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The socio-technical adoption and diffusion of digital health innovations: The development of the STAD-HC model based on telemedicine in Germany

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ABSTRACT

Digital and telemedicine innovations are increasingly central to healthcare transformation, yet their adoption and diffusion remain complex. While the *Diffusion of Innovations* (DOI) theory explains staged adoption processes, it underrepresents socio-political and institutional factors. The *Social Shaping of Technology* (SST) approach complements DOI by focusing on the co-construction of technology through cultural, organizational, and political dynamics. This study investigates how DOI and SST can be combined to explain the adoption and diffusion of digital health innovations, with a focus on telemedicine in the German healthcare system. Using the Decision Matrix for Theory Borrowing, DOI and SST were selected as complementary frameworks. A secondary analysis of 12 expert interviews was conducted using SST-based content analysis. Data were coded according to Rogers' five adoption stages and four SST dimensions. Findings were mapped in a DOI-SST matrix and analysed across micro-, meso-, and macro-levels. The analysis shows that innovation trajectories are shaped by interdependent socio-technical factors across all adoption stages. Key barriers include cultural skepticism, organizational inertia, fragmented governance, and economic misalignment. The *Socio-Technical Adoption and Diffusion Model for Healthcare* (STAD-HC) was developed to represent these dynamics, linking DOI's stage logic with SST's contextual dimensions. The STAD-HC model offers a multi-level framework to analyse how digital health technologies are adopted, contested, and institutionalized. By integrating behavioural processes with structural influences, it provides practical guidance for managing innovation and supports future research on complex digital health technologies such as AI and blockchain.

1. Introduction

The integration of digital technologies into healthcare systems has become a strategic imperative in response to resource constraints, demographic shifts, and rising expectations for accessible, high-quality care. Digital and telemedicine innovations are perceived as central to healthcare transformation strategies, enabling both clinical decision-making and broader system-level efficiencies (Odone, Buttigieg, Ricciardi, Azzopardi-Muscat, & Staines, 2019; Orton, Agarwal, Muhoza, Vasudevan, & Vu, 2018; Rechel et al., 2013). Over the past decade, academic interest in this field has increased significantly, reflecting its interdisciplinary relevance across medical, technological, and business domains. This is evidenced by a substantial and growing body of literature on the topic published across major scientific databases (e.g. ~12,223 search results in PubMed from 2014 to 2024).

Telemedicine comprises a wide array of digital infrastructures and

applications, including national health information exchange (HIE) platforms, decentralised diagnostic devices, and mobile health solutions. These technologies enable the collection, transmission, and analysis of health data across both stationary and mobile platforms (Klesper & Zerth, 2021). They support a growing number of data-driven use cases, such as remote monitoring, clinical decision support, predictive analytics, and personalised treatment - reshaping not only how care is delivered, but how healthcare organizations operate (Inglis, Clark, Dierckx, Prieto-Merino, & Cleland, 2015; Mathew, Lail, Chang, & Jefferies, 2018).

Digital health innovations should not be viewed solely as technical artefacts, but as complex socio-technical systems that transform workflows, professional roles, and governance structures. They represent product innovations (e.g. wearable sensors, blockchain-based data systems), process innovations (e.g. remote diagnostics, automated reporting), and social innovations (e.g. digital interaction between providers

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and patients) (Cho & Mathiassen, 2007; Posenau, 2021; Zerth & Forster, 2021). A prominent example is blockchain technology, which, while offering technical capabilities for decentralised data integrity and traceability, also requires cross-organizational trust, aligned governance structures, and robust legal and ethical frameworks to be effectively implemented (Adeghe, Okolo, & Ojeyinka, 2024; R. Zhang, George, Kim, Johnson, & Ramesh, 2019). These requirements illustrate that even technically promising innovations can fail without alignment across organizational and systemic structures.

Despite their transformative potential, digital health technologies frequently encounter substantial barriers to adoption, implementation, and sustained integration. Adoption is not driven by technical performance alone, but also by organizational readiness, user perceptions, governance mechanisms, and socio-cultural alignment (Gagnon, Nngangue, Payne-Gagnon, & Desmartis, 2016; Gleiss & Lewandowski, 2022). Addressing these multi-level dynamics requires theoretical approaches that can capture both the staged nature of innovation uptake and the institutional structures within which it occurs.

This study focuses on the integration of two established theoretical perspectives—the *Diffusion of Innovations* (DOI) theory (Rogers, 2003) and the *Social Shaping of Technology* (SST) framework (MacKenzie & Wajcman, 1999; Williams & Edge, 1996) - to analyse the adoption and diffusion of digital health innovations. DOI conceptualizes innovation adoption as a staged process - comprising knowledge, persuasion, decision, implementation, and confirmation - that primarily describes how individuals and organizations evaluate and integrate new technologies (Rogers, 2003). However, it has been critiqued for its linearity and for insufficiently accounting for political, institutional, and cultural influences (Greenhalgh et al., 2017).

Conversely, SST foregrounds how technologies are socially constructed through institutional logics, cultural expectations, and power dynamics. It argues that technologies do not evolve independently, but are co-constructed through interaction with professional norms, regulatory frameworks, and organizational practices (Ulucanlar, Faulkner, Peirce, & Elwyn, 2013; Williams & Edge, 1996). While SST contributes valuable insights into structural and normative determinants, it lacks the processual clarity offered by DOI for modelling adoption dynamics at the micro and meso levels.

Scholars such as Boczkowski (2004) have advocated integrating DOI and SST to better account for the reciprocal interplay between technology development and institutional embedding. This approach is especially relevant in healthcare, where innovations such as telemedicine or blockchain operate within dense layers of regulation, legacy infrastructure, and professional culture.

Building on this foundation, the article introduces the STAD-HC model - a multi-level, socio-technical framework that aligns DOI's process-based adoption logic with SST's contextual sensitivity. While the model draws selectively on the Consolidated Framework for Implementation Research (CFIR) (Damschroder et al., 2009) and Actor Network Theory (ANT) (Borgatti & Foster, 2003; Latour, 2005) to contextualise implementation dynamics and actor interdependencies, the conceptual core remains grounded in the integration of DOI and SST. The STAD-HC model thus aims to bridge behavioural adoption processes with structural, political, and cultural forces that shape the diffusion of digital health innovations.

Accordingly, this study explores how the Diffusion of Innovations (DOI) theory and the Social Shaping of Technology (SST) framework can be combined to explain the adoption and diffusion of digital innovations in healthcare - particularly in the context of telemedicine implementation in the German healthcare setting. In doing so, it contributes to theory development in digital innovation and offers practical insights for managing socio-technical transformation in regulated and networked domains such as healthcare and digital business.

2. Theoretical background

A growing body of empirical research demonstrates that the adoption and diffusion of digital innovations in healthcare are shaped by a complex interplay of individual, organizational, and systemic factors. Systematic reviews have consistently shown that, beyond personal willingness to innovate, factors such as organizational capacity, leadership engagement, internal communication structures, and regulatory as well as infrastructural preparedness are critical to determining whether digital solutions are accepted and successfully implemented (Cresswell & Sheikh, 2013; Kruse et al., 2018; Odendaal et al., 2020; Ross, Stevenson, Lau, & Murray, 2016; Sieck et al., 2021).

Within implementation research, the Diffusion of Innovations (DOI) theory, developed by Rogers (2003), has emerged as one of the most influential frameworks for analyzing how digital technologies are introduced into healthcare systems (Greenhalgh, Robert, MacFarlane, Bate, & Kyriakidou, 2004). The theory distinguishes between two interrelated yet analytically distinct processes: adoption and diffusion. Adoption refers to the individual or organizational decision-making process through which an innovation is evaluated and ultimately accepted or rejected. This process is structured into five stages: knowledge, persuasion, decision, implementation, and confirmation (Gagnon et al., 2016; Greenhalgh et al., 2004; Rogers, 2003). In contrast, diffusion is defined as the broader social process by which innovations spread over time through communication channels within a social system. While adoption focuses on local behavioural decisions, diffusion captures how these accumulate and influence others at the system level (Dearing, 2009; Litfin, 2000; Rogers, 2003). Both processes are influenced by the perceived attributes of the innovation - namely, relative advantage, compatibility, complexity, trialability, and observability - which shape the pace and extent of both initial uptake and broader dissemination (Kristensson, Brunstrom, & Pedersen, 2015; Rogers, 2003).

The DOI framework has been extensively applied in health services research to explain technology adoption among clinicians, patients, and organizations (Gagnon et al., 2016; Perla et al., 2018). Nevertheless, it has been criticised for underemphasising structural, institutional, and political factors that shape diffusion trajectories - particularly in complex and highly regulated sectors such as healthcare (Dryden-Palmer, Parshuram, & Berta, 2020; Greenhalgh et al., 2017). More recent studies underscore the limitations of DOI's largely linear and actor-centric logic. Innovation trajectories in healthcare are often disrupted by policy uncertainty, institutional resistance, infrastructural gaps, or contextual contingencies - factors that DOI alone cannot fully capture (Greenhalgh et al., 2017). As a result, implementation frameworks such as the Consolidated Framework for Implementation Research (CFIR) have promoted multi-level approaches that integrate individual, organizational, and systemic perspectives (Birken et al., 2017; Damschroder et al., 2009; Lynch et al., 2018).

In contrast to DOI's process-based structure, the *Social Shaping of Technology* (SST) perspective offers an interpretive framework to analyse how social, cultural, and institutional conditions influence the design, meaning, and use of technology. Initially developed by Donald MacKenzie and Judy Wajcman in their 1985 volume *The Social Shaping of Technology* and later expanded in their revised 1999 edition, SST emerged as a critique of technological determinism (MacKenzie & Wajcman, 1999; Wheeler, 1985). It argues that technological artefacts are co-constructed through interactions between users, designers, institutional arrangements, and socio-cultural norms (MacKenzie & Wajcman, 1999; Pinch & Bijker, 1989). According to SST, innovations are embedded in broader societal structures, and their diffusion depends on alignment with prevailing cultural values, organizational routines, and governance regimes (Bijker, 1997; Williams & Edge, 1996).

The SST approach has gained traction in digital health and information systems research, offering insight into how innovations are not only adopted but also reframed, contested, or resisted in everyday

practice (Ulucanlar et al., 2013; Wyatt, 2008). It also sheds light on how professional identities, normative expectations, and institutional legitimacy influence perceptions of value and appropriateness of digital tools (Lund, Andersen, & Christensen, 2016; Richardson et al., 2022; Yao & Sheng, 2022). For example, Ulucanlar et al. (2013) introduce the concept of an “adoption space” - a dynamic field shaped by professional norms, political discourse, and social narratives.

To more accurately reflect the complexity of digital transformation in healthcare, scholars increasingly apply a multi-level analytical perspective. At the micro level, individual perceptions, cognitive framing, and social identity influence the assessment and adoption of innovations (Gagnon et al., 2016; Yao & Sheng, 2022). The meso level includes organizational practices, leadership behavior, and change management structures that mediate between user actions and systemic forces (Glæss & Lewandowski, 2022; X. Zhang, Yu, Yan, & Spil, 2015). The macro level encompasses political will, regulatory frameworks, and infrastructural capabilities that shape the overall diffusion environment (Hashiguchi, 2020; Ross et al., 2016; Schmitt, Haarmann, & Shaikh, 2023).

Infrastructural inequality further constrains equitable diffusion. Studies by Sieck et al. (2021) and Benda, Veinot, Sieck, and Ancker (2020) show that limited access to digital infrastructure - such as broadband connectivity - produces systemic exclusion effects. Complementing these findings, Saigí-Rubió et al. (2022) provide a comprehensive overview of telemedicine adoption across the WHO European Region, illustrating how strategic alignment and policy coherence influence national readiness.

Additional complexity emerges in the context of emerging technologies such as artificial intelligence, blockchain, and the Internet of Things (IoT). Niknejad, Ismail, Bahari, and Nazari (2021) emphasize the need for cross-stakeholder coordination whereas Liang (2012) introduces a multi-level gap model for eHealth that differentiates between awareness, willingness, and actual use - highlighting misalignments in real-world implementation. Similarly, Adeghe et al. (2024) and R. Zhang et al. (2019) underscore that successful blockchain adoption depends on institutional trust and governance alignment. These findings reflect SST’s emphasis on institutional legitimacy and co-construction processes.

Numerous studies also point out that innovation trajectories in healthcare are frequently non-linear, marked by institutional inertia, external shocks, and shifting political priorities (Dryden-Palmer et al., 2020; Odendaal et al., 2020). These dynamics further challenge stage-based models and highlight the need for integrative frameworks, such as the STAD-HC model proposed in this study.

