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What's next in hospital digitization? A Delphi-based scenario study

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Abstract

The digital transformation has induced significant social and economic changes, impacting services of general interest, including healthcare. National healthcare systems serve as crucial pillars of social and prosperity security, necessitating adaptation in the face of digital transformation. Among healthcare institutions, hospitals play a vital role due to the nature and scope of their care services. This study presents a scenario-based investigation to explore the forthcoming changes in the healthcare environment and their potential effects on inpatient care. The study employed an iterative approach, commencing with an exploratory survey of experts to identify impact areas and descriptors. Subsequently, a two-round Delphi survey, involving a four-member stakeholder expert group, was conducted to evaluate and refine the identified parameters. A fuzzy clustering algorithm was utilized in the study to derive four different scenarios. These scenarios elucidate alternative development paths and describe the characteristics that may lead to these developments. The study's findings offer valuable insights for formulating proactive recommendations and interventions to effectively address future developments in healthcare.

Keywords Delphi method, Scenario planning, Fuzzy clustering, Healthcare delivery, Hospital, Digital transformation

Introduction

Healthcare plays a pivotal role in delivering essential services to a population [1, 2], and its quality, accessibility, and funding paradigm significantly impact the productivity of an economy and the social security of the populace [3, 4]. The focus of our study primarily revolves around the healthcare situation in Germany, which serves as a benchmark for the Central European region [5]. Germany boasts a resilient and effective healthcare system [6], operating under the Bismarck financing model, ensuring comprehensive healthcare access for its population of 84 million individuals [7, 8]. Notably, the hospital sector constitutes the largest share of healthcare expenditure, amounting to EUR 127 billion out of the total EUR 474 billion spending in 2021 [9, 10]. Interestingly, the proportion of inpatient spending relative to total healthcare expenditure has remained relatively constant over the past two decades, despite the trend of increasing outpatientization observed in several other countries [11, 12]. The varying designs of European healthcare systems render direct comparisons feasible only through performance-based parameters [6, 13].

Regarding digitization, there exists a notable absence of a unified strategy and cohesive approach across the European Union thus far [14, 15]. Consequently, the levels of digitization in European healthcare systems exhibit significant disparities [16]. Within this context, a diverse array of both public and private initiatives aiming to foster, implement, and reimburse eHealth services can be observed [17–20]. It is essential to clarify that our study focuses on formulating a developmental trajectory specific to the German hospital system, which may lead to varying courses of action in other countries, subject to their unique circumstances. Nonetheless, we aim to identify generalizable trends that present a future path not yet explored in existing research [21]. Such insights may serve as a catalyst for political decision-makers and

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stakeholders to intervene in the developmental process, thereby steering its direction effectively.

The digital transformation pervading all aspects of social life and the economy necessitates proactive consideration of its profound implications on the healthcare domain [22–24]. The increasing autonomy of patients demands enhanced involvement throughout the treatment process, facilitated by novel technologies that have already become an integral part of daily life, such as smartphones, IoT, and self-tracking capabilities [25–27]. Moreover, the growing adoption of technological innovations like robotics, telemedicine, and electronic patient files is reshaping the healthcare landscape, and these changes must be duly acknowledged in future planning. Digitization also brings forth a plethora of opportunities to enhance the quality of care and optimize the utilization of available resources [28, 29]. At the systemic level, digitalization facilitates more efficient allocation of services and timely identification of potential risks through continuous monitoring. At the provider level, the integration of big data, artificial intelligence (AI), and smart systems holds the potential for making informed decisions, streamlining processes, and achieving improved outcomes [30–33].

Challenges in the VUCA environment

The aforementioned aspects can be comprehensively examined in the context of the prevailing environmental conditions, commonly known as the VUCA environment [34]. VUCA is an acronym encompassing four essential terms: volatility, uncertainty, complexity, and ambiguity. In the domain of digital transformation, the VUCA approach has found considerable application within academic circles [35–37]. As demonstrated in Fig. 1, we can categorize its influence into two primary sub-areas.

Firstly, VUCA exerts its impact on the hospital environment [38–40]. Volatility reflects the presence of an unpredictable and fluctuating performance pattern, primarily driven by unforeseen emergencies and urgent interventions [41]. Concurrently, existing uncertainties arise from multiple crises and dependencies on suppliers and other stakeholders throughout the value chain [42]. The hospital setting operates amidst a high degree of complexity, characterized by an extensive and ever-changing regulatory framework, influenced by frequent legislative initiatives. Often, short-term measures are implemented in response to acute financing challenges, leading to an altered environment for patient care, and intensifying its complexity [43]. Moreover, ambiguity arises due to the continuous advancements in medical technology, resulting in a constant influx of new innovations for treatment [44]. Consequently, therapy guidelines experience perpetual modifications, and the knowledge half-life diminishes significantly in light of these rapid developments.

Second, the impact of digital transformation itself warrants scrutiny [37, 45, 46]. The market witnesses an influx of numerous new digital providers and services, and their rapid entry and exit create an environment of volatility, making decisions in favor of specific services or technologies challenging [39]. Uncertainty factors emerge due to the substantial investments required for adopting new

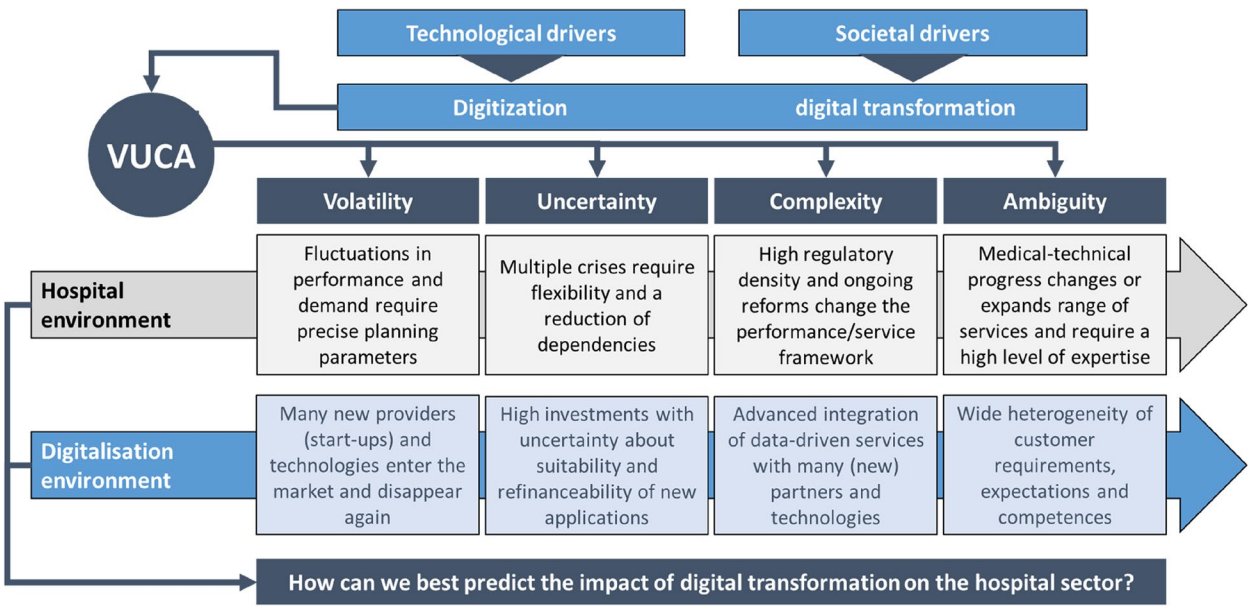

Fig. 1 Prospects of change in the hospital sector due to the digital transformation

technologies or digital treatment processes [47]. Ensuring adequate remuneration and conducting comprehensive cost–benefit analyses become crucial in this context. Moreover, as hospitals increasingly collaborate with partners outside their core business, the complexity of service provision escalates further [29, 48]. Achieving seamless data integration and enabling data-driven process control by digital service providers become critical considerations. Ambiguity emerges from the ever-changing needs and behaviors of patients [27, 49]. Wide variations are observed in both their expectations, encompassing factors like customer experience, and their competencies, including digital literacy. Consequently, three pivotal questions arise for future development: How will the hospital sector transform in response to digital transformation? What approach is most suitable for outlining the change paradigm? How can decision-makers effectively prepare for the impending change process?

