazemi Matin et al.	2021	Anticipate Respond	Skills of procurement department	External integration (hospitals, blood production centre, blood collection centre, blood distribution centre)	Quantitative	Mathematical model and simulation
Koch et al.	2022	Respond		External integration: Health-care coalitions (hccs)	Empirical	Interviews
Ladak et al.	2021	Adapt Respond	Skills and competence of clinical nurse specialists (create expert team)		Empirical	Interviews
Lloyd-Smith	2020	Adapt	Skills of crisis team included board members, departmental	Organizational capability (reorganisation of tasks,	Researchers' opinions	Commentary

			managers and medical leaders	services and spaces; staff increases and reassignments; new rules and protocols); internal integration: interdisciplinary collaboration		
Marulli et al.	2022	Anticipate	Digital technologies (cybersecurity)		Quantitative	Simulation
Pandit et al.	2021	Adapt Respond	Skills and experience of physicians and hospital managers, skills of multidisciplinary response committee, and the medical director, the infectious disease specialists, members of the infection control committee	Internal integration (daily briefing) external integration (integrated care partnerships, universities, the independent sector and charities)	Researchers' opinions	Commentary
Pomare et al.	2022	Adapt	Interpersonal skills, Information sharing	Internal integration (inter-departmental meeting)	Empirical	Longitudinal mixed methods case study
Mervyn et al.	2019	Respond	Managerial skills, interpersonal skills, information sharing	External integration (collaborative place-based networks, new inter-organizational partnership,	Empirical	Case study

				collaboration-based healthcare network)		
Patrone et al.	2020	Anticipate	Quality culture (lean principles)		Quantitative	Scenarios
Sim et al.	2022	Anticipate	Digital technologies (cybersecurity through blockchain technology)		Researchers' opinions	Commentary