The STAD-HC model builds on this integrative logic by aligning the adoption and diffusion processes described in DOI theory with SST’s structural and normative shaping dimensions, across the micro-, meso-, and macro-levels. It offers a theoretically grounded and empirically informed framework for analyzing the diffusion of digital innovations within complex healthcare systems. By synthesising process-based dynamics with contextual complexity, the model is particularly well-suited to explain innovation outcomes in healthcare—where successful adoption depends not only on individual acceptance, but also on organizational readiness and broader system-level alignment.

While DOI and SST originate from distinct epistemological paradigms - positivist and constructivist respectively - they provide complementary insights into how innovations emerge, are adopted, and evolve within socio-technical systems. As Boczkowski (2004) noted, integrating structured innovation models with interpretive approaches enables a more comprehensive understanding of how technologies are negotiated, stabilised, and transformed in practice.

In conclusion, the DOI-SST framework as operationalised in the STAD-HC model offers a multi-level, socio-technical perspective that helps to illuminate both the behavioural mechanisms underlying adoption and the institutional dynamics influencing diffusion. It provides a promising foundation for analyzing digital transformation in

complex environments and may contribute to theoretical and practical understanding of innovation processes in healthcare and related sectors.

3. Materials and methods

This study investigates how Rogers’ Diffusion of Innovation (DOI) theory and the Social Shaping of Technology (SST) perspective can be integrated to yield a richer framework for understanding the diffusion of digital health innovations in healthcare. To establish the theoretical appropriateness and integration of these approaches, we applied the Decision Matrix for Theory Borrowing by Hanafizadeh and Alipour (2024), confirming that DOI and SST jointly address our research context. Building on this foundation, we re-analysed pre-existing semi-structured interview transcripts from our earlier DOI study of key stakeholders in the German telemedicine sector. Employing a deductive-inductive content analysis, each excerpt was coded both to one of Rogers’ five adoption stages (knowledge, persuasion, decision, implementation, confirmation) and to one of Williams and Edge (1996) four SST factors (cultural, organizational, political, economic). For each DOI-SST pairing, we selected representative anchor quotes to document the alignment between empirical data and theoretical constructs. The detailed results of the DOI-only analysis are reported separately (Rauner & Stummer, 2024a); in this article, we focus on the SST analysis and its integration with DOI. Subsequently, we mapped and synthesized these qualitative findings into a two-dimensional matrix and, from there, distilled a conceptual framework that unites DOI and SST perspectives. This framework captures decision-making processes at the individual (micro), organizational (meso), and systemic (macro) levels, alongside the socio-technical forces that shape innovation in healthcare. The resulting mapping matrix underpins our multi-level impact analyses. Finally, we constructed a conceptual model that illustrates how digital telehealth innovations are both adopted—through clinician decisions at the micro level, organizational routines at the meso level, and policy negotiations at the macro level—and socially shaped by cultural attitudes, institutional capacities, regulatory dynamics, and economic incentives. Ethical approval was granted by the Research Commission for Scientific and Ethical Issues of UMIT Tyrol, Austria, and the study was conducted in accordance with the Declaration of Helsinki.

3.1. Literature research and application of the decision matrix of theory borrowing

To examine the current state of research on the use of diffusion of innovation theory and social shaping of technology theory in the context of innovation diffusion in healthcare systems, an exploratory literature search was conducted to assess how both Diffusion of Innovation (DOI) theory and Social Shaping of Technology (SST) theory have been employed in studies of innovation diffusion within healthcare. Systematic searches of the PubMed and EBSCO databases were performed for English-language, full-text articles published between January 2015 and March 2025. Search terms - “diffusion of innovation,” “telemedicine,” “digital health,” “healthcare,” and “social shaping of technology theory” - were combined with the Boolean operators AND and OR. This initial literature search was augmented by citation-tracking and manual screening of key journals and reference lists.

To ensure a robust theoretical integration of DOI and SST, findings from the literature review were systematically applied within the Decision Matrix for Theory Borrowing according to Hanafizadeh and Alipour (2024). This matrix comprises seven steps for theory acceptance testing, including: analysis of theories used in the chosen research context; listing of identified theories; justification for selecting the most appropriate theories; description of the general theoretical conceptualization; articulation of each theory’s core assumptions and reasoning mechanisms; and definition of the area of interest (Hanafizadeh & Alipour, 2024).

The following steps of the Decision Matrix of Theory Borrowing

according to Hanafizadeh and Alipour (2024) were applied to the Diffusion of Innovations (DOI) and Social Shaping of Technology (SST) theories in the context of digital telemedicine innovations in healthcare:

- Identification of candidate theories via systematic literature research
- Analysis of each theory's relevance to the research domain via systematic literature research
- Justification for selecting the most appropriate theories
- Specification of the general theoretical conceptualizations
- Articulation of each theory's core assumptions and reasoning mechanisms
- Definition of the area of interest
- Synthesis into an integrated theoretical approach

3.2. Interview material – SST content analysis

The data to be analysed was collected between August and September 2022 in Germany as part of a guideline-based interview study on the adoption and diffusion processes of innovations in the healthcare context, using telemedicine as an example. A total of 30 experts in the fields of medicine or telemedicine were contacted via professional networks and snowball sampling to participate in an expert interview. The selection of experts from the fields of medicine and telemedicine was necessary to incorporate both clinical-medical and technology-innovation perspectives in the study of innovation diffusion within telemedicine. From a methodological standpoint, including actors with a broad medical background enables a comprehensive representation of the heterogeneous contexts in which telemedicine innovations are applied, as these experts possess essential knowledge of clinical application, patient care, and the organizational as well as interdisciplinary interfaces within healthcare. Additionally, pure telemedicine experts were selected to focus on the technology implementation and innovation-specific challenges, as they offer in-depth insights into the technical, economic, and regulatory hurdles associated with the introduction and dissemination of telemedicine applications. This differentiated approach facilitates the integration of both clinical and technology-oriented dimensions of innovation diffusion, thereby generating a more comprehensive and robust explanatory model. Building on this integrated framework, a written information letter was sent to potential participants, and 13 experts ($m = 9, f = 4$) subsequently provided their written consent and participated in the expert interview after scheduling an appointment. The number of interviews was determined in accordance with the concept of theoretical saturation (Guest, Bunce, & Johnson, 2006; Saunders et al., 2018), ensuring that data collection ceased once no new themes or insights emerged.

Due to one interview in which two experts participated together at their request, 12 transcripts from 13 experts were available for analysis. Data were collected using a standardized short questionnaire, an interview guide, and a reminder protocol. The standardized short questionnaire was employed to collect demographic data (including gender and year of birth), while the template for the reminder protocol was used to document specific interview situations. The primary instrument for data collection was the interview guide, which was based on Rogers' adoption and diffusion theory. This guide comprised four thematically linked sections: understanding the innovation, adoption-specific questions, diffusion-specific questions, and a final summarizing question.

The participants in the expert interviews were as follows: nine participants with a specific telemedical background in the areas of telemedicine and telecommunications ($n = 2$), hospital and home automation management ($n = 2$), economic evaluation of telemedicine applications ($n = 2$), medical informatics ($n = 1$), and chief medical officer ($n = 2$), of whom four were additionally licensed physicians. There were also four physicians without specific telemedical training, specializing in dermatology ($n = 2$), pediatrics ($n = 1$), and internal medicine ($n = 1$). The mean age of the respondents was 42.8 years. The expert interviews were conducted via video call, recorded, and then

transcribed according to the simplified transcription rules of Kuckartz and Rädiker. The data collected orally in the short questionnaire were recorded in Excel.

As part of the study, a total of 12 audio files—based on 13 expert interviews—were transcribed in MP3 format according to standardized transcription guidelines for computer-assisted analysis. The manual transcription was performed by the interviewer, who continuously compared the transcripts with the original audio files to ensure high data validity (Rädiker & Kuckartz, 2019). The transcripts, available in Word format, were then imported into the qualitative data analysis software MaxQDA 2022. The analysis was conducted using hermeneutic content analysis, whereby additional notes from the short questionnaire and memory protocols were incorporated for in-depth interpretation in the sense of the hermeneutic circle (Gadamer, 1975).

Building on our prior DOI analysis, we re-analysed twelve interview transcripts using the Social Shaping of Technology (SST) framework (Williams & Edge, 1996); ten contained material relevant to SST coding, and two were excluded due to lack of applicable content (Table 1). Employing a deductive–inductive content-analysis approach, the remaining ten transcripts were coded according to the four SST dimensions—cultural, organizational, political, and economic defined by Williams and Edge (1996). (See Table 2.)

Following Attride-Stirling (2001) thematic network method, each SST dimension was elaborated into basic themes and refined into differentiated subcodes, ensuring internal homogeneity and external heterogeneity. This combined deductive–inductive process applied predefined theoretical criteria and iteratively integrated emergent themes through constant comparison (Mayring, 2022). To bolster reliability, a detailed coding scheme grounded in both the theoretical frameworks and the data-driven themes was implemented. We further enhanced validity by triangulating data across a diverse expert sample and conducting peer debriefing: an independent colleague reviewed the coding process and theme development to confirm interpretive credibility.

3.3. Analytical framework and model development

In the final analytical stage, results from the DOI-centred and SST-centred content analyses were combined to generate a unified, socio-technical account of telemedicine diffusion. This integrative process comprised three stages and was guided by established methodological approaches to qualitative model construction in socio-technical systems research (Geels, 2002; Papachristos & Adamides, 2016).

(1) Mapping

(2) Drawing on our prior DOI analysis (Rauner & Stummer, 2024a), each interview excerpt—initially coded according to Rogers' (2003) five innovation adoption stages (knowledge, persuasion, decision, implementation, confirmation) - was systematically mapped onto one of the four socio-technical dimensions defined by Williams and Edge (1996): cultural, organizational, political, and economic. This analytical alignment positioned each unit of meaning at the intersection of a temporal adoption stage and a contextual socio-technical factor. To retain analytical richness while enabling clarity and synthesis, we selected one representative anchor quote per DOI–SST pairing (e.g., Int. 12, para. 16 → Knowledge + Cultural) to exemplify the underlying mechanism at play.

(3) Multi-Level-Analysis

(4) Each anchor quote was then subjected to a structured multi-level examination, tracing its relevance across the micro-level (individual actors), meso-level (organizational structures and routines), and macro-level (institutional, societal, and policy contexts). This step drew on the conceptual orientation of the Multi-Level Perspective (MLP) as articulated by Geels (2010), which views socio-technical change as resulting from dynamic

Table 1
Participant overview by role and domain expertise.

ID	Role	Affiliation Type	Domain Expertise	Med. License	sex	in SST Analysis	in DOI Analysis
P1	Physician	outpatient medical care	dermatology	yes	f	included	included
P2	Retail manager	medtech company	Management for hospital and home automation (Germany & Austria)	no	m	included	included
P3	MBA, Physician	transition period	Management, physician for internal medicine	yes	m	included	included
P4	Telemedicine provider	medtech company	Management, emergency physician	yes	m	included	included
P5	Physician	hospital	pediatrics	yes	f	excluded	included
P6	Retail manager	medtech company	Hospital Automation	no	m	included	included
P7	Physician	outpatient medical care	dermatology	yes	f	excluded	included
P8	Chief physician	hospital, science	neurology	yes	m	included	included
P9	Physician	hospital, science	anaesthetist	yes	m	included	included
P10	Health economics and medical management, eHealth consultant	consulting	Health economic assessment in telematics and telemedicine, accompanying research	no	f	included	included
P11	Medical Informatics, Industrial Engineering	consulting	Head of Telematics and Telemedicine, Technical Consulting, Telematics Evaluation	no	m	included	included
P12	Chief physician	hospital, science	neurology	yes	m	included	included
P13	Managing Director	consulting	Project management and consulting in telemedicine	no	m	included	included

Participant overview of expert interviewees included in the SST- and DOI-based analysis. Roles are summarized according to primary expertise. “Affiliation type” denotes the organizational sector at the time of the interview. “Domain expertise” provides additional thematic focus, e.g., medical discipline, informatics, or telemedicine strategy. “Med. License” indicates whether the participant holds a formal medical qualification (yes/no). The final two columns indicate whether the respective transcript was included in the SST- and/or DOI-specific analysis. Out of 13 expert interviews (12 transcripts), 10 were analysed using SST criteria; all were analysed under the DOI framework.

interactions across different structural levels. The resulting interpretations were synthesized via a qualitative meta-analytic process to identify cross-cutting patterns, thematic convergences, and notable tensions between levels.