To date, only a limited number of studies in the field of futurology have specifically focused on healthcare [13, 50–52]. Some of these studies address future aspects of social security [53] or explore individual technologies [19, 23, 25, 54]. Often, these investigations consist of feasibility studies [55, 56], assessments of potential applications [31, 33], or discussions of care-related possibilities [57]. While certain trend forecasts have examined the broader implications of digital transformation on the hospital sector [58], a comprehensive examination of how the care setting may evolve within its broader context, and the concrete effects that may ensue, has not been extensively explored. Our study endeavors to bridge this research gap by conducting a forward projection, utilizing well-established methods of futurology. The scenario technique presents itself as highly suitable for addressing this research question [13, 59], given its established efficacy as a tool in similar contexts. The method of scenario analysis has rarely been used in the past for scientific research questions in health care [60]. Consequently, our study seeks to demonstrate the suitability of the scenario technique in effectively portraying the impacts of digital transformation on the hospital sector.

Methodology

In line with the comprehensive approach of our study, we adopted a sequential research design, incorporating initial expert interviews and a two-round Delphi format [61, 62]. The Delphi technique, originally developed in the military domain during the late 1940s, has gained significant prominence in economic and social science research since the early 2000s [63]. Delphi methods are also increasingly being used to address issues in health care [64–67]. This method facilitates the structured communication and management of expert groups, guided by four fundamental features: (i) anonymity, (ii) iteration, (iii) controlled feedback, and (iv) statistical group response [68]. Particularly, the Delphi technique proves invaluable when physical meetings among experts are unfeasible [69]. Notably, this technique has demonstrated superiority over traditional opinion polling methods in such contexts, as it provides enhanced accuracy and mitigates potentially detrimental group dynamics and biases, such as follower or anchoring effects [70].

The Delphi technique was the chosen method for the present study, as it offered a well-suited approach to engage multiple experts representing diverse healthcare providers in an extensive discourse concerning the impact of digital transformation on hospital structures in Germany [71]. This unique contribution enriches the existing literature on this subject. To ensure a robust and systematic implementation [72], we adhered to the three distinct phases of Delphi-based research (refer to Fig. 2). In the preparatory phase, we carefully delineated the scope of our study and formulated a well-defined research question. Consequently, we opted for the classical sequential Delphi format, which entailed conducting two consecutive rounds [64]. In the initial round, participants evaluated a set of future-oriented descriptive parameters, attributing expected probabilities (EP) and estimated expressions (E) to each parameter. These influencing fields and descriptive parameters were derived from a combination of secondary research and expert interviews conducted with representatives from four specific stakeholder groups. Subsequently, in the second round, participants had the opportunity to review and revise their initial estimates, taking into consideration the statistical means derived from the first round.

During the preparatory phase, our study commenced with a primary research question centered on the potential effects of digital transformation on inpatient service delivery within hospitals, encompassing various stakeholder groups [73]. As our research primarily focused on the influence of digital tools, innovative technologies, and novel business models, we deliberately adopted a quadrilateral perspective on stakeholders, enabling us to explore unforeseen and improbable scenarios. To ensure a manageable scope for our prospective investigation, we made the deliberate decision to restrict our projections to the year 2032. At the time of conducting this study, this timeframe represented a 10-year horizon, allowing us to concentrate on medium-term impacts and offering a relatively practical and comprehensible timeframe for the participating experts [74].

Based on an initial topic list of trends and drivers of digital transformation in healthcare, derived from desk research [58], we proceeded to conduct the first

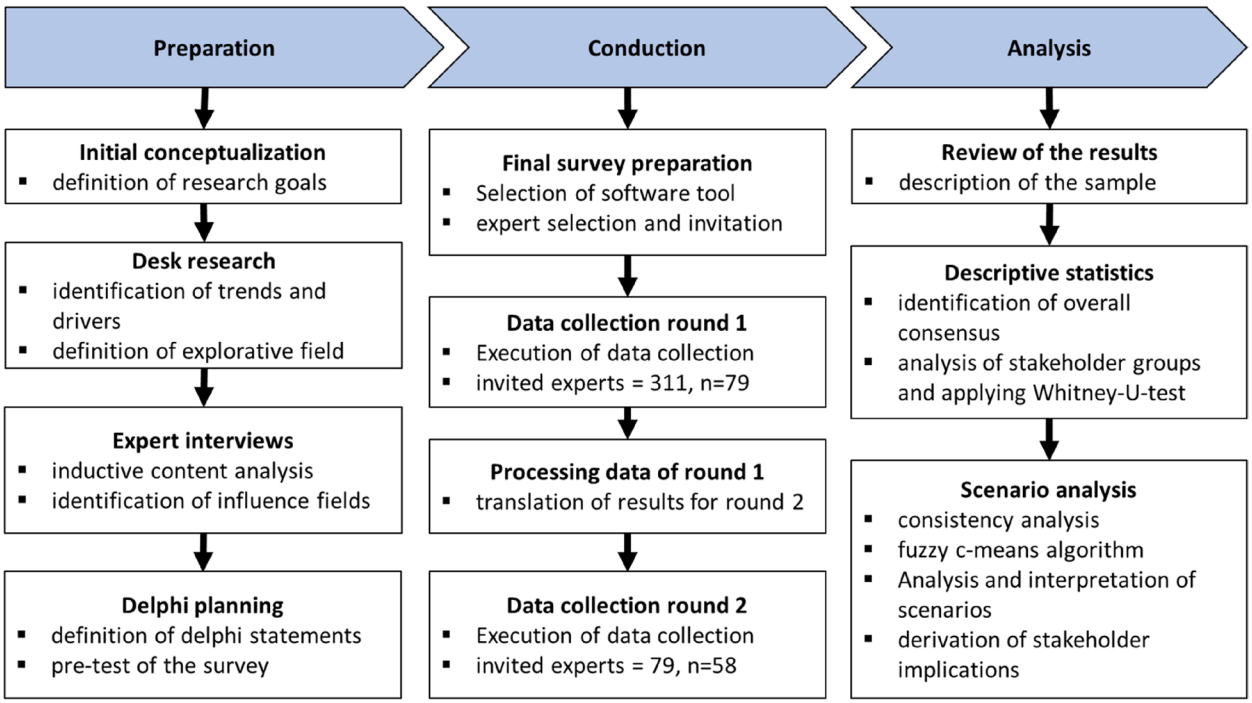

Fig. 2 Empirical approach

empirical part of our study, focusing on an exploratory topic area. To gain comprehensive insights into the baseline situation, we conducted semi-structured guided expert interviews [75]. The interviews were meticulously analyzed using MAXQDA12 software, employing coding techniques [76]. Throughout this phase, we adhered to the inclusion of experts representing the four identified stakeholder groups [77]. In terms of the number of interviews, we initially aimed to cover as many parameters as possible, keeping it open-ended [78]. However, after conducting twelve interviews, we achieved data saturation, indicating a sufficient depth of information. We adopted an inductive approach for data evaluation, employing content analysis to extract relevant features and characteristics [79]. These findings subsequently served as the foundation for formulating descriptive parameters to be utilized in our Delphi survey [80, 81]. To ensure methodological rigor, we condensed these parameters and transformed them into statements, drawing on the latest research regarding the formulation of Delphi descriptors. Furthermore, to validate the quality and comprehensibility of our final projections, we engaged two experts who had not been involved previously in the study. Their input and verification bolstered the overall rigor of our methodology [59, 82]. As a result of this comprehensive process, we derived a total of thirty descriptive parameters, which are presented in the *Results of the expert survey* chapter, offering a detailed overview of the insights gained from the expert interviews.