(5) Model Construction and Hypothesis Generation

Building on these cross-level insights, we constructed an integrative SST–DOI model that delineates how cultural, organizational, political, and economic dimensions interact with each adoption stage and may influence diffusion. Consistent with Papachristos and Adamides (2016) retroductive systems-based methodology, this model functions as both a mid-range theoretical abstraction and an empirically grounded framework. From this synthesis, we derived a series of testable hypotheses to inform future quantitative and comparative research on digital health technology adoption and diffusion.

This structured approach enabled a robust alignment between empirical observations and theoretical frameworks, fostering the development of an explanatory model that moves beyond descriptive accounts toward conceptual generalization.

4. Results

4.1. Literature review and decision matrix of theory borrowing

The exploratory literature search of PubMed and EBSCO covering the period from 2015 to March 2025 identified 43 articles on the application of Diffusion of Innovation (DOI) theory in healthcare, 64 on the Social Shaping of Technology (SST) perspective, and 10 that explicitly combined both frameworks. Of these, 15 articles met our inclusion criteria for in-depth analysis.

The literature review underscores that social factors are central to the adoption and diffusion of healthcare innovations. Multiple studies demonstrate that social influences, individual perceptions, and organizational and technological conditions critically shape these processes.

Liu, Son, and Cao (2023), Tahsin et al. (2022), and Evering, Postel, van Os-Medendorp, Bults, and Ouden (2022) contend that social influences and cognitive processes - particularly perceived usefulness - exert a significant impact on innovation uptake. Liu et al. (2023) explore

how public perception of an innovation’s value affects its acceptance. Evering et al. (2022) examine the role of colleagues and the professional environment in shaping how healthcare professionals implement innovations. Tahsin et al. (2022) highlight the provider-patient relationship as a key determinant of how patients perceive and accept healthcare innovations.

Communication emerges as another pivotal social determinant: X. Zhang et al. (2015) demonstrate that the quality of information exchange shapes both acceptance and rejection of innovations, thereby influencing diffusion trajectories. Beyond these social drivers, policy instruments (e.g., incentive schemes) and market forces also play critical roles (Robinson, Savage, & Campbell, 2003). Liang (2012) further illustrates how innovation awareness and adoption intent are interdependent, with diffusion following a cyclical interplay of technology push and consumer pull.

From a social constructivist perspective, the adoption and diffusion of innovations in healthcare are shaped by social constructions (Lund et al., 2016; Richardson et al., 2022; Ulucanlar et al., 2013), social identity (Yao & Sheng, 2022), and habitual behaviors (Richardson et al., 2022). Lund et al. (2016) show that clinical competencies are informed by socially constructed treatment norms, while Richardson et al. (2022) and Söling et al. (2023) reveal that past experiences and physicians’ beliefs about efficacy - shaped by cultural and normative frameworks - affect the evaluation of technologies such as AI. Yao and Sheng (2022) also underscore the influence of psychosocial factors and identity on individual acceptance and integration of innovations.

Ulucanlar et al. (2013) describe these social influences, normative beliefs, and professional identities within the concept of an “adoption space”—a dynamic network of actors in the healthcare system who construct technology identities. These socially constructed attributes determine how innovations are perceived in terms of efficacy, benefit, and risk, thereby guiding acceptance at both individual and societal levels.

Organizational conditions further determine innovation trajectories. Patel and Antonarakis (2013) and Khalil (2019) identify technological infrastructure and organizational readiness as essential for successful implementation. X. Zhang et al. (2015) and Lin, Lin, and Roan (2012) suggest that ineffective communication and a low perceived value of innovations (X. Zhang et al., 2015), as well as management attitudes and

Table 2
DOI-SST mapping.

DOI Stage	SST Factor	Anchor Quote	Level	Analytical Assumption	Hypothesis
Knowledge	Cultural	“Well, the very first thing, I think, is the mindset of those affected. In Germany, we have a very critical attitude toward technical innovation in this area.” (Int. 12, para. 16)	micro	Individual reluctance to adopt digital tools stems from a culturally embedded professional mindset that favors established, analogue practices. This cultural orientation may suppress proactive information-seeking behavior, limiting awareness and understanding of emerging innovations.	H1 KC: Individuals embedded in professional cultures that prioritize analogue practices and exhibit skepticism toward digital change are less likely to enter the knowledge phase of innovation diffusion, due to reduced proactive engagement with innovation-related information.
Knowledge	Cultural		meso	Organizational cultures differ in their openness to digital innovation. Variability in digital readiness across affiliated institutions reflects internal cultural heterogeneity, which may disrupt the diffusion of knowledge and hinder the development of collective engagement strategies.	H2 KC: Healthcare organizations characterized by culturally conservative norms will exhibit lower collective progression into the knowledge phase of digital innovation diffusion, as such cultures inhibit internal communication, knowledge sharing, and organizational learning.
Knowledge	Cultural		macro	Broader societal norms and cultural narratives—such as skepticism toward digital technologies or concerns about data privacy—shape political and institutional support structures. These cultural influences may delay policy-driven knowledge mobilization and inhibit systemic diffusion efforts.	H3 KC: In health systems where dominant societal cultures express skepticism toward digital technologies (e.g., concerns over surveillance or depersonalization), the collective entry into the knowledge phase is delayed, limiting early policy attention and institutional investment in digital health innovation.
Knowledge	Organizational	“For example, a digital stethoscope, a high-resolution digital camera that can be used to photograph moles, and other technical devices. These are not yet available to us on a regular basis.” (Int. 9, para. 12)	micro	Clinicians may possess general awareness of digital diagnostic tools but lack routine, institutionalized exposure. This limits their ability to engage meaningfully with the innovation and develop confidence in its relevance or utility, thereby constraining entry into the knowledge phase of the diffusion process.	H1 KO: Clinicians with limited institutional exposure to digital diagnostic tools are less likely to reach the knowledge phase of innovation adoption, as organizational conditions restrict routine engagement and reduce confidence in the innovation’s relevance.
Knowledge	Organizational		meso	The absence of digital tools in everyday clinical workflows reflects potential organizational inertia, competing operational priorities, or insufficient infrastructure. These conditions hinder experiential knowledge-sharing and collective learning, reducing institutional readiness to support early-stage innovation engagement.	H2 KO: Healthcare organizations characterized by weak integration of digital tools into routine workflows will demonstrate lower levels of institutional knowledge-sharing and staff engagement in the knowledge phase of innovation diffusion.
Knowledge	Organizational		macro	Systemic barriers such as delayed regulatory approval, fragmented financing mechanisms, and misaligned policy frameworks impede the broader endorsement needed for knowledge diffusion. These factors slow the institutional legitimization of digital innovations and limit the conditions for early adoption at scale.	H3 KO: Health systems with delayed regulatory approval, fragmented funding, and uncoordinated policy support will exhibit lower levels of organizational uptake and knowledge diffusion of digital innovations during the early adoption phase.
Knowledge	Political	Certainly a lack of information. Information needs to be made accessible to doctors in some way. And the benefits need to be clearly demonstrated. Above all, the time benefits. Time is a huge issue: if time could be saved, that would be a huge advantage, or the financial benefits. (Int. 1, para. 23)	micro	At the micro level, fragmented or vague policy messaging can prevent healthcare professionals from understanding the practical benefits of telemedicine, stalling their entry into the knowledge phase.	H1 KP: Healthcare professionals exposed to unclear or fragmented political communication are less likely to progress through the knowledge phase of telemedicine adoption, as insufficiently actionable political messaging limits their understanding of the innovation’s benefits.
Knowledge	Political		meso	At the meso level, inconsistent guidance contributes to organizational inertia, making it difficult for institutions to plan, adopt, and internalize digital strategies.	H2 KP: Healthcare organizations operating under inconsistent or vague political guidance will exhibit lower levels of internal knowledge dissemination and delayed decision-making regarding telemedicine adoption during the knowledge phase.
Knowledge	Political		macro	At the macro level, weakly coordinated policy efforts undermine the formation of a shared vision, reducing system-wide trust and engagement.	H3 KP: Health systems characterized by fragmented or poorly coordinated digital health policies will demonstrate weaker collective progression into the knowledge phase of innovation diffusion, due to reduced public trust and lack of a unified understanding of telemedicine’s value.

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Table 2 (continued)

DOI Stage	SST Factor	Anchor Quote	Level	Analytical Assumption	Hypothesis
Knowledge	Economic	General practitioners can bill a limited number of points for video consultations. Next year, there will probably be an OPS code for video consultations between intensive care units for very specific patient groups. At least, that is what the GBA has recommended. (Int. 4, para. 16)	micro	At the micro level, limited financial incentives can reduce clinicians' motivation to engage with telemedical tools, potentially affecting familiarity and initial uptake.	H1_KE: Clinicians who perceive limited financial incentives or unclear reimbursement options are less likely to actively engage with telemedicine in the knowledge phase of adoption, due to reduced motivation to explore or learn about its practical value.
Knowledge	Economic		meso	At the <i>meso</i> level, healthcare institutions may find it difficult to prioritize telemedicine when financial sustainability is unclear, which could limit staff exposure and opportunities for practical learning.	H2_KE: Healthcare institutions operating under uncertain or narrowly scoped funding conditions are less likely to expose staff to telemedicine tools during the knowledge phase, limiting opportunities for experiential learning and organizational knowledge diffusion.
Knowledge	Economic		macro	At the macro level, reimbursement structures—such as narrowly defined billing codes—may not fully support broader implementation efforts, affecting system-wide engagement. Collectively, these conditions may reduce the perceived trialability and relative advantage of telemedicine, shaping the pace and reach of early diffusion.	H3_KE: Health systems with fragmented or narrowly defined reimbursement structures will demonstrate weaker system-level engagement with telemedicine during the knowledge phase, as economic misalignment undermines broad institutional commitment and early diffusion efforts.
Persuasion	Cultural	And unfortunately, there is a (...) in the established sector, in the larger sector, quantitatively speaking, which can be seen time and again when you read the German Medical Journal, where warning voices are repeatedly raised and then presented very prominently, so that ideally nothing much should change. But I think that's the general problem we humans are struggling with, that we simply can't afford to cling to what has worked well so far. (Int. 12, para. 22)	micro	Healthcare professionals may develop risk-averse attitudes shaped by long-standing norms and routine clinical practices. This cultural cautiousness can reduce openness to telemedicine, particularly when it is perceived as disruptive or unfamiliar, thereby slowing progression through the persuasion phase of innovation adoption.	H1_PC: Healthcare professionals with strong adherence to established clinical norms are less likely to form positive attitudes toward telemedicine during the persuasion phase, as cultural conservatism reduces openness to perceived disruptions in care routines.
Persuasion	Cultural		meso	Medical institutions and professional organizations may reinforce conservative attitudes through internal communications and editorial decisions. By repeatedly highlighting critical perspectives on telemedicine, these actors may maintain a status quo mindset that limits positive framing and weakens institutional support for innovation.	H2_PC: Healthcare organizations and professional bodies that emphasize critical or cautious narratives about telemedicine in their internal communications are less likely to foster positive staff attitudes during the persuasion phase, reinforcing resistance to innovation.
Persuasion	Cultural		macro	National publications, such as the German Medical Journal, may shape the broader discourse by emphasizing traditional or sceptical viewpoints. This can contribute to a wider cultural climate that validates hesitation among professionals and organizations, hindering favorable opinion formation during the persuasion phase.	H3_PC: In health systems where national medical media predominantly present conservative viewpoints on digital health, healthcare professionals and institutions are less likely to develop supportive attitudes toward telemedicine during the persuasion phase.
Persuasion	Organizational	But unfortunately, I see – and I don't want to paint a bleak picture – major obstacles in many areas of the established medical profession. On the other hand, it must be said that they are also constrained by all kinds of regulations and then say, 'Oh no, something new again.' (Int. 12, para. 23)	micro	Healthcare professionals operating under high workload conditions may perceive telemedicine as an added administrative burden or disruption to routine, reducing their openness to new technologies during the persuasion phase of adoption.	H1_PO: Healthcare professionals working within organizations that prioritize routine clinical practices over experimentation are less likely to develop favorable attitudes toward telemedicine during the persuasion phase, as organizational norms reduce openness to unfamiliar technologies.
Persuasion	Organizational		meso	Healthcare institutions with limited resources, competing priorities, or complex regulatory obligations may struggle to generate the organizational momentum needed to support telemedicine. This can reinforce hesitancy among staff and slow institutional engagement with innovation.	H2_PO: Healthcare institutions and professional bodies that regularly communicate critical or cautious views on telemedicine are less likely to foster positive staff attitudes during the persuasion phase, as organizational messaging reinforces resistance to change.
Persuasion	Organizational		macro	Fragmented governance structures and complex compliance requirements at the system level may indirectly encourage a	H3_PO: In healthcare systems where prominent national publications emphasize conservative viewpoints on

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Table 2 (continued)

DOI Stage	SST Factor	Anchor Quote	Level	Analytical Assumption	Hypothesis
				cautious approach to digital transformation, making broad organizational endorsement of telemedicine more difficult during the persuasion phase.	digital health, professionals and institutions are less likely to develop persuasive-level support for telemedicine adoption, due to the broader reinforcement of organizational skepticism.
Persuasion	Political	I believe that we have this dichotomy between inpatient care and private practices, which are subject to completely different regulatory bodies and have different lobbying interests. (Int. 12, para. 22)	micro	Clinicians across care settings face differing incentives and administrative demands, which may obscure telemedicine's practical benefits and reduce openness to change.	H1_PP: Clinicians operating under divergent administrative demands and incentive structures across care settings are less likely to form positive attitudes toward telemedicine during the persuasion phase, as inconsistent conditions reduce the perceived relevance and clarity of its benefits.
Persuasion	Political		meso	Fragmented regulatory environments complicate institutional coordination and undermine a shared vision for digital innovation, fostering organizational hesitation.	H2_PP: Healthcare institutions embedded in fragmented regulatory environments are less likely to engage in coordinated telemedicine strategies during the persuasion phase, as political complexity undermines organizational clarity and confidence in innovation alignment.
Persuasion	Political		macro	Dispersed political authority and competing stakeholder agendas limit unified policy messaging, weakening the broader narrative needed to build momentum for telemedicine adoption.	H3_PP: Health systems characterized by dispersed political authority and conflicting stakeholder agendas are less likely to develop a strong, unified narrative around telemedicine during the persuasion phase, reducing system-wide buy-in and slowing adoption momentum.
Persuasion	Economic	Since there is not really a need for it at the moment, and the market is very special in that patients, as customers, do not demand it in the same way as they would in the private market. (Int. 10_11, para. 8)	micro	When patients do not actively request telemedical services, clinicians may perceive them as less relevant or necessary, reducing motivation to engage or advocate for their use.	H1_PE: Clinicians who perceive low patient demand for telemedicine are less likely to form positive attitudes during the persuasion phase, as the absence of user-driven economic signals reduces their motivation to explore or advocate for adoption.
Persuasion	Economic		meso	Healthcare organizations facing resource constraints may deprioritize telemedicine without clear market signals or patient demand, viewing it as non-essential amid competing priorities.	H2_PE: Healthcare organizations that do not receive clear market or patient signals prioritizing telemedicine are less likely to allocate resources to its implementation during the persuasion phase, as economic uncertainty limits its strategic positioning.
Persuasion	Economic		macro	In publicly funded health systems, the absence of market-based dynamics can mute demand-driven incentives, slowing system-wide momentum for adoption despite potential efficiency benefits.	H3_PE: In publicly funded healthcare systems with limited exposure to market-based incentives, system-level engagement with telemedicine during the persuasion phase is less likely, as economic structures reduce the pressure to respond to evolving service expectations.
Decision	Cultural	So they're already complaining about the situation they're in, especially about what's being imposed on them in terms of digitalisation, in quotation marks, that somehow something political has to be done in order to exert pressure somewhere. (Int. 10_11, para. 24)	micro	Clinicians may perceive telemedicine as a top-down mandate misaligned with daily practice, leading to reluctance in actively supporting implementation.	H1_DC: Clinicians who perceive telemedicine initiatives as externally imposed and misaligned with daily practice routines are less likely to support or participate in telemedicine-related decision-making during the adoption process.
Decision	Cultural		meso	Organizations that adopt externally driven directives without local adaptation may limit staff engagement and weaken institutional ownership of innovation decisions.	H2_DC: Healthcare organizations that implement telemedicine based on top-down directives without contextual adaptation are less likely to achieve strong staff commitment during the decision phase, as limited local engagement weakens institutional ownership.
Decision	Cultural		macro	Cultural skepticism toward bureaucratic or technocratic change may lead policymakers and professional bodies to take a cautious stance, slowing decisive support for telemedicine.	H3_DC: In health systems characterized by cultural skepticism toward technocratic or bureaucratic reforms, policymakers and professional associations are less likely to endorse telemedicine decisively during the decision phase, slowing formal adoption.
Decision	Organizational	So it really must be accompanied by simplification, (...) because the biggest problem we have is when digitisation suddenly leads to extra work because it has been poorly structured. (Int. 12, para. 23)	micro	Clinicians may hesitate to commit when digital tools disrupt workflows or increase administrative burden, lowering perceived usability and delaying clear decisions.	H1_DO: Clinicians who experience digital tools as disruptive to established workflows or administratively burdensome are less likely to make affirmative adoption decisions during the decision phase, due to reduced perceived usability and organizational fit.

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Table 2 (continued)

DOI Stage	SST Factor	Anchor Quote	Level	Analytical Assumption	Hypothesis
Decision	Organizational		meso	Healthcare organizations that cannot align digitalisation efforts with existing routines or capacities may face reduced staff buy-in, weakening institutional readiness for adoption.	H2_DO: Healthcare organizations that are unable to align digitalisation efforts with existing routines, resource structures, or staff capabilities are less likely to reach strong internal adoption decisions during the decision phase.
Decision	Organizational		macro	Without supportive, interoperable policy frameworks, system-level uncertainty may trickle down, leaving local actors cautious and slowing adoption decisions.	H3_DO: In healthcare systems lacking coherent, interoperable policy frameworks, decision-making around telemedicine adoption is more likely to be delayed or fragmented at the local level, as organizational actors face system-level uncertainty.
Decision	Political	So there has to be a bit of political will, even when it comes to bringing different groups of stakeholders to the table, because then you end up with the same old fronts facing each other in the committees. (Int. 10_11, para 24)	micro	Unclear or inconsistent political signals may leave individual clinicians uncertain about how to engage in adoption decisions, weakening confidence and slowing commitment.	H1_DP: Clinicians exposed to unclear or inconsistent political guidance are less likely to engage confidently in telemedicine-related decisions during the adoption process, as political ambiguity undermines trust and commitment in the decision phase.
Decision	Political		meso	Fragmented governance and competing institutional mandates may hinder inter-organizational dialogue, making collaborative decision-making difficult—even when readiness exists.	H2_DP: Healthcare organizations operating under fragmented governance or competing mandates are less likely to engage in coordinated decision-making on telemedicine adoption, even when technically ready, due to reduced political coherence and inter-organizational alignment.
Decision	Political		macro	Inconsistent or uncoordinated policy direction can prolong national-level deliberation and dilute strategic momentum, delaying system-wide commitment to telemedicine.	H3_DP: In health systems with inconsistent or uncoordinated policy direction, national decision-making bodies are less likely to reach timely, system-wide commitments to telemedicine adoption, as strategic focus is diluted during the decision phase.
Decision	Economic	So, if you take the example of telemonitoring to enable patients to be discharged, you will not be credited for this as a hospital. You will only be credited for the time the patient spends in your hospital, not for the time they spend at home. (Int. 6, para. 28)	micro	Clinicians may be less inclined to support or adopt telemonitoring when their efforts are not matched by financial recognition, weakening individual commitment in the decision phase.	H1_DE: Clinicians who perceive telemonitoring as inadequately reimbursed are less likely to make affirmative adoption decisions during the decision phase, as the absence of financial recognition reduces motivation to engage.
Decision	Economic		meso	Hospital administrators may deprioritize telemonitoring investments when reimbursement mechanisms are unclear, favoring services with predictable financial returns.	H2_DE: Healthcare organizations lacking clear reimbursement pathways for telemonitoring are less likely to invest in digital infrastructure during the decision phase, as uncertain economic return lowers the perceived strategic priority of adoption.
Decision	Economic		macro	Reimbursement and funding policies that reinforce traditional care models may make digital health strategies economically unattractive, slowing broader institutional decisions in favor of telemonitoring.	H3_DE: Health systems with reimbursement structures that primarily support traditional care models are less likely to generate system-wide decisions in favor of telemonitoring during the decision phase, as economic frameworks disincentivize innovation.
Implementation	Cultural	The technology has to adapt, moving away from connectors, card readers and so on, as these are no longer in line with the reality of care provision. (Int. 10_11, para. 48)	micro	Healthcare professionals may be less inclined to adopt new tools when outdated systems disrupt daily workflows, creating frustration and reducing engagement.	H1_IC: Healthcare professionals who experience digital tools as misaligned with daily workflows are less likely to actively engage in implementation efforts, as cultural expectations for functional efficiency reduce tolerance for disruptive technologies.
Implementation	Cultural		meso	Organizations may resist embedding innovations if implementation strategies conflict with established routines or staff capacities, as cultural norms emphasize reliability over change.	H2_IC: Healthcare organizations with strong adherence to routine-based operational cultures are less likely to successfully implement digital innovations when those innovations challenge existing workflows or staff capacities
Implementation	Cultural		macro	Reliance on legacy standards and governance frameworks may reflect a systemic preference for stability, limiting responsiveness to emerging digital innovations.	H3_IC: Health systems that rely heavily on legacy technological standards and stable governance frameworks are less likely to support the timely implementation of novel digital solutions, as cultural preferences for continuity slow institutional adaptation.

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Table 2 (continued)

DOI Stage	SST Factor	Anchor Quote	Level	Analytical Assumption	Hypothesis
Implementation	Organizational	But the fact that the daily routine of doctors and nurses in hospitals, and also that of doctors in private practice, is so tightly scheduled that any external disruption, and that is ultimately what telemedicine is, is a huge challenge. (Int. 10_11, para 42)	micro	Clinicians working within tightly scheduled routines may view telemedicine as an added burden, making it difficult to integrate into daily workflows.	H1_IO: Clinicians working under tightly scheduled workflows are less likely to implement telemedicine tools, as organizational time constraints reduce their capacity to integrate new routines during the implementation phase.
Implementation	Organizational		meso	Healthcare organizations may lack the flexibility and planning capacity to align new digital tools with existing responsibilities, creating friction during implementation.	H2_IO: Healthcare organizations with limited flexibility in staffing and operational planning are less likely to successfully implement telemedicine, as structural misalignment creates barriers during the implementation phase.
Implementation	Organizational		macro	System-level policies that emphasize standardization over adaptability may hinder alignment between innovation initiatives and the complex realities of service delivery.	H3_IO: Health systems governed by policy frameworks that prioritize standardization over contextual adaptability are less likely to achieve effective telemedicine implementation, as organizational misfit delays or derails integration efforts.
Implementation	Political	The last 20 years have shown that the market does not necessarily regulate itself. (Int. 10_11, para 25)	micro	Clinicians and administrators may lack motivation or confidence to implement telemedicine in the absence of clear policy backing, making adoption harder to justify in local practice settings.	H1_IP: Clinicians and administrators who perceive a lack of clear policy support are less likely to engage in telemedicine implementation efforts, as political ambiguity reduces local confidence and perceived legitimacy during the implementation phase.
Implementation	Political		meso	Healthcare organizations often rely on external legitimacy—such as mandates or incentives—to prioritize telemedicine amid competing demands, using political signals to guide internal alignment.	H2_IP: Healthcare organizations are less likely to prioritize telemedicine implementation in the absence of political signals such as legislative mandates or financial incentives, as these mechanisms provide external legitimacy and guide resource alignment.
Implementation	Political		macro	Without coordinated governance and policy coherence, national strategies for telemedicine lack the direction and equity needed for consistent, system-wide implementation.	H3_IP: Health systems lacking coordinated governance and policy coherence are less likely to achieve consistent and equitable telemedicine implementation, as the absence of strategic direction impedes system-wide alignment during the implementation phase.
Implementation	Economic	Of course, there are also various other issues, including administrative matters such as procurement in the public sector and contract awarding, i.e. barriers that are now purely pragmatic in terms of implementation. When it comes to implementation beyond a research project, there are naturally very significant barriers. (Int. 10_11, para. 8)	micro	Clinicians working with outdated or inadequate tools may experience frustration and reduced engagement, especially when resource constraints add to daily pressures, weakening support for new systems.	H1_IE: Clinicians who work with outdated or insufficient digital tools are less likely to support the implementation of new telemedicine systems, as resource-related frustration undermines engagement during the implementation phase.
Implementation	Economic		meso	Hospitals with limited budgets may struggle to translate policy goals into lasting change, facing delays in procurement, restricted training capacity, and fragmented implementation.	H2_IE: Hospitals operating under financial constraints are less likely to achieve coherent telemedicine implementation, as limited budgets delay procurement, reduce staff training, and fragment execution efforts.
Implementation	Economic		macro	National initiatives like the Hospital Future Act, while politically significant, may be perceived as underfunded relative to the scale of systemic digital transformation, limiting infrastructure development.	H3_IE: Health systems that allocate insufficient funding relative to the scope of digital transformation are less likely to develop robust, interoperable infrastructure during the implementation phase, as underinvestment constrains systemic readiness.
Confirmation	Cultural	Yes, they've been developing it for a long time, and so far it doesn't work, so I remain sceptical. And the hurdles are high. And the electronic patient record, which is being hyped so much, is of course not intended for everyday use. Well, it's just a file on a computer where they save PDFs. (Int. 4, para. 29)	micro	When digital tools are seen as misaligned with clinical workflows or offering limited practical value, individual engagement may decline, reducing confidence in their utility.	H1_CC: Healthcare professionals who perceive digital tools as poorly aligned with clinical workflows are less likely to confirm continued use, as perceived misfit reduces engagement and confidence during the confirmation stage.
Confirmation	Cultural		meso	Organizational uptake may be cautious if clinical teams remain unconvinced of a tool's relevance, slowing broader integration of supporting digital processes.	H2_CC: Healthcare organizations are less likely to fully institutionalize digital tools like the ePA when clinical teams remain culturally unconvinced of their value, delaying confirmation and broader integration of digital processes.