We employed the Limesurvey platform as our survey tool of choice, which facilitated the collection of data in multiple rounds while ensuring the experts' complete anonymity [83]. Recognizing that our panel of experts might not be familiar with the Delphi technique, we provided a comprehensive introduction to the research method [71]. This introduction was conveyed through written communication, both in the initial invitation emails to the participants and at the beginning of the survey within the online tool. During the selection process of experts, we defined specific criteria, focusing on their experience within the healthcare sector and expertise in the field of digitization. The expert panel was structured into four distinct groups [84, 85]. The first group comprised stakeholders directly involved in service delivery. To ensure their expertise, priority was given to Chief Information Officers, Heads of Information Technology, or individuals holding comparable positions within their respective organizations. This group provided an internal perspective on the topic. The second group consisted of companies providing digital services within the inpatient care delivery sector. These included manufacturers of hospital information systems, providers of platform models, and other digital service partners in primary care. Their participation ensured an external perspective on the subject matter. The third group represented

stakeholders who possessed a comprehensive understanding of the sector, including its overall dynamics, specific opportunities, and associated risks within the realm of care delivery. This group served as a complement to the first group, balancing individual perspectives within organizations and providing both internal and external viewpoints. The fourth group comprised academic researchers actively engaged in studying digitization within the healthcare sector. These researchers were affiliated with institutions involved in applied research with practice partners, as well as foundational research from interdisciplinary fields such as social sciences, health sciences, or engineering. By assembling experts from these diverse groups, our study benefited from a broad range of perspectives, ensuring a comprehensive analysis of the impact of digital transformation on the hospital sector.

Data collection for our study was conducted over two rounds: the first round took place between July and September 2022, while the second round occurred between November 2022 and January 2023. A total of 311 individuals from the four stakeholder groups were invited to participate in our study. In the first round, we received responses from 79 participants. Among them, 58 participants successfully completed both rounds of the Delphi process and were included in the final sample, resulting in a completion rate of 73%. The demographic characteristics of this sample are presented in Fig. 4. During the survey, participants were asked to provide quantitative ratings for our 30 descriptive parameters. To facilitate their responses, we provided a metric scale ranging from 1 to 10 for expected probability (EP) and expression (E). To ensure methodological rigor, we adhered to established recommendations for Delphi procedures when designing our survey setting [85]. Prior to each survey round, pre-tests were conducted to validate the questioning technique [86]. These pre-tests were directly observed, and immediate feedback was provided [87]. Contact with participants was maintained via email, with up to two reminders sent at suitable intervals to encourage their participation.

In our final analysis, we employed a qualitative approach by utilizing the information derived from the last round of the Delphi process and grouping the evaluated parameters. This methodology allowed for a comprehensive and integrated perspective and analysis at an aggregate level [61]. To achieve this, we employed a non-hierarchical fuzzy C-Means algorithm, following a well-established approach used in previous studies utilizing the Delphi method [88–90]. The fuzzy C-Means algorithm was executed using R software to conduct the cluster analysis. To visualize the clusters, we transformed the expression of the descriptors recorded in the second round of the Delphi process into three equally ranked dimensions. The first dimension represents the overall degree of digitization, following the ten-point scaling employed in the original evaluation matrix. The second dimension captures the level of structural transformation, categorized into four sectors ranging from zero to four, where zero indicates no structural change and four represents a complete overhaul of existing structures. This dimension reflects the systemic extent of transformation affecting the healthcare landscape as a consequence of digitization. The third dimension focuses on the disruption potential, with transformation considered at three levels spanning from zero to two, where zero signifies no disruption and two represents a strong disruption. The clustering results, obtained through this analysis, are presented in Fig. 6, illustrating the grouping of parameters based on their characteristics and relationships within the dataset. In order to select a suitable number of clusters, we tested different variants in R. Starting from two to six clusters, we finally decided on the number of four clusters [61]. Here, the best possible definable clusters were formed, such as an equal distribution of the parameters to be included provided.

Results

Results of the expert survey

Figure 3 presents the results of the analysis conducted on the expert interviews, which served as the basis for identifying the fields of influence, represented as the main categories in the content analysis. The analysis yielded a total of five main categories, each consisting of six subcategories. These subcategories provided a more granular understanding of the content and themes derived from the interviews. Furthermore, the descriptors obtained from the content analysis were classified into three distinct types: one leading descriptor, three deepening descriptors, and two limiting descriptors. To facilitate concise presentation in this paper, the descriptors were assigned brief names that capture their essence. Table 1 provides a comprehensive overview of the descriptors, along with the corresponding hypotheses formulated for each descriptor. This information serves as the foundation for the subsequent Delphi survey, allowing for a structured investigation of the experts' perspectives and insights.

The assignment of descriptors to their respective types was based on the arguments presented by the experts during the analysis. Through the content analysis, the experts' statements were categorized and summarized according to their response directions. This process identified particularly compelling arguments that were subsequently designated as leading descriptors for each main category. Additionally, the content analysis facilitated

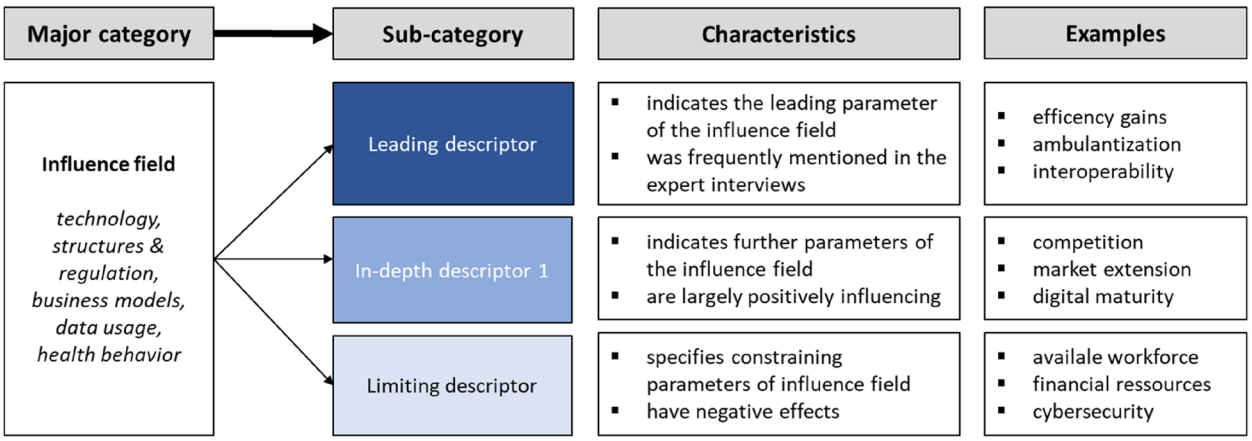

Fig. 3 Derivation of the parameters for the Delphi survey

the identification and organization of more detailed descriptors that captured specific aspects within each main category. These in-depth descriptors captured individual arguments that played a significant role in shaping the understanding of the main category. Some of these descriptors drew upon less frequently mentioned arguments that the authors deemed highly relevant. The limiting descriptors, on the other hand, encompassed negative or constraining arguments expressed by the experts, highlighting their concerns regarding the ongoing digital transformation. It is noteworthy that, regardless of the positive or negative nature of the impact, all hypotheses were formulated in a positive manner to ensure consistency in wording across the descriptors. These hypotheses serve as the basis for deriving the projection parameters for the subsequent scenario development, enabling a systematic exploration of potential future outcomes in the digital transformation of the hospital sector.

In the field of Technology as a category of influence, the leading descriptor identified by experts is efficiency. This descriptor encompasses the achievement of enhanced productivity resulting from the utilization of innovative digital technologies. Experts highlighted the significance of increased efficiency as a crucial parameter in this context. Conversely, limiting factors include the availability of skilled technical personnel for implementing digitization initiatives and the subsequent adoption of digital applications. Additionally, the lack of previous funding for digital infrastructure by payers was identified as a constraint. In the Structures and Regulation category, the leading descriptor is outpatientization. Experts recognized the substantial potential for catching up to international standards in this area. In Germany, the separation between primary care and hospital sectors and the absence of remuneration incentives were identified as key challenges. Limiting factors include the fragmented and localized planning of service providers by planning authorities, as well as the slow adaptation to current regional conditions. Regarding the Business Model category, the guiding descriptor is the shift in value creation. The presence of numerous new actors in the digitally interconnected healthcare market has resulted in the relocation of value-creating activities from hospitals to other service providers. Limiting parameters in this domain include the need for private capital and the attractiveness of entering this market. In the realm of Data Utilization, interoperability is defined as the leading descriptor. Experts frequently highlighted interoperability as a crucial means of effectively managing available patient and process data. However, comprehensive data protection and cybersecurity requirements pose limiting factors in this area. Given that hospitals are part of critical infrastructure and have faced significant challenges posed by cyberattacks in the past, urgent action is required to address this issue. When considering Digital Health Behavior, the leading descriptor is the population's willingness to use digitally interconnected applications and services. In this context, the health literacy and digital competence of the population must be taken into account. Additionally, transparency and trust in health information play a significant role in influencing individuals' ability to engage in digital health-related activities.