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Table 2 (continued)

DOI Stage	SST Factor	Anchor Quote	Level	Analytical Assumption	Hypothesis
Confirmation	Cultural		macro	A disconnect between political narratives and real-world user experience can deepen skepticism, undermining public trust and system-wide confirmation of digital health initiatives.	H3_CC:Health systems that exhibit a disconnect between political promotion and clinical user experience are less likely to achieve widespread confirmation of digital tools, as cultural skepticism erodes public and institutional trust.
Confirmation	Organizational	The processes must be digitally transformed so that there are new procedures that were not possible before without telemedicine. And in the third step, users are not yet sufficiently trained. So we need more new training professions that are then also prepared to accept telemedicine or other digital tools, use them directly and then also think creatively about their own solutions. (Int. 9, para. 32)	micro	Ongoing training and support can build clinicians' confidence and competence, reinforcing commitment to digital tools and consolidating early positive experiences.	H1_CO:Clinicians who receive ongoing training and hands-on support are more likely to confirm continued use of telemedicine tools, as organizational investment in skill development reinforces confidence and sustained engagement.
Confirmation	Organizational		meso	Institutions that promote structured education, peer learning, and a culture of experimentation are more likely to normalize telemedicine as part of routine care.	H2_CO:Healthcare organizations that embed structured educational pathways, peer-learning mechanisms, and a culture of experimentation are more likely to confirm telemedicine integration, as these factors normalize digital workflows and support routine use.
Confirmation	Organizational		macro	Policy efforts that support new digital care roles and invest in long-term workforce development help align system goals with frontline realities, strengthening conditions for lasting adoption.	H3_CO:Health systems that promote new digital care roles and fund long-term workforce development are more likely to achieve system-wide confirmation of telemedicine, as aligned organizational structures support durable adoption.
Confirmation	Political	And I believe that politicians have a responsibility to promote and implement appropriate tenders or to set priorities, which is what Innofond is already doing. Of course, it is important that these projects do not simply come to nothing, but that they continue to be supported or that there is the possibility of follow-up funding so that, once certain conditions have been met, this model can be rolled out across a larger region. (Int. 9, para. 24)	micro	Clinicians rely on transparent communication and institutional support to maintain or reassess adoption decisions with confidence, especially when political backing fluctuates.	H1_CP:Clinicians are more likely to confirm continued use of telemedicine tools when institutional communication is transparent and political support is stable, as such clarity strengthens confidence in adoption decisions.
Confirmation	Political		meso	Organizations need stable funding and formal evaluation mechanisms to either integrate or responsibly phase out telemedicine tools based on outcomes, not ad hoc judgments.	H2_CP: Healthcare organizations with access to stable funding and structured evaluation processes are more likely to make evidence-based confirmation or rejection decisions about telemedicine tools, minimizing ad hoc or reactive choices.
Confirmation	Political		macro	Clear, data-driven policy frameworks support informed decisions about scaling, refining, or discontinuing innovations, reducing the influence of short-term political shifts.	H3_CP:Health systems guided by clear, data-driven policy frameworks are more likely to make consistent, strategic decisions about scaling or discontinuing telemedicine programs, as such frameworks buffer against short-term political shifts.
Confirmation	Economic	This must be a clearly recognised service, i.e. one that is rewarded in the remuneration system. This is already the case to some extent, but we certainly need to take a much more proactive approach to identifying the areas that need to be addressed directly. And not only when it becomes necessary, as is currently the case during the pandemic, when people are left scrambling to chase after their money and end up with nothing. In the outpatient sector, very few areas were actually named at the beginning of the pandemic in the EBM, which is basically the area that covers the fees for registered doctors, so there was no way to represent many areas. (Int. 8, para. 15)	micro	Practitioners and small practices may hesitate to invest further without clear, immediate financial returns, limiting continued use of telemedicine tools.	H1_CE: Practitioners and small practices that perceive low or delayed financial returns are less likely to confirm continued use of telemedicine tools, as economic uncertainty diminishes motivation to sustain adoption.
Confirmation	Economic		meso	Healthcare organizations, constrained by tight budgets and wary of upfront costs,	H2_CE:Healthcare organizations operating under budgetary constraints and high

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Table 2 (continued)

DOI Stage	SST Factor	Anchor Quote	Level	Analytical Assumption	Hypothesis
				may delay or scale back expansion decisions for digital health initiatives.	sensitivity to upfront costs are less likely to confirm and expand telemedicine initiatives, as limited financial flexibility impedes commitment during the confirmation phase.
Confirmation	Economic		macro	A lack of robust financial incentives and reimbursement policies can weaken system-wide confidence that early investments will be recovered, slowing institutional commitment and broader scaling.	H3_CE:Health systems lacking robust financial incentives and reimbursement structures are less likely to achieve system-wide confirmation of telemedicine, as uncertainty around cost recovery limits institutional willingness to scale digital innovations.

staff technological literacy (Lin et al., 2012), are critical for successful implementation. Furthermore, Lennon et al. (2017) emphasize that that diffusion is shaped by interactions across macro, meso, and micro levels, underscoring the need for a multi-tiered analytical lens.

In conclusion, the literature on health innovations highlights three central themes. Firstly, social and cognitive factors, such as the perceived usefulness of an innovation or support from colleagues, appear to have a subtle yet significant impact on clinicians’ willingness to adopt telemedicine. Second, professional social networks appear to contribute to the subtle formation of collective ‘technology identities’ (Evering et al., 2022; Liu et al., 2023; Tahsin et al., 2022; Ulucanlar et al., 2013). Secondly, communication and political dynamics appear to steer the diffusion process. A balanced interplay between top-down technology push and bottom-up user pull, modified by incentive and regulatory measures, as well as clear messaging, can influence the visibility and testability of innovations (Liang, 2012; Robinson et al., 2003; X. Zhang et al., 2015). Third, organizational and identity-related factors appear to influence implementation and long-term use. Institutional maturity, shaped by professional norms, leadership styles, and institutionalized routines, can facilitate or impede the transition from pilot projects to regular operation (Lin et al., 2012; Patel & Antonarakis, 2013; Ulucanlar et al., 2013). Overall, the review confirms that social, organizational, and technological factors are crucial in determining the adoption and dissemination of health innovations.

The following results were yielded by applying the identified literature to the seven steps of the Decision Matrix of Theory Borrowing by Hanafizadeh and Alipour (2024):

4.1.1. *Analysed theories in the context of implementation and diffusion research in healthcare*

In the context of innovation and implementation research in healthcare, several reviews of the theoretical frameworks in use have been published. One of the best-known works in this area is by Greenhalgh et al. (2004) which examines over 20 theoretical frameworks, with the Diffusion of Innovations (DOI) theory by Rogers’ being the most frequently utilized. While Rogers’ Diffusion of Innovations (DOI) theory focuses on the processes of adoption and diffusion, the Social Shaping of Technology (SST) approach emphasizes the influence of social, economic, cultural, and political factors on the development and implementation of technologies, highlighting the dynamic interplay between society and technology.

4.1.2. *Listing of most identified theories*

According to Greenhalgh et al. (2004), the most frequently cited theoretical approaches in healthcare innovation and implementation research include the Diffusion of Innovations (DOI) theory by Rogers (2003), as well as organizational change theories such as Kotter (2018). Additionally, socio-technical approaches play a prominent role - most notably the Actor-Network Theory (ANT) by Latour (2005), which conceptualizes innovation as emerging through relational networks of human and non-human actors, and the Social Shaping of Technology

(SST) framework developed by MacKenzie and Wajcman (1999) and further expanded by Williams and Edge (1996), which focuses on the institutional, political, and cultural construction of technologies. Another widely used framework is the Consolidated Framework for Implementation Research (CFIR), proposed by Damschroder et al. (2009), which synthesises implementation determinants across multiple domains, including the characteristics of the innovation, the inner and outer context, individual actors, and implementation processes. CFIR is particularly common in empirical implementation studies but has been critiqued for underemphasising interpretive and discursive processes.

4.1.3. *Justification for selection*

Within the field of telemedicine, Rogers’ Diffusion of Innovations (DOI) theory is widely recognised for elucidating the mechanisms underlying individual and organizational technology adoption. Its structured, stage-based logic provides a valuable lens for examining how innovations move from awareness to confirmation across healthcare settings. In contrast, the Social Shaping of Technology (SST) framework offers a complementary perspective by foregrounding how technologies are co-constructed through institutional norms, cultural values, and political contexts. By integrating DOI and SST, the present study aims to develop a comprehensive socio-technical perspective that captures both the temporal dynamics of adoption and the contextual conditions that shape diffusion across system levels. Alternative frameworks such as the Consolidated Framework for Implementation Research (CFIR) and Actor-Network Theory (ANT) were carefully considered but not selected as the primary theoretical foundations. While CFIR is a well-established tool for identifying implementation determinants - particularly at the meso level (Damschroder et al., 2009) - it lacks DOI’s temporal focus on stage-based adoption and does not offer SST’s interpretive sensitivity to legitimacy, meaning-making, or political discourse (Birken et al., 2017; Kirk et al., 2016). Similarly, ANT provides robust tools for mapping relational dynamics within socio-technical systems (Latour, 2005), but its ontological symmetry and primarily descriptive orientation are less suited to explaining structured adoption sequences or institutional resistance in regulated domains like healthcare (Greenhalgh & Stones, 2010). Therefore, the integration of DOI and SST offers a more analytically balanced framework for capturing both adoption pathways and the structural shaping conditions that influence innovation outcomes.

4.1.4. *Description of the general theoretical conceptualization*

The DOI theory proposes that innovations are typically introduced according to a discernible sequence, with key attributes such as relative advantage, compatibility, complexity, trialability, and observability playing a central role. Conversely, the SST perspective contends that technological developments cannot be examined in isolation; instead, they must be evaluated within a broader social framework that incorporates interdisciplinary and organizational influences.

4.1.5. *Description of theoretical assumptions and reasoning mechanisms*

DOI posits that innovations are disseminated through networks that

include opinion leaders, early adopters, and the broader population, with the diffusion process being evaluated using both quantitative and qualitative metrics. In contrast, SST argues that technological implementations are continually shaped by the interactions among various social actors. It investigates patterns of discourse and the intricate interdependencies between technology, organizational structures, and society. Both theoretical assumptions and reasoning mechanisms of DOI and SST support the description of innovation adoption and diffusion.

4.1.6. Description of the area of interest

The focus of the study is on digital telemedicine innovations and their spread in healthcare systems, using the example of Germany. The objective is to analyse how technological developments and social frameworks reciprocally influence each other, thereby providing a comprehensive explanation of innovation diffusion in this specific context.

Based on both our literature review and the integrative analysis arising from the application of the Decision Matrix for Theory Borrowing, the DOI and SST frameworks offer complementary yet distinct lenses on innovation diffusion in healthcare. DOI conceptualizes diffusion as a relatively linear process unfolding through discrete stages - knowledge, persuasion, decision, implementation, and confirmation - guided by quantifiable innovation attributes such as relative advantage and compatibility (Rogers, 2003). Its explanatory mechanism centers on categorizing actors (e.g., opinion leaders, early adopters, the majority) and tracking diffusion via measurable metrics (Liang, 2012; Lund et al., 2016), whereas SST argues that technological change is fundamentally situated within complex social, organizational, and cultural milieus (MacKenzie & Wajcman, 1999; Williams & Edge, 1996). Together, these approaches seem to offer comprehensive frameworks that could enhance understanding of the measurable progression of innovation adoption and diffusion, as well as the nuanced, context-specific factors that influence technological change in healthcare.

4.2. SST content analysis

The transcript analysis identified 194 coded segments across ten interviews, using both deductive and inductive approaches to capture social-shaping determinants. These segments were allocated to four primary domains—cultural (n = 93), organizational (n = 42), political (n = 41) and economic (n = 18) - to examine their relevance to adoption and diffusion processes.

Among these, the cultural domain was most prevalent, comprising 93 segments distributed over 15 subcategories (Fig. 1). The

organizational domain accounted for 42 segments across five subcategories (Fig. 2), the political domain comprised 41 segments in seven subcategories (Fig. 3), and the economic domain included 18 segments within three subcategories (Fig. 4). Subsequent sections present detailed descriptions of each subcategory. Fig. 5 presents an overview of all primary domains and their respective subcategories (see Fig. 5).

4.2.1. Social shaping factors “cultural”

The social factors described in the superordinate category ‘cultural’ pertain to the perceived cultural influences on the implementation of telemedicine. The most frequently mentioned aspects in this category can be summarized under the term ‘mindset’. The subcategory captures statements referring to individual and collective attitudes toward digital innovation in healthcare, particularly telemedicine. This subcategory was frequently coded across interviews and forms a core component of the superordinate category cultural. Respondents described the mindset of stakeholders as a critical factor influencing adoption dynamics, often framing it as either an enabler or a barrier to change.

Multiple interviewees noted a general reluctance or cautious attitude among healthcare professionals and institutions when confronted with technological innovations. For example, one respondent remarked: “Well, the very first thing, I think, is the mindset of those affected. In Germany, we have a very critical attitude towards technical innovation in this area.” (Int. 12, para. 16). This view was echoed through additional references to “shyness” (Int. 8, para. 28), “voices of warning” (Int. 12, para. 22), and “doomsaying” (Int. 12, para. 23), suggesting recurring expressions of skepticism or hesitancy. Respondents also highlighted a perceived inconsistency between the openness to digital technologies in everyday life and the more reserved stance within healthcare contexts.

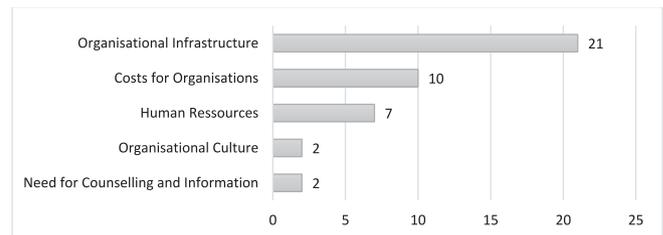


Fig. 2. Distribution of subcodes within the main category “Organizational”. “Organizational infrastructure” was the most frequently coded subcategory, followed by “costs for organisations” and “human resources”. “Organizational culture” and “need for counselling and information” were mentioned only rarely.

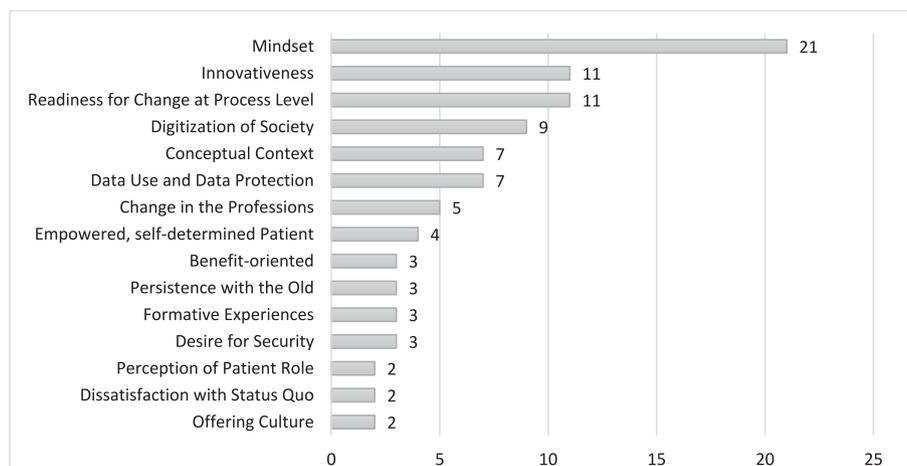


Fig. 1. Distribution of subcodes within the main category “Cultural”. “Mindset” was the most frequently coded subcategory, followed by “innovativeness” and “readiness for change at the process level”. Less frequently mentioned were aspects such as “offering culture”, “dissatisfaction with the status quo”, and “perception of the patient role”.

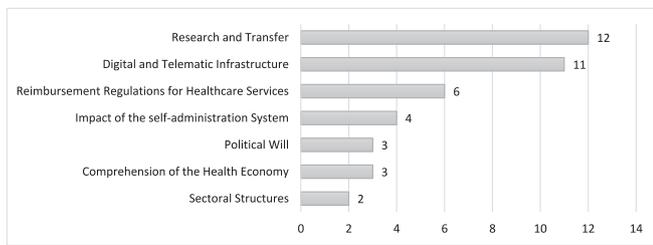


Fig. 3. Distribution of subcodes within the main category “Political”. “Research and transfer” and “digital and telematic infrastructure” were the most frequently coded subcategories, while “sectoral structures” and “comprehension of the health economy” were mentioned least.

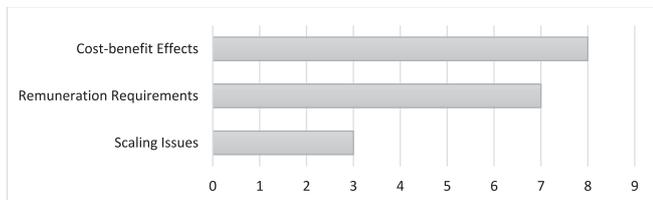


Fig. 4. Distribution of subcodes within the main category “Economic”. “Cost-benefit effects” and “remuneration requirements” were the most frequently mentioned subcategories, while “scaling issues” were referenced less often.

This was described as a paradox by several participants (e.g., Int. 4, paras. 8 + 23), where individuals who actively use smartphones, online services, and digital communication tools display resistance when such tools are introduced in medical settings. The mindset theme further included reflections on institutional inertia and a preference for established routines. While some respondents pointed to a slowly growing

openness to innovation, others emphasized the persistent dominance of risk-averse thinking within healthcare organizations. Across interviews, the mindset was not described as static but as influenced by role, context, and exposure to digitalization processes. Overall, the subcategory mindset aggregates a broad spectrum of internal orientations—ranging from caution and resistance to cautious optimism—highlighted by respondents as a key cultural influence on the implementation of telemedicine.

The category ‘innovativeness’ captures aspects of the perceived innovativeness of telemedicine solutions within the healthcare context. Respondents highlighted innovative ‘ideas’ (Int. 10_11, para. 13) and ‘pioneers’ (Int. 10_11, para. 24) alongside changes within existing professional groups involved in telemedicine development (Int. 6, para. 26; Int. 8, para. 7; Int. 2, para. 5).

The category ‘willingness to change at the process level’ includes statements that reflects the readiness to modify processes. These statements highlight both the critical perception of necessary process changes due to digitalisation (Int. 9, para. 32; Int. 10_11, para. 42) and the desire to transition from processes that are technology-driven to those that allow technology to adapt to existing processes (Int. 10_11, para. 48).

Additional cultural aspects were identified in the subcategories ‘digitalised society’ and ‘conceptual context’. These subcategories describe the interactive effect of various characteristics of the digital society on a digital healthcare system (Int. 2, para. 11; Int. 10_11, paras. 28 + 26), as well as the framing and meaning attributed to digital innovations such as telemedicine (Int. 13, para. 19; Int. 12, para. 27; Int. 3, para. 34). Other subcategories reflect the perceived peculiarities of data use and data protection within the German healthcare system, along with the transformation of healthcare professions. For instance, data protection is noted as a complex and sometimes challenging area of implementation (Int. 4, para. 16), and the transformation of healthcare professions is evidenced by the emergence of new professional groups

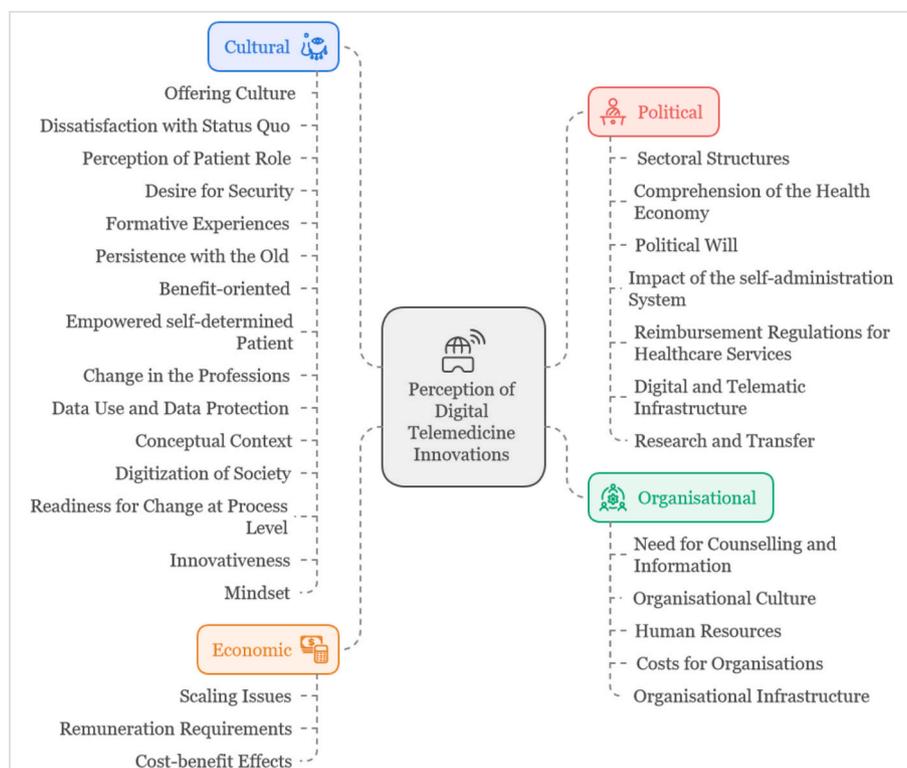


Fig. 5. Thematic network of potential social shaping determinants, illustrated through digital telemedicine innovations in the German healthcare system. The figure visualises how perceptions of digital telemedicine are shaped by the interplay of cultural, political, organizational, and economic factors. (Original depiction by the authors).

(Int. 2, para. 19). Additional social shaping factors in the cultural category were summarized in the subcategories ‘empowered, self-determined patient’ ($n = 4$), ‘benefit oriented’ ($n = 3$), ‘persistence of the old’ ($n = 3$), ‘formative experiences’ ($n = 3$), ‘desire for security’ ($n = 3$), ‘perception of the patient role’ ($n = 2$), ‘dissatisfaction with the status quo’ ($n = 2$), and ‘offering culture’ ($n = 2$). An overview of all subcodes of the main category ‘cultural’ can be found in Fig. 1.

The factors identified under the main category “cultural” reflect internal orientations that may shape the implementation of telemedicine - ranging from skepticism and institutional inertia to innovation readiness and interpretive reframing. These themes encompass both facilitating and inhibiting conditions for technology adoption and diffusion. In particular, *mindset* emerged as a **cross-cutting determinant** that influenced perceptions at the micro (individual), *meso* (organizational), and macro (societal-normative) levels, and across multiple DOI stages, including **knowledge, persuasion, and confirmation**.

These findings align with insights from the DOI analysis (Rauner & Stummer, 2024a, 2024b), where cultural framing - especially around data protection and professional identity - was identified as a key barrier or enabler to diffusion.

Importantly, *mindset* informed the construction of the **STAD-HC model** as a central socio-technical variable, particularly within the **cultural dimension** of the model. As such, it provides a theoretically and empirically grounded bridge between adoption behavior and institutional context, and is operationalised in multiple hypotheses across the DOI-SST matrix (e.g. H1_KC, H1_PC, H1_CC).

4.2.2. Social shaping factors “organizational”

The category ‘organizational’ captures factors that participants perceive as influencing the implementation of digital telemedical innovations at the organizational level. This category encompasses perceived needs, costs, infrastructures and cultures within organizations and comprises a total of 42 coded segments distributed across 5 subcategories.