In the first round of our Delphi survey, a total of 79 participants took part. The second round included 58 participants. Among these participants, 81% (64) were male, while 19% (15) were female. The average age of the participants was 45 years, with the youngest individual being 24 years old and the oldest being 75 years old. The panel attrition rate was 27%. We also collected information on the participants' expertise in different domains. Specifically, we inquired about their experience in the healthcare sector as well as their involvement with digitization.

Table 1 Explanation of the used descriptors

Influence field	Descriptor	Hypothesis
Technologies	Efficiency	Over the next 10 years, the potential to increase hospital productivity through digital technologies will be realized
	Assistance	Over the next 10 years, assistive systems will be used in all core hospital processes; e.g., assistive care robots
	Autonomous	Over the next 10 years, fully automated autonomous systems will be used in secondary hospital processes; for example, inventory and ordering systems
	Qualification	Over the next 10 years, all healthcare professionals will be trained or upskilled with digital competencies
	Staff	Over the next 10 years, the labor market will provide sufficient IT specialists to operate complex digital systems and project managers to implement digitization
	Investments	Over the next 10 years, (additional) investment budgets will be allocated for equipment, infrastructure, and training to implement the digital transformation
Structures and regulation	Ambulantization	Over the next 10 years, there will be a shift from inpatient to outpatient services, regardless of whether they are provided in a hospital setting or other care structures
	Integrated care	Over the next 10 years, integrated service provision will take place in which sector boundaries do not (or no longer) play a role
	Competition	Over the next 10 years, service offerings will form according to regional needs in free competition, without government planning of needs
	Reimbursement	Over the next 10 years, the compensation system will be outcome- or performance-oriented; e.g., through pay-for-performance elements
	Service planning	Over the next 10 years, outpatient and inpatient services will be planned by a single planning entity
	Regional need	Over the next 10 years, innovative care models will be available on the market that are based on regional conditions
Business models	Value creation	Over the next 10 years, elements of hospital value creation will be outsourced to digital service providers; e.g., in the context of software-as-a-service partnerships or AI solutions based on cloud computing
	Patient journey	Over the next 10 years, the patient journey will be controlled by care platforms; e.g., the allocation of resources (including appointment slots) depending on utilization or quality
	Market extension	Over the next 10 years, services in the second and third healthcare markets will gain in importance as a result of the digital transformation; e.g., the use of health apps
	External player	Over the next 10 years, digital companies from outside the industry will penetrate the healthcare sector with services; e.g., Google, Apple, Tencent, Xiaomi etc
	Privatization	Over the next 10 years, private sector-oriented companies will gain importance in healthcare delivery
	Platforms	Over the next 10 years, citizens will ask for innovative care offerings or be directed specifically through platforms to the providers with the best/fastest service
Date usage	Interoperability	Over the next 10 years, the interacting systems will be fully compatible in terms of their interfaces; e.g., integration of wearable data into the HIS
	Digital maturity	Over the next 10 years, all hospitals will be fully digitized, as measured by maturity models available today, such as DigitalRadar
	Data platforms	Over the next 10 years, (government or private) data platforms will be available and all hospitals will be comprehensively connected to them; e.g., for training AI algorithms
	Real-time data	Over the next 10 years, services will be managed on the basis of data collected in real time; e.g., admission to an emergency room based on currently available triage data (expected waiting time) in the hospital
	Data protection	Over the next 10 years, data protection legislation will limit data use within the hospital and interaction with third parties
	Cybersecurity	Over the next 10 years, minimum cybersecurity requirements will increase

Table 1 (continued)

Influence field	Descriptor	Hypothesis
(digital) health behavior	Digital affinity	Over the next 10 years, digital applications, media, or devices will be used by a broad range of the population in the healthcare sector
	Digital interaction	Over the next 10 years, individuals will interact with healthcare providers via digital applications to monitor their health, collect data, and manage their behavior
	Gatekeeper	Over the next 10 years, digital applications will be used for initial diagnosis, recommending the optimal care provider in terms of availability and range of treatments, or prescribing them through specific care contracts
	Prevention	Over the next 10 years, there will be a shift from curative to preventive medicine
	Transparency	Over the next 10 years, transparency about the quality of service delivery will change; e.g., the digitally available comparative data from different hospitals on the outcome of services
	Health literacy	In the next 10 years, the health literacy competence of the population will improve; e.g., the handling and evaluation of health information and data

On average, participants had 19 years of experience in the healthcare setting. The shortest period of experience was 5 years, while the longest was 43 years. In terms of digitization, the average experience was 14 years, with the shortest period being 3 years and the longest being 40 years. Figure 4 presents the distribution of expert experience in terms of years. We ensured that no participant had less than 3 years of experience, and the number of participants with short expertise time was notably low. The distribution of expertise among the different expert groups was as follows: hospital experts (IT managers/CIOs) accounted for 28% of the participants, experts from digital service providers (including startups and software providers) represented 37%, experts from healthcare institutions comprised 13%, and experts from research and academia constituted 23% of the total sample.

Results of the Delphi survey

Regarding descriptive statistics, our primary focus was on the analysis of quantitative data. We obtained a total of 4740 numerical estimates based on projections in the first round, 1740 estimates in the second round, and 395 data points related to participant characteristics. Additionally, we collected metadata, including response time to the survey and the time spent answering specific question groups. However, no analyses were conducted on the methodological approach in this study. If there is a legitimate interest in this information, it can be made available to other researchers. For each descriptor, panel consensus was assessed based on the interquartile ranges (IQRs), which is a widely accepted indicator of consensus in Delphi studies. In the first round, we collected data on expression and probability of occurrence, while

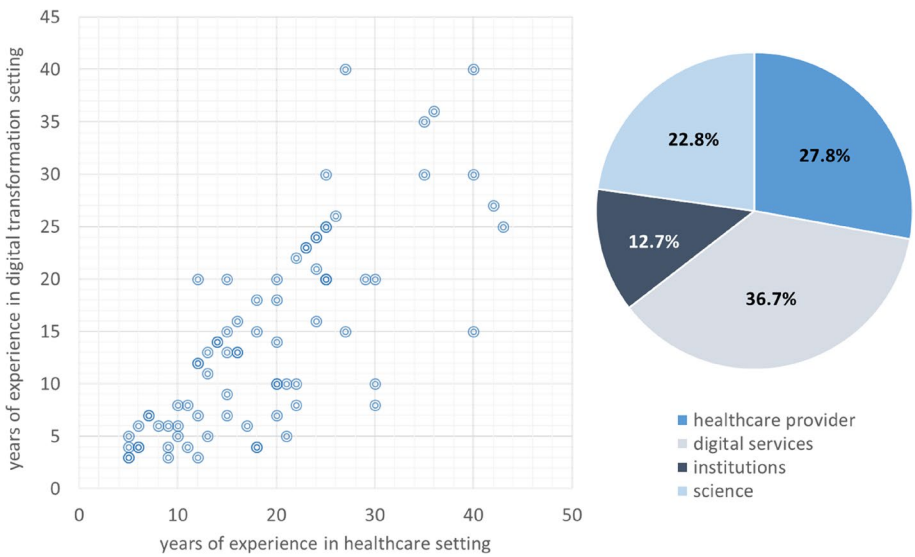

Fig. 4 Information on the panel's expertise

in the second round, only the expression was condensed. All items were measured using a 10-point Likert scale, ranging from 1 = strongly disagree to 10 = strongly agree. The results of the descriptive statistics can be found in Table 2.