The subcategory ‘organizational infrastructures’ was the most frequently mentioned, with 21 coded segments. It includes perceived needs for developing digital infrastructures within organizations (e.g. Int. 10_11, para. 29; Int. 2, para. 17; Int. 8, para. 36), as well as supporting infrastructures such as overarching telemedical centres to which organizations are connected (Int. 2, para. 5), and infrastructures for patients (e.g. Int. 9, para. 10; Int. 1, para. 16). This subcategory encompasses both **technical and structural components**. On the technical side, respondents referred to the necessity of **technical equipment**, including secure communication platforms, video consultation tools and electronic health records. On the structural side, participants highlighted the importance of **institutional support mechanisms**, such as access to IT support teams or standardized implementation protocols. The need for interoperability across systems and the availability of staff training opportunities were also frequently mentioned.

Additionally, participants mentioned the need to ‘rethink’ existing processes and structures, and to define responsibilities for this (Int. 9, para. 34), as illustrated by the following anchor quote:

“It is more about how to rethink the processes. And who is responsible for that? And there are certainly many different political factors at play. Who has sovereignty over the telemedicine centre? [...]” (Int. 9, para. 34).

Other factors are summarized under the subcategories ‘costs for organisations’ and ‘human resources’. These subcategories capture the multiple costs and impacts on organizations resulting from digital telemedical innovations, such as disruptions to existing workflows (Int. 10_11, para. 42; Int. 12, para. 23), insufficient remuneration (Int. 13, para. 20; Int. 12, para. 8; Int. 8, para. 15), and, in terms of human resources, a lack of personnel to support the implementation process (Int. 10_11, para. 40; Int. 12, para. 5; Int. 2, para. 33; Int. 3, para. 26). Furthermore, the need for low-threshold counselling and information services for organizations was also highlighted (e.g. Int. 1, para. 23). An

overview of all subcodes for the main category “organizational” can be found in Fig. 2.

The current findings of the “organizational” category align with the results of DOI analysis which identified organizational readiness, infrastructure development, and resource allocation as key factors influencing the adoption and diffusion of telemedicine innovations (Rauner & Stummer, 2024a, 2024b).

Importantly, *organizational infrastructure* emerged as a core meso-level determinant that influenced multiple DOI stages, particularly **decision-making and implementation**. Thematic recurrence across interviews revealed that infrastructural readiness was often perceived as the primary enabler or barrier to translating awareness and motivation into concrete action. These insights were directly incorporated into the **STAD-HC model**, where *organizational infrastructure* is conceptualized as a structural precondition for routinising telemedicine innovations. It is also reflected in several of the model’s derived hypotheses (e.g., H2_DO, H2_IO), which link infrastructure-related barriers to lower adoption likelihood and fragmented diffusion. As such, the theme is not only empirically salient but analytically central to the model’s logic and practical relevance.

4.2.3. Social shaping factors “political”

The category ‘political’ captures the political factors influencing the implementation of digital telemedicine innovations as perceived by the participants. A total of 41 text segments were coded in this category, divided into seven subcategories. The subcategories ‘research and transfer’ ($n = 12$) and ‘digital telematic infrastructure’ ($n = 11$) were most frequently mentioned. These subcategories include statements regarding the perceived responsibility of politics for research tenders (Int. 9, para. 24), research activities (Int. 4, para. 29) and implementation processes (Int. 9, para. 24). Additional subcategories address political accountability concerning ‘reimbursement regulations for healthcare services’ ($n = 6$), the ‘impact of self-administration system’ ($n = 4$) in the German healthcare system, the ‘political will’ ($n = 3$), the ‘comprehension of the health economy’ ($n = 3$) and ‘sectoral structures’ ($n = 2$). An overview of all subcodes of the main category “political” is provided in Fig. 3.

The present study’s political category, comprising 41 coded text segments across seven subcategories, aligns with the findings of the DOI analysis on the influence of political factors in the diffusion of digital telemedicine innovations (Rauner & Stummer, 2024b).

4.2.4. Social shaping factors “economic”

The category ‘Economic’ describes the perceived economic factors influencing the implementation of digital telemedical innovations. The category comprises a total of 18 text segments that were distributed into three subcategories (Fig. 4). These subcategories capture the perceived necessity of realizing ‘cost-benefit effects’ (Int. Int. 10_11, para. 10) through implementation along with associated ‘remuneration requirements’ (Int. 6, para. 28), which are expected to be achieved via ‘scaling effects’ (Int. 6, para. 29). These results align with the DOI analysis findings which identified economic concerns such as cost-benefit considerations and remuneration as key determinants in the adoption and diffusion of digital health innovations within the German healthcare system.

4.2.5. Thematic network of potential social shaping determinants

To consolidate the findings of the SST-based content analysis, a thematic network was developed to illustrate the potential interrelationships between the four socio-technical dimensions—cultural, organizational, political, and economic. As depicted in Fig. 5, each category comprises multiple subcodes that reflect how participants described influences on telemedicine implementation in the German healthcare system.

The visualization serves to highlight that these categories may not operate independently but appear to interact in ways that shape

perceptions, priorities, and barriers across stakeholder groups. For example, cultural attitudes toward innovation may intersect with organizational readiness or political decision-making, suggesting the presence of layered and potentially reinforcing dynamics. Rather than presenting isolated themes, the network aims to provide a more integrated view of how telemedicine-related challenges and enablers are interpreted by different actors. It also serves as a preliminary foundation for the DOI–SST matrix (Section 4.3), by structuring the social shaping factors that inform adoption processes across micro-, meso-, and macro levels.

4.3. Multi-level mapping of DOI stages and SST factors

The following section presents key findings from the DOI–SST matrix, combining empirical anchor quotes, analytical insights, and hypothesis development. For each DOI stage, dominant socio-technical factors (SST)—cultural, organizational, political, and economic—are examined at the micro, meso, and macro levels. Across all stages, these dimensions seem to shape the trajectory of telemedicine adoption and diffusion within the German healthcare system.

4.3.1. DOI stage knowledge

Findings from the knowledge phase reveal that the emergence and uptake of digital, telemedical innovations are shaped by a combination of cultural, organizational, political and economic conditions operating at all levels of the healthcare system. Barriers to awareness, information-seeking and initial perception of relevance seem to hinder the early progression of the innovation adoption process across these dimensions.

4.3.1.1. Cultural dynamics

“Well, the very first thing, I think, is the mindset of those affected. In Germany, we have a very critical attitude towards technical innovation in this area.” (Int. 12, para. 16)

This quote illustrates the influence of culturally embedded skepticism toward digital innovation within the healthcare system. Based on this anchor quote and its analytical interpretation, several cultural barriers were identified across levels. At the micro level, this skepticism is reflected in clinicians’ preference for analogue practices and reluctance to seek information about unfamiliar tools. From this, the authors derive H1_KC, proposing that individuals embedded in conservative professional cultures are less likely to progress into the knowledge phase due to reduced proactive engagement.

At the meso level, differences in digital maturity across affiliated organizations point to internal cultural heterogeneity. The analysis suggests that such divergence disrupts collective learning and institutional readiness, forming the basis for H2_KC.

At the macro level, broader societal narratives—centered on concerns such as surveillance or depersonalization—appear to influence public trust and political momentum, supporting H3_KC, which links societal skepticism to delayed policy engagement and early-stage investment.

4.3.1.2. Organizational infrastructure

“For example, a digital stethoscope, a high-resolution digital camera that can be used to photograph moles, and other technical devices. These are not yet available to us on a regular basis.” (Int. 9, para. 12).

Analytical insights based on the above mentioned anchor quote may highlight a lack of routine access to digital diagnostic tools, revealing structural barriers to early engagement. At the micro level, clinicians’ limited exposure may constrain their ability to assess innovation relevance, prompting H1_KO: insufficient institutional support undermines clinicians’ confidence and slows knowledge acquisition.

At the meso level, the absence of digital tools in everyday workflows suggests organizational inertia and a lack of prioritization, reinforcing H2_KO, which links weak integration with poor knowledge-sharing and innovation learning.

At the macro level, the analysis identifies systemic constraints - such as delayed regulatory approvals and fragmented funding - as key obstacles. These informed H3_KO, which posits that such misalignment impairs the legitimacy and spread of innovation in its early stages.

4.3.1.3. Political communication and policy signaling

“Certainly a lack of information. Information needs to be made accessible to doctors in some way. And the benefits need to be clearly demonstrated. Above all, the time benefits. Time is a huge issue: if time could be saved, that would be a huge advantage, or the financial benefits.” (Int. 1, para. 23).

From analysis of statements referencing “lack of information” and the need to clearly demonstrate benefits (Int. 1, para. 23), political communication was identified as a critical enabler - or barrier - to early-stage knowledge formation.

At the micro level, the absence of clear and targeted messaging was seen to inhibit clinicians’ understanding of telemedicine’s practical advantages, which grounds H1_KP.

At the meso level, organizational decision-making was reportedly hindered by vague or shifting political signals, forming the analytical basis for H2_KP, which links policy inconsistency to institutional inertia.

At the macro level, the broader absence of coordinated digital health policy was interpreted as weakening public trust and strategic alignment, giving rise to H3_KP, focused on how weak governance impairs collective progression into the knowledge phase.

4.3.1.4. Economic incentives and structural alignment

“General practitioners can bill a limited number of points for video consultations. Next year, there will probably be an OPS code for video consultations between intensive care units for very specific patient groups. At least, that is what the GBA has recommended.” (Int. 4, para. 16).

Based on responses regarding limited billing options and delayed reimbursement models (e.g., Int. 4), the analysis shows that financial misalignment shapes early-stage engagement across levels.

At the micro level, clinicians questioned the value of engaging with telemedicine in the absence of financial incentives. This interpretation supports H1_KE, which links low perceived return to weak motivation.

At the meso level, institutions operating under tight budgets were found to deprioritize telemedical investment and limit staff exposure, providing the rationale for H2_KE.

At the macro level, narrowly defined billing schemes and insufficient funding infrastructure were seen to slow systemic uptake. These findings underpin H3_KE, which associates economic fragmentation with limited early diffusion capacity.

The findings from the knowledge phase highlight how structural inertia, cultural skepticism, fragmented communication, and economic uncertainty converge to limit early engagement with digital health innovations across micro, meso, and macro levels. These conditions may restrict clinicians’ awareness, organizational preparedness, and system-wide momentum, ultimately delaying entry into the innovation process.

4.3.2. DOI stage persuasion

The analysis of the persuasion phase reveals that cultural norms, organizational structures, political fragmentation, and weak demand-driven signals shape how attitudes toward telemedical, digital health innovation are formed across the healthcare system. The following insights are based on qualitative data and have been analytically derived

by the authors to develop a series of multi-level hypotheses.

4.3.2.1. Cultural dynamics

“And unfortunately, there is a (...) in the established sector, in the larger sector, quantitatively speaking, which can be seen time and again when you read the German Medical Journal, where warning voices are repeatedly raised and then presented very prominently, so that ideally nothing much should change. But I think that’s the general problem we humans are struggling with, that we simply can’t afford to cling to what has worked well so far.”(Int. 12, para. 22).

Based on expressions of professional skepticism and references to conservative editorial narratives (e.g., in the German Medical Journal), the analysis suggests that cultural norms significantly influence openness to digital innovation. At the micro level, clinicians may adopt risk-averse attitudes rooted in long-standing clinical routines, reducing receptivity to innovations perceived as disruptive (H1_PC). At the meso level, institutions may reinforce such conservatism through internal messaging and editorial emphasis on risks rather than benefits (H2_PC). At the macro level, dominant public discourse characterized by cautious or traditional narratives may validate hesitation among professionals, thereby weakening favorable opinion formation during the persuasion stage (H3_PC).

4.3.2.2. Organizational structures

“But unfortunately, I see – and I don’t want to paint a bleak picture – major obstacles in many areas of the established medical profession. On the other hand, it must be said that they are also constrained by all kinds of regulations and then say, ‘Oh no, something new again.’” (Int. 12, para. 23)

Statements describing high workload and resistance to added administrative demands were interpreted to reflect organizational reluctance toward change. At the micro level, clinicians working in tightly regulated environments may perceive telemedicine as an added burden, inhibiting openness (H1_PO). At the meso level, limited institutional resources and regulatory complexity can reduce strategic prioritization of telehealth, reinforcing internal resistance (H2_PO). At the macro level, fragmented governance and procedural rigidity may limit system-wide encouragement for innovation, making broad organizational support more difficult to establish (H3_PO).

4.3.2.3. Political fragmentation and regulatory misalignment

“I believe that we have this dichotomy between inpatient care and private practices, which are subject to completely different regulatory bodies and have different lobbying interests.”(Int. 12, para. 22).