Notable findings include the leading descriptor outpatientization, which received consistently high ratings in both the first and second rounds. The indicators of market expansion and the influx of new players in healthcare also received high ratings in the first round, although their ratings decreased in the second round. Among the limiting factors, the significant threat of cybersecurity risks was consistently highlighted and maintained a high rating across both rounds. Parameters such as digital maturity, interoperability, and data protection exhibited particularly large standard deviations. The interquartile range (IQR) was lowest for cybersecurity and the patient journey in the first round, and for cybersecurity and staff availability in the second round.

In order to assess the uncertainty associated with the expression of each descriptor, we have presented the two parameters in Fig. 5. We have transformed the "Expected probability" parameter into "Uncertainty" and displayed its values in reverse order for better comprehension. On the left side of the figure, all aggregated data points are depicted, while the right side shows the mean values. It is evident that the participants' level of uncertainty was not particularly high. Among all data points, the maximum value for uncertainty never reached 10, with the highest value observed being 9. Similarly, among the mean values, a value of 4 was never attained. This observation demonstrates that the experts displayed a remarkably high level of confidence in their proficiency ratings. We interpret this as a positive indication of the careful

Table 2 Descriptive statistics

Descriptor	E round 1			U round 1			E round 2		
	Mean	SD	IQR	Mean	SD	IQR	Mean	SD	IQR
Efficency	5.41	2.03	3.00	2.32	1.58	2.00	4.97	2.08	2.75
Assistance	5.82	2.33	4.00	2.25	1.66	2.00	5.69	2.45	3.75
Autonomous	7.58	2.19	2.00	2.09	1.58	2.00	7.16	1.91	1.75
Qualification	6.48	2.27	3.00	2.16	1.60	2.00	6.07	2.11	3.00
Staff	3.28	1.68	2.00	1.89	1.53	1.00	2.71	1.64	1.00
Investments	7.00	2.09	2.00	2.67	1.87	3.00	5.79	1.89	2.00
Ambulantization	8.19	1.68	2.00	1.82	1.88	3.00	8.14	1.31	1.75
Integrated care	5.44	2.07	3.00	2.75	1.98	3.00	4.88	1.93	3.00
Competition	4.09	2.27	3.00	3.10	2.08	2.00	3.10	1.80	2.00
Reimbursement	5.20	2.08	3.00	3.38	1.86	3.00	4.36	2.09	3.00
Service planning	4.53	2.22	3.00	3.57	2.24	3.00	3.29	2.05	2.00
Regional need	6.90	1.89	2.00	2.66	1.61	3.00	6.24	1.82	3.00
Value creation	7.86	2.00	2.00	1.87	1.66	2.00	7.81	1.36	2.00
Patient journey	7.29	1.96	1.50	2.29	1.61	2.00	6.41	1.88	3.00
Market extension	8.16	1.98	2.00	1.56	1.57	2.00	7.47	1.78	2.00
External player	8.06	2.00	3.00	1.77	1.64	1.50	7.29	2.23	2.75
Privatization	7.52	1.82	3.00	2.38	1.82	2.50	6.71	1.77	2.00
Platforms	7.71	1.87	2.00	2.22	1.69	2.00	7.33	1.73	2.75
Interoperability	5.90	2.52	4.00	2.28	1.69	2.00	5.16	2.30	4.00
Digital maturity	4.89	2.53	4.00	1.91	1.36	1.50	4.03	2.24	4.00
Data platforms	5.43	2.44	4.00	2.53	1.58	2.00	4.53	1.90	3.00
Real-time data	6.68	2.05	3.00	2.48	1.61	2.50	6.10	2.04	2.75
Data protection	7.16	2.49	3.50	1.97	1.81	2.00	6.45	2.04	3.00
Cybersecurity	9.14	1.38	1.50	0.86	1.24	1.00	9.09	0.93	1.00
Digital affinity	8.11	1.43	2.00	1.54	1.17	1.00	7.79	1.41	1.75
Digital interaction	8.04	1.36	2.00	1.52	1.26	2.00	7.69	1.46	2.00
Gatekeeper	7.05	1.84	2.00	2.48	1.89	3.00	6.53	2.01	2.75
Prevention	6.43	2.29	3.00	3.01	2.16	2.00	5.31	2.18	3.75
Transparency	7.24	1.86	2.00	2.56	1.89	2.50	6.28	1.70	2.00
Health literacy	6.72	1.93	3.00	2.59	2.00	2.00	5.97	1.94	2.00

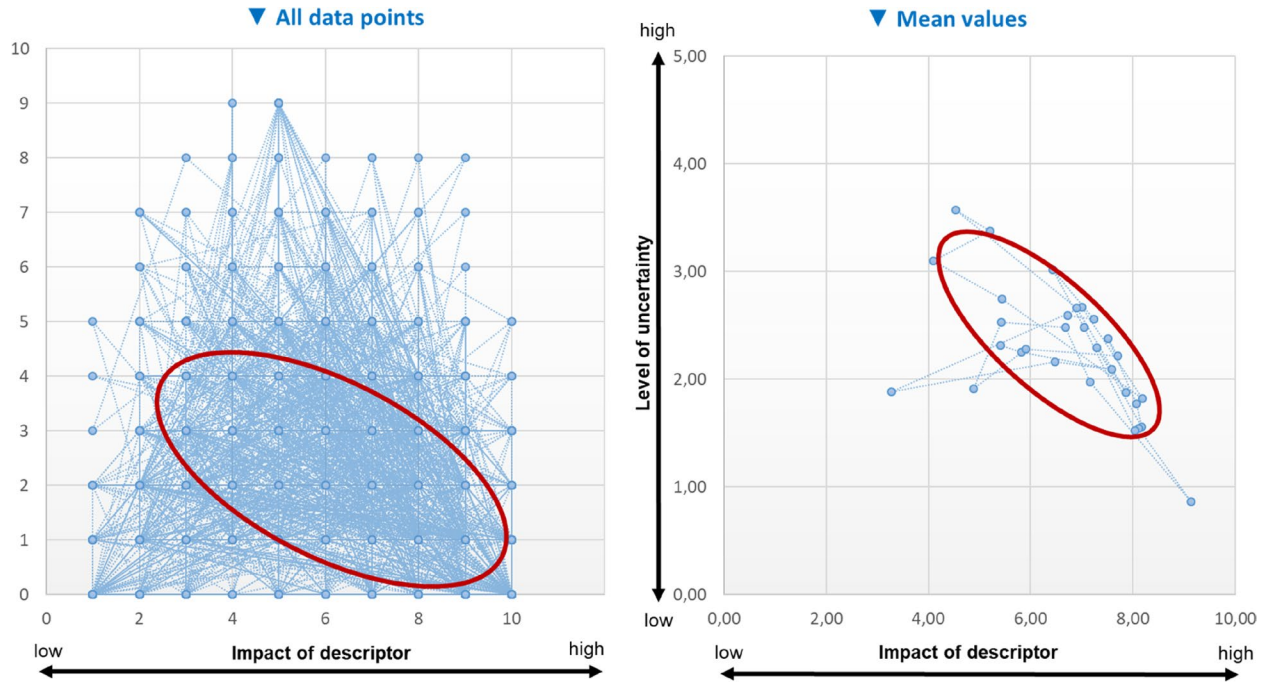

Fig. 5 Distribution of descriptor expression and level of uncertainty

selection of experts, as it reflects their strong conviction regarding their expertise in the respective field. Regarding the descriptors, we observed that almost all of them fell within the range of 3 to 9 for all data points, and 4 to 8 for the mean values. This finding corroborates the serious relevance of the selected descriptors, thus validating their derivation from the expert interviews.

The datasets from the two rounds underwent a Mann–Whitney *U* test, which is well-suited for analyzing Delphi surveys with multiple rounds. This test allows for the comparison of central tendencies between two independent samples. In our analysis, we conducted three tests, which are presented in Table 3. Firstly, we examined the differences between the samples from the first and second rounds of the survey. The test statistics indicate significant differences for eleven parameters, including descriptors such as staff availability, adequate investment, performance planning, and patient journey. Thus, we can demonstrate that there are indeed differences of approximately one-third in the distribution of certain descriptors between the samples of the two Delphi rounds. However, none of these differences involve leading descriptors. Among the eleven parameters, five of them correspond to the limiting descriptors, indicating greater uncertainty in the evaluation of these aspects. Additionally, we applied the statistical testing procedure to the two largest groups of experts: hospital managers and digital service providers. In this analysis, only three descriptors exhibited significant differences between the two samples. Notably, the leading descriptor related to shifting value creation showed significantly different scores in the two samples. Finally, we performed a test based on age groups. The sample was divided into two parts: an age cohort below and above the mean, with both groups being nearly equally distributed in size. We explored whether using the median as a parameter to split the groups would yield different results, but no differences were observed. The test statistics indicate that only one descriptor demonstrates a significant difference in the evaluation of the samples. Thus, the overall sample proves to be particularly robust with regard to age.

Results of the cluster analysis

The selection of clusters was performed using a fuzzy C-Means algorithm, which was chosen to ensure maximum objectivity and validity of the clusters. This algorithm has been widely acknowledged in recent research as particularly effective in achieving our research goals. In our view, the formation of four clusters yielded the most meaningful and significant outcomes. The results of our cluster analysis are presented in Fig. 6. On the left side of the figure, the four clusters are projected along the three dimensions of digitization progress, structural change, and disruption of the existing business. It can be observed that the distribution of descriptors within the clusters is relatively balanced, which validates the

Table 3 Test statistics

Descriptor	Round 1/2		Groups		Age	
	U	*p* value	*U*	*p* value	*U*	*p* value
Efficency	1920	0.184	351	0.544	698	0.435
Assistance	1826	0.426	265	0.304	756	0.842
Autonomous	1928	0.169	227	0.076	705	0.478
Qualification	1900	0.226	263	0.286	644	0.188
Staff	2125	**0.012**	311	0.892	874	0.330
Investments	2432	**0.000**	239	0.124	733	0.665
Ambulantization	1821	0.432	336	0.745	591	0.061
Integrated care	1909	0.205	295	0.651	651	0.212
Competition	2208	**0.003**	268	0.331	850	0.467
Reimbursement	2061	**0.035**	324	0.930	711	0.517
Service planning	2243	**0.001**	251	0.196	738	0.701
Regional need	2023	0.056	233	0.097	775	0.992
Value creation	1875	0.276	214	**0.043**	789	0.904
Patient journey	2225	**0.002**	181	**0.006**	740	0.713
Market extension	2108	**0.016**	261	0.259	768	0.935
External player	1982	0.092	367	0.347	836	0.553
Privatization	2126	**0.012**	308	0.846	693	0.404
Platforms	1865	0.304	279	0.437	732	0.658
Interoperability	1924	0.180	278	0.437	683	0.354
Digital maturity	1986	0.090	253	0.212	705	0.481
Data platforms	2097	**0.021**	214	**0.045**	766	0.921
Real-time data	1853	0.342	282	0.482	712	0.521
Data protection	1926	0.174	352	0.525	765	0.912
Cybersecurity	1906	0.182	249	0.133	625	0.093
Digital affinity	1833	0.394	285	0.518	517	**0.009**
Digital interaction	1893	0.234	325	0.906	654	0.219
Gatekeeper	1911	0.202	239	0.126	675	0.313
Prevention	2131	**0.012**	262	0.282	719	0.572
Transparency	2219	**0.002**	298	0.696	674	0.305
Health literacy	1998	0.078	318	0.992	778	0.992

suitability of four clusters for achieving high significance. On the right side of Fig. 6, R software outputs the relationships among the individual dimensions as a result of the cluster analysis.

Scenarios and discussion

Scenario analysis

The clusters depicted in Fig. 5 serve as the foundational framework for the subsequent scenarios. We have identified four distinct scenarios that exhibit well-defined characteristics, which are elaborated upon in detail in Table 4. The three dimensions encompass the essential attributes as they are expressed. As anticipated, one scenario exhibits a minimal expression in all three dimensions, while another scenario demonstrates a comprehensive expression. For each scenario, we have identified the driving descriptors that significantly influence the scenario's expression. The detailed characteristics provide an interpretive framework that guides decision-making in shaping the scenarios. By doing so, it becomes possible to prevent undesirable scenarios or promote desirable ones.

In scenario 1, all three core characteristics are low. This development is driven by stringent data protection requirements, escalating cyber risks, inadequate availability of technical personnel, and a lack of competitive parameters to foster dynamic care models. The assessment of improving the digital maturity level of hospitals is also low. Consequently, it can be inferred that a substantial increase in the digital maturity level across a broad spectrum of hospitals is unlikely, and digitization is progressing at a sluggish pace, yielding far-reaching implications for all related parameters. This situation may stem from the limited availability of individuals possessing adequate qualifications to handle the demands

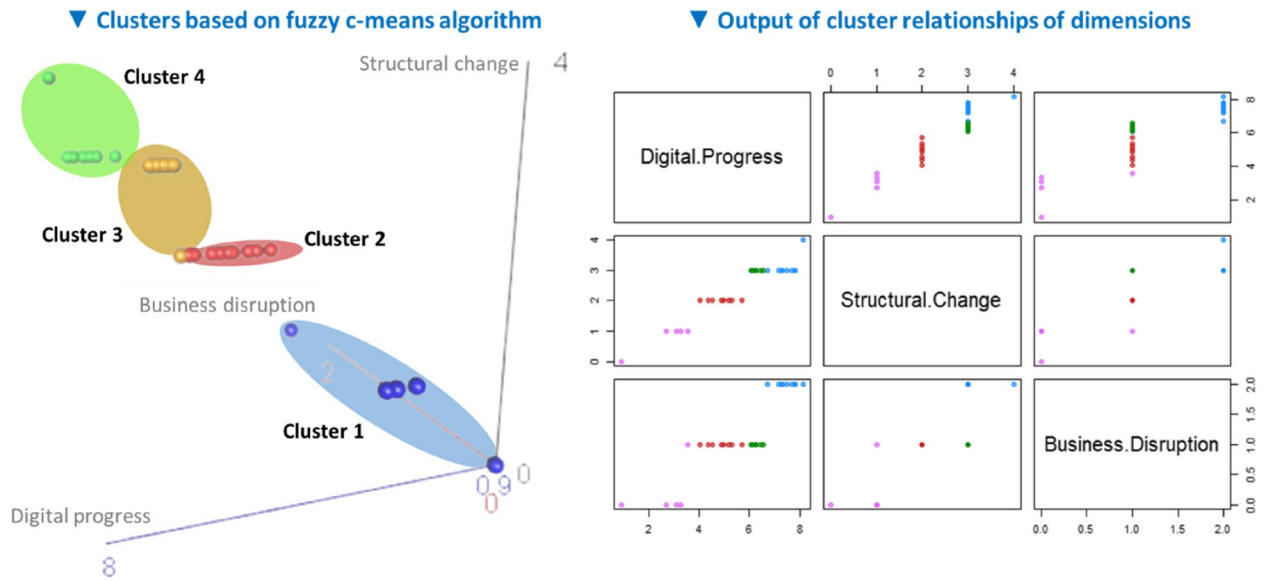

Fig. 6 Output of cluster analysis

of digitization tasks. In scenario 2, there are notable advancements in digitization; however, the structures within the healthcare system remain largely unchanged, and disruptive elements have limited influence. This scenario is characterized by inadequate investment in digital infrastructure, insufficient incentives for remuneration, moderate utilization of efficiency reserves, and a failure to fully leverage the potential for automation. While some aspects of prevention are realized through digital elements in the hospital setting, the level of implementation remains relatively low. Scenario 3 involves comprehensive digitization accompanied by significant structural changes. The disruptive potential in this scenario is primarily harnessed by existing players who undergo transformations in their business models. The scenario is driven by a focus on regional needs and the provision of targeted care offerings to meet those needs. As part of this scenario, new digital gatekeepers for patient management emerge. Moreover, the healthcare sector attracts an increasing number of private-sector players motivated by the high market potential. Within this context, the business model of hospitals undergoes a comprehensive transformation. The utilization of real-time data and the establishment of a high level of transparency regarding the service market are critical components of this scenario. Scenario 4 signifies a substantial shift from the current care paradigm of hospitals. Unlike scenario 3, this scenario involves the entry of new external players who disrupt existing business models and completely reenvision patient care. Platforms assume a prominent role in this scenario, alongside comprehensive process automation and the utilization of the outpatient sector for service delivery. Of particular significance is the anticipated transformation of value-adding activities, which will increasingly be transferred from hospitals to digital service providers. Broadly speaking, hospitals will serve as physical spaces where patients are physically present, while data-driven diagnostic procedures and automated therapy monitoring take place in the background.

Health policy implications

For the successful advancement of digital transformation in healthcare, including the inpatient sector, an appropriate institutional framework is crucial. Given the highly regulated nature of the healthcare market, stakeholders heavily rely on the established framework within which they operate [91]. Legislative intervention should be considered when market players require incentives for innovation or when long-term viable business models become evident. The healthcare market as a whole is highly attractive to investors and offers a wide range of future-oriented business models [25]. The hospital market, with its significant volume of services, is particularly appealing [92]. Opportunities exist to directly implement new care concepts within service provision, as already observed in telemedicine and integrated care offerings for specific medical conditions [93]. Emphasizing the utilization of new technologies to enhance efficiency is essential in these areas, and political entities can support this through investment incentives. Furthermore, the emergence of new digital services presents substantial potential for bringing about disruptive changes in the healthcare system [94]. Software providers, cloud providers, and other data- or technology-driven companies

Table 4 Scenario characteristics

No	Core characteristic	Driving descriptors	Scenario characteristics
Scenario 1	Degree of digitization: low Structural change: small Disruption potential: weak	Staff	Insufficient skilled workers for digitization tasks
		Competition	Low level of competition within the provisioning landscape
		Integrated care	Stagnant integrated care
		Service planning	Continued sectoral supply planning by different entities
		Data protection	Comprehensive data protection requirements
		Cybersecurity	High cyber risks and growing cybersecurity measures
		Digital maturity	Extraordinarily low increase in digital maturity level
Scenario 2	Degree of digitization: advanced Structural change: partial Disruption potential: moderate	Efficiency	Behind potential efficiency gains
		Investments	Insufficient investment to expand digital infrastructure and personnel resources
		Reimbursement	Lack of reimbursement and innovation incentives
		Data platforms	Data-driven platforms are rather underutilized
		Assistance	Assistance systems are not used sufficiently in every area
		Interoperability	Continued problems with data integration due to lack of interfaces
		Prevention	Full potential of data-driven prevention is not being exploited
		Health literacy	Improved health literacy, but not comprehensively developed
Scenario 3	Degree of digitization: increased Structural change: comprehensive Disruption potential: expanded	Qualification	An offensive of further education and training is taking place
		Regional need	The healthcare delivery environment is geared to regional conditions
		Patient journey	Platforms and data-driven information significantly control patient journey
		Privatization	Profit-oriented providers spread out in the market with increasing attractiveness
		Real-time data	Real-time data is available and used for adequate capacity utilization
		Gatekeeper	Digital applications exercise control function with extended steering modality
		Transparency	High transparency about the service offering, quality, and availabilities
Scenario 4	Degree of digitization: high Structural change: enormous Disruption potential: strong	Ambulantization	Broad substitution of inpatient services into the outpatient sector
		Autonomous	Use of autonomous systems in all available operational areas
		Value creation	Transfer of value creation from hospitals to digital service providers
		Market extension	Expansion of the market for healthcare services
		External player	New companies from outside the industry enter the market
		Platforms	Platforms enable new business models and control patient flow
		Digital interaction	High direct digital interaction between patients and healthcare providers
		Digital affinity	Significantly increased acceptance of and affinity for using digital services

have the opportunity to capture a portion of the value-creation process. Consequently, medical value creation may shift from traditional hospital care toward the digital economy. This transition does not imply a loss of quality or accessibility; instead, these new providers can contribute to compensating for delays in the digitization of hospitals [95]. Consequently, the patient journey can be significantly improved and sustained as a result [58].

Institutional challenges have been identified as factors contributing to weak digitization in healthcare [24, 93]. For instance, cybersecurity and the availability of interoperable interfaces are fundamental components necessary to fully harness the potential of data utilization and facilitate seamless data exchange and networking among healthcare stakeholders [96]. However, the responsibility of defining a uniform interface standard should not rest solely with individual hospitals [97]. Instead, it requires oversight from higher-level entities, which may necessitate the establishment of their own regulatory framework. The same holds true for addressing various security aspects, ranging from data protection to safeguarding against cyberattacks [98]. Hospitals should be able to concentrate on their core objective of providing patient care. Peripheral tasks, which involve specialized expertise and complex technical functions, should be entrusted to government bodies that can provide oversight and monitoring. Another crucial consideration is the appropriate management of highly sensitive health data. The European Commission's initiative to establish a common European health data space holds promise for addressing this challenge in the medium term [99]. It is important to recognize that this issue is not trivial, as effective data-driven healthcare within hospitals and beyond necessitates the presence of central platforms for data exchange

[100]. The question of whether these platforms should be operated by private sector-oriented providers or involve government entities requires careful deliberation and should be addressed through societal dialogue.

Future-related implications on resilience

In the initial phase of our study, we employed a consensual Delphi process to examine the changes within the hospital sector. Subsequently, we utilized the data to develop scenarios that depict potential future trajectories. Based on these scenarios, we have already formulated preliminary recommendations for action. In the final phase, our focus is on addressing how decision-makers can effectively adapt to these changes [101]. To accomplish this, we have adopted Behrens and colleagues' resilience model for healthcare systems [102], as depicted in Fig. 7. We believe that this resilience model aligns well with our strategic foresight perspective [73]. Our target timeframe extends until 2032, and it is crucial to establish clear goals for digitalization in hospitals from the outset. This is followed by two distinct phases: the preparation phase and the reaction phase. During the preparation phase, it is imperative to understand the opportunities and risks associated with the various scenarios [103]. We have presented these aspects within each scenario and emphasized the need for anticipatory measures and preparedness for potential adjustments.

At an unknown point in the future, various events may transpire. Firstly, a disruptive event may occur, which has the potential to significantly promote digital transformation and drive substantial changes. We do not evaluate whether this event will have a positive or negative impact on individual hospitals within the market. Instead, the critical factor is the functionality of the healthcare system as a whole. Such an event can be triggered by the introduction of new technologies or leap innovations. Secondly, adverse events may arise due to political interventions or gradual adjustments within the system. An example of this could be a change in data usage regulations or platform-related legislation. Furthermore, labor market shortages for specific occupations can also have a significant impact. Lastly, harmful individual events may occur, leading to a decline in the functionality of the healthcare system. Past instances of cyberattacks on hospitals have demonstrated the direct adverse effects on digitally enabled patient care. Additionally, the insolvency or unexpected withdrawal of key digital service providers can result in significant short-term limitations.

Our research findings provide valuable insights for the actors involved in healthcare and hospitals to prepare for the aforementioned events using our scenarios. We have identified various features that can be proactively influenced to mitigate potential challenges. Additionally, for

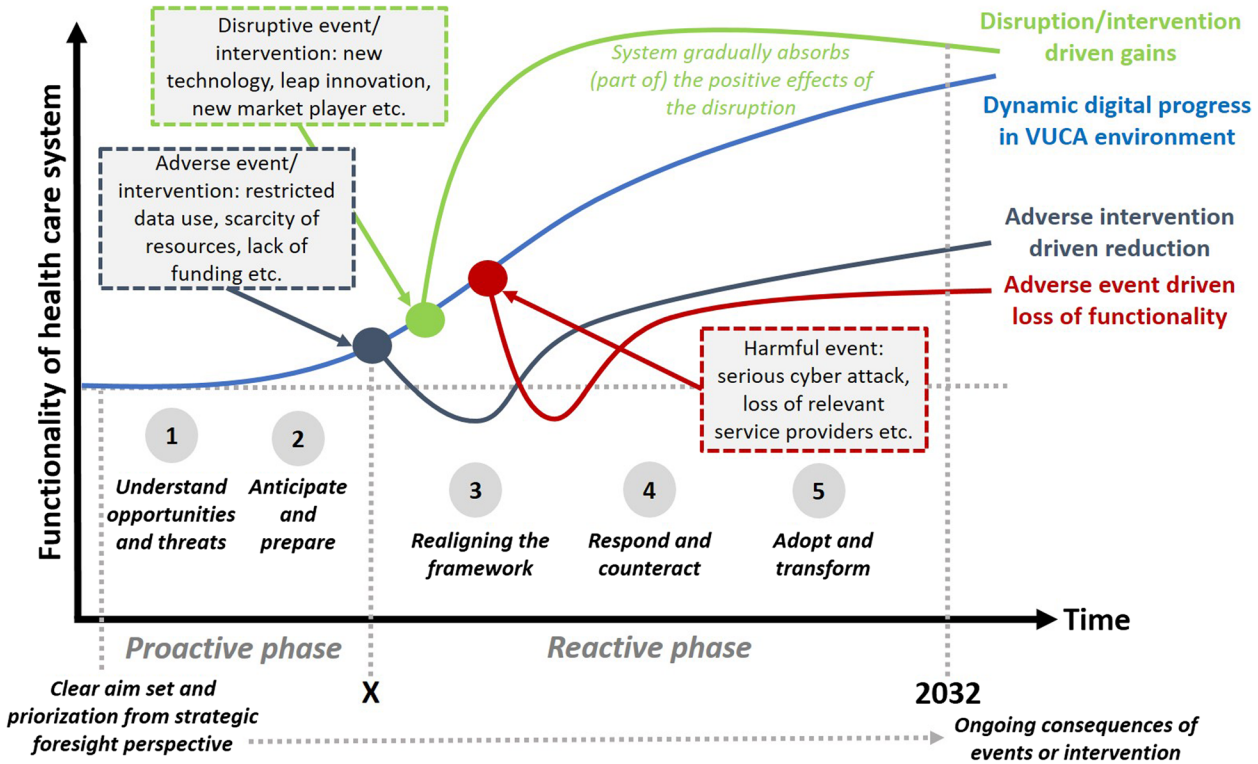

Fig. 7 Foresight perspective for resilient strategic framework in VUCA environments

the reactive phase, action frameworks can be developed to effectively address and resolve issues as they arise [104]. One crucial aspect to consider is how to respond to significant dependencies on individual companies when the level of digitization is high. This becomes particularly relevant in the context of an advanced digital transformation within the healthcare and hospital sector. Considerations of resilience play a pivotal role in maintaining the functionality of care in such circumstances. By taking into account the findings from our study, actors can be better equipped to anticipate and prepare for these events [105]. Proactive measures can be implemented to mitigate risks, and frameworks can be established to address challenges in a responsive manner. Ultimately, incorporating resilience considerations is essential for ensuring the continued functionality of healthcare services [102].

Limitations

The observation of future developments inherently entails a significant level of uncertainty [106]. Despite this uncertainty, the use of established scientific methods in futurology allows us to generate projections of potential future outcomes [107]. The scenario technique we have employed in our study has proven to be highly effective in this regard, as evidenced by numerous published studies [88–90]. In our study, we have chosen the year 2032 as the time horizon for our scenarios. This timeframe is considered moderate, as it spans a period of 10 years, which is more manageable compared to longer-term projections spanning several decades [108]. By considering this timeframe, we aim to provide a comprehensive depiction of potential development paths. It is important to note that our scenarios represent a wide spectrum of possibilities and do not assert the occurrence of any single scenario with certainty. However, the likelihood is high that the future will lie somewhere within the range of these scenarios, providing valuable insights into potential future trajectories.

It should be noted that the generalizability of our findings cannot be uniformly applied to all countries due to the considerable diversity and complexity of country-specific healthcare systems. In our study, we specifically emphasize the German context, which may also be of interest to numerous European countries. However, it is essential to consider individualized recommendations for each country, taking into account the unique characteristics of their respective healthcare systems. In terms of digitization progress, Germany lags behind when compared internationally across various parameters. The overall level of digitization in the hospital sector can be considered relatively weak. From this standpoint, the results can be interpreted in two ways. Firstly, they highlight the significant catch-up potential that exists in Germany, as other countries have already made significant progress in this regard [109]. Secondly, it is possible that inhibiting factors in Germany might be overestimated, as they may not have a significant impact on other countries. This could be particularly applicable to the comprehensive and intricate regulatory framework. Consequently, Germany may be relatively less attractive for private investments and as a location for healthcare startups. This is further exemplified by the fact that leading providers of platform solutions tend to originate from the USA, while only a few German or European technology companies hold a prominent position in the healthcare market. As a result, countries outside the European Union could potentially exhibit more substantial momentum in the digital transformation of inpatient care.

During the expert selection process, we made concerted efforts to ensure the optimal representation of relevant stakeholders. From the perspective of the authors, the selection process was highly successful, as evidenced by the high participation rate in this specialized topic. This indicates a strong interest among participants and suggests that their viewpoints are representative and encompass a balanced range of opinions. However, it is important to acknowledge potential biases that may exist. Firstly, our selection may not have captured the entire spectrum of opinions, potentially resulting in an overestimation of positive sentiment if pessimistic experts chose not to participate. Additionally, it is possible that a greater proportion of younger experts participated, although they may not hold decision-making positions where they actively shape the digital transformation. On the other hand, it is conceivable that certain aspects relevant to the future were not adequately addressed. This could be the case if visionary arguments were not fully considered in the exploratory phase and consequently not included in the selection of descriptors. Nonetheless, we conducted our selection process in accordance with rigorous scientific standards and assessed all aspects based on applicable quality criteria. Therefore, we are confident in the validity of our data and believe that if the same methods were employed, other researchers would arrive at similar conclusions.

Conclusion

We employed a sequential study design to address three fundamental questions in our research. Firstly, we aimed to uncover potential changes that may occur in the hospital sector as a result of the ongoing digital transformation. To achieve this, we conducted exploratory interviews with experts and subsequently conducted a two-round Delphi survey, in which we evaluated 30 descriptors. Secondly, we selected and applied the scenario technique as

an appropriate approach to illustrate the potential development trajectories. To cluster these scenarios, we utilized a fuzzy C-Mean algorithm, which allowed us to generate four distinct scenarios. The key determinants of these scenarios are the levels of digitalization within hospitals, the extent of structural changes in service provision, and the potential for disruptive forces. Scenario 1 depicts a scenario characterized by weak digitalization, minimal changes to existing care structures, and low disruptive potential. This scenario emphasizes defensive concerns such as data protection and cybersecurity. Scenario 2 illustrates an advanced level of digitalization accompanied by limited structural changes. While improvements are achieved, there is a failure to fully exploit existing potential. Interoperability of systems and appropriate remuneration incentives are critical factors in this scenario. Scenario 3 showcases a significantly advanced level of digitalization, substantial structural changes, and a comprehensive disruptive element. In this context, innovative business models from existing players drive the emergence of new regional care offerings. Finally, scenario 4 represents the highest level of digitization, extensive structural changes, and high disruptive potential. This scenario attracts new players from outside the healthcare sector, significantly reshaping the hospital landscape. The focus in this scenario is on patient-centric care. Lastly, we explored how decision-makers can effectively navigate the outlined changes and introduced a resilience model. By considering this model, decision-makers can proactively anticipate change parameters and establish a resilient environment conducive to a high-functioning health and hospital system.

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Authors' contributions
PK and SBJ jointly discussed the research question and determined an appropriate research design. All authors evaluated the data independently. PK and SBJ reviewed all data and discussed the results. Extensive validation of the results by the author team took place. The completed manuscript was reviewed and approved by PK and SBJ. All authors read and approved the final manuscript.

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Availability of data and materials
We offer access to our data to other scientists with a legitimate research interest. This is especially true for methodological studies that want to use our metadata. The survey was conducted in German. For further research, the authors can be contacted for access to our data.

Declarations

Ethics approval and consent to participate
We conducted our study using a variety of survey instruments in compliance with all scientific standards. Various experts were involved in the process. Due to the method design and the selection of the experts, no approval by the Ethics Board was necessary. No persons outside the described circle of experts were interviewed at any time. All included experts were continuously and extensively informed about the subject of the research and consented to the use of the resulting research data. Consent was obtained at several points during the course of data collection.

Consent for publication
Not applicable.

Competing interests
The authors declare that they have no competing interests.

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