Participants highlighted differences in regulation between care sectors as a source of confusion and disengagement. At the micro level, inconsistent administrative structures and incentive schemes across inpatient and outpatient settings may reduce clinicians’ motivation to engage with telemedicine (H1_PP). At the meso level, regulatory fragmentation impairs cross-institutional coordination, fostering organizational hesitation (H2_PP). At the macro level, dispersed political authority and conflicting stakeholder interests may weaken the development of a unified narrative on telemedicine, thereby limiting strategic momentum and system-wide endorsement (H3_PP).

4.3.3. Economic signals and demand-side engagement

“Since there is not really a need for it at the moment, and the market is very special in that patients, as customers, do not demand it in the same way as they would in the private market.”(Int. 10_11, para. 8).

The analysis also points to the perceived absence of patient-driven demand as a barrier to forming positive attitudes toward telemedicine. At the micro level, when patients do not actively request digital services, clinicians may perceive them as unnecessary or irrelevant, reducing exploratory engagement (H1_PE). At the meso level, in the absence of clear market signals, organizations may deprioritize telehealth in favor of more financially predictable services (H2_PE). At the macro level, publicly funded systems without embedded market responsiveness may lack the structural incentives to encourage sustained innovation interest (H3_PE).

The analysis of the persuasion phase indicates that cultural conservatism, organizational rigidity, political fragmentation, and weak economic incentives may influence how healthcare professionals and institutions form attitudes toward telemedicine. Risk-averse professional norms, regulatory complexity, and limited patient-driven demand were identified as possible factors that reduce openness to innovation across micro, meso, and macro levels.

4.3.4. DOI stage decision

The analysis of the decision phase highlights how cultural expectations, organizational fit, political coherence, and economic viability shape commitment to telemedicine adoption across all levels of the healthcare system. The following hypotheses were analytically derived by the authors based on qualitative data, illustrating how structural and contextual factors influence actors’ willingness to support or formalize adoption decisions.

4.3.4.1. Cultural considerations

“So they’re already complaining about the situation they’re in, especially about what’s being imposed on them in terms of digitalisation, in quotation marks, that somehow something political has to be done in order to exert pressure somewhere.”(Int. 10_11, para. 24).

Based on participant reflections regarding externally imposed digitalization efforts, the analysis suggests that perceptions of top-down mandates affect decision-making. At the micro level, clinicians may view telemedicine as misaligned with clinical routines, reducing their willingness to actively support implementation (H1_DC). At the meso level, organizations that adopt externally driven strategies without contextual adaptation may struggle to build internal support and staff ownership (H2_DC). At the macro level, cultural skepticism toward technocratic reform may contribute to political hesitation and delay formal endorsement of telemedicine at the system level (H3_DC).

4.3.4.2. Organizational structures

“So it really must be accompanied by simplification, (...) because the biggest problem we have is when digitisation suddenly leads to extra work because it has been poorly structured.”(Int. 12, para. 23).

Interview statements pointing to increased workload from poorly integrated tools were interpreted to reflect structural misalignment in telemedicine implementation. At the micro level, clinicians may resist digital tools that disrupt established workflows, leading to reduced perceived usability and slower decision-making (H1_DO). At the meso level, organizational readiness is weakened when digital initiatives cannot be aligned with routines, capacities, or resources (H2_DO). At the macro level, a lack of interoperable policy frameworks was identified as a barrier to coordinated adoption, creating uncertainty for decision-makers at lower system levels (H3_DO).

4.3.4.3. Political environment

“So there has to be a bit of political will, even when it comes to bringing different groups of stakeholders to the table, because then

you end up with the same old fronts facing each other in the committees.” (Int. 10_11, para 24).

Participants described the difficulty of unifying stakeholders under fragmented political structures. At the micro level, inconsistent political signals may cause clinicians to feel uncertain about how and when to engage in decision processes (H1_DP). At the *meso* level, governance fragmentation and competing mandates inhibit inter-organizational coordination, complicating collective decision-making (H2_DP). At the macro level, the absence of a unified policy direction was linked to diluted strategic focus, limiting timely and consistent system-wide adoption (H3_DP).

4.3.4.4. Economic conditions

“So, if you take the example of telemonitoring to enable patients to be discharged, you will not be credited for this as a hospital. You will only be credited for the time the patient spends in your hospital, not for the time they spend at home.” (Int. 6, para. 28).

Economic disincentives were consistently mentioned as barriers to formalizing telemedicine adoption. At the micro level, clinicians may hesitate to support services like telemonitoring when reimbursement is unclear or lacking (H1_DE). At the *meso* level, hospitals may deprioritize telemedicine infrastructure due to uncertainty around economic returns (H2_DE). At the macro level, prevailing reimbursement models favoring traditional inpatient care were interpreted as discouraging systemic investment in digital innovations (H3_DE).

The analysis of the decision phase indicates that cultural perceptions, organizational conditions, political fragmentation, and economic misalignment influence whether telemedicine adoption is formalized across the healthcare system.

4.3.5. DOI stage implementation

The analysis of the implementation phase highlights how cultural norms, organizational capacity, political structures, and economic constraints shape the ability to integrate telemedicine into healthcare practice across micro, *meso*, and macro levels. The following hypotheses were analytically derived by the authors based on qualitative data, illustrating how these contextual conditions influence the transition from decision to operational use.

4.3.5.1. Cultural considerations

“The technology has to adapt, moving away from connectors, card readers and so on, as these are no longer in line with the reality of care provision.” (Int. 10_11, para. 48).

The analytical interpretation of participant responses suggests that cultural expectations for routine stability and technological reliability affect implementation. At the micro level, healthcare professionals may disengage from telemedicine when digital tools are perceived as misaligned with established workflows, particularly when outdated systems (e.g., connectors or card readers) introduce inefficiencies or frustration (H1_IC).

At the *meso* level, organizations may resist embedding digital innovations when implementation strategies disrupt established routines or exceed existing staff capacities. These conditions reflect cultural preferences for operational reliability and predictability, supporting H2_IC.

At the macro level, a broader reliance on legacy technologies and rigid governance structures was interpreted as indicating a systemic preference for continuity over change, limiting responsiveness to digital transformation efforts (H3_IC).

4.3.5.2. Organizational capacity

“But the fact that the daily routine of doctors and nurses in hospitals, and also that of doctors in private practice, is so tightly scheduled that any external disruption, and that is ultimately what telemedicine is, is a huge challenge.” (Int. 10_11, para 42).

The data highlight the role of organizational structure and resource planning in shaping implementation. At the micro level, clinicians working under tightly scheduled routines may find it difficult to integrate telemedicine into their daily workflows, perceiving it as an additional burden rather than a supportive tool (H1_IO).

At the *meso* level, institutions may lack the planning capacity, flexibility, or staffing structures needed to realign existing responsibilities to accommodate digital tools. This structural rigidity creates friction during implementation, providing the basis for H2_IO.

At the macro level, system-wide policy frameworks that emphasize standardization without allowing for contextual adaptability may reduce alignment between innovation goals and local service realities, as reflected in H3_IO.

4.3.5.3. Political structures

“The last 20 years have shown that the market does not necessarily regulate itself.” (Int. 10_11, para 25).

The analysis further indicates that the presence or absence of political support influences implementation momentum. At the micro level, clinicians and administrators may lack confidence in adopting telemedicine when political backing or regulatory clarity is missing. This uncertainty can diminish perceived legitimacy and hinder engagement (H1_IP).

At the *meso* level, healthcare organizations often look to external political signals—such as legislative mandates or funding mechanisms—to legitimize telemedicine and guide internal resource allocation (H2_IP).

At the macro level, inconsistent or uncoordinated governance was identified as a factor limiting strategic direction, which, in turn, reduces system-wide alignment and impedes consistent telemedicine implementation (H3_IP).

4.3.5.4. Economic constraints

“Of course, there are also various other issues, including administrative matters such as procurement in the public sector and contract awarding, i.e. barriers that are now purely pragmatic in terms of implementation. When it comes to implementation beyond a research project, there are naturally very significant barriers.” (Int. 10_11, para. 8).

Economic considerations were found to affect implementation efforts. At the micro level, clinicians may disengage from digital health initiatives when faced with outdated equipment or limited resources, especially when such conditions add pressure to already demanding routines (H1_IE).

At the *meso* level, hospitals operating under financial constraints may delay procurement, restrict staff training, or implement telemedicine in a piecemeal manner. These findings inform H2_IE, which links budget limitations to fragmented execution.

At the macro level, national funding programs such as the Hospital Future Act were interpreted as insufficient relative to the scale of digital transformation required, limiting the development of robust and interoperable infrastructure. This interpretation underlies H3_IE.

The implementation phase is shaped by the interaction of cultural expectations, organizational constraints, political structures, and economic conditions across all levels of the healthcare system.

4.3.6. DOI stage confirmation

The analysis of the confirmation phase demonstrates how cultural

alignment, organizational support, political stability, and economic assurance influence whether telemedicine tools are maintained, expanded, or abandoned following initial adoption. The following hypotheses were analytically derived by the authors based on qualitative data, reflecting how conditions across system levels affect the consolidation of digital health innovations in routine care.

4.3.6.1. Cultural considerations

“Yes, they’ve been developing it for a long time, and so far it doesn’t work, so I remain sceptical. And the hurdles are high. And the electronic patient record, which is being hyped so much, is of course not intended for everyday use. Well, it’s just a file on a computer where they save PDFs.”(Int. 4, para. 29).

Analytical interpretations of participant responses indicate that skepticism toward the clinical usefulness of tools such as the electronic patient record (ePA) shapes confirmation behavior. At the micro level, clinicians who perceive a misalignment between digital systems and daily practice are less likely to maintain their use (H1_CC). At the *meso* level, organizational reluctance was linked to a lack of perceived value among clinical teams, slowing broader institutional integration (H2_CC). At the macro level, discrepancies between political narratives and frontline experience were associated with reduced trust in digital health strategies (H3_CC).

4.3.6.2. Organizational support

“The processes must be digitally transformed so that there are new procedures that were not possible before without telemedicine. And in the third step, users are not yet sufficiently trained. So we need more new training professions that are then also prepared to accept telemedicine or other digital tools, use them directly and then also think creatively about their own solutions.”(Int. 9, para. 32).

Based on reflections about insufficient training and the need for new digital roles, the analysis shows that organizational investment is central to sustaining adoption. At the micro level, ongoing training and support were identified as factors reinforcing clinician confidence and continued use (H1_CO). At the *meso* level, organizations with structured education and a culture of experimentation were seen as more likely to normalize telemedicine in practice (H2_CO). At the macro level, system-level investment in new professional roles and long-term workforce development was analytically linked to stronger institutional alignment and durable confirmation (H3_CO).

4.3.6.3. Political stability

“And I believe that politicians have a responsibility to promote and implement appropriate tenders or to set priorities, which is what Innofond is already doing. Of course, it is important that these projects do not simply come to nothing, but that they continue to be supported or that there is the possibility of follow-up funding so that, once certain conditions have been met, this model can be rolled out across a larger region.”(Int. 9, para. 24).

Interview material reflecting concerns about policy continuity and support was interpreted to highlight the importance of stable governance. At the micro level, clinicians were more likely to confirm use when institutional messaging was transparent and political support remained consistent (H1_CP). At the *meso* level, organizations with access to reliable funding and evaluation mechanisms were seen as better positioned to make informed continuation or discontinuation decisions (H2_CP). At the macro level, policy frameworks that offer consistent and data-driven guidance were analytically associated with strategic clarity and system-wide implementation stability (H3_CP).

4.3.6.4. Economic viability

“This must be a clearly recognised service, i.e. one that is rewarded in the remuneration system. This is already the case to some extent, but we certainly need to take a much more proactive approach to identifying the areas that need to be addressed directly. And not only when it becomes necessary, as is currently the case during the pandemic, when people are left scrambling to chase after their money and end up with nothing. In the outpatient sector, very few areas were actually named at the beginning of the pandemic in the EBM, which is basically the area that covers the fees for registered doctors, so there was no way to represent many areas.”(Int. 8, para. 15).

Finally, financial considerations were found to shape confirmation behavior across all levels. At the micro level, practitioners and small practices were less inclined to sustain telemedicine use in the absence of clear, reliable financial returns (H1_CE). At the *meso* level, institutions with tight budgets and high sensitivity to upfront costs were less likely to invest in long-term expansion (H2_CE). At the macro level, underdeveloped reimbursement models and a lack of economic incentives were analytically associated with reduced commitment to scaling digital innovations (H3_CE).

The analysis of the confirmation phase suggests that the sustained use and institutionalization of telemedicine are influenced by cultural perceptions, organizational investment, political continuity, and economic viability.

4.4. Developed model – STAD-HC

This section presents the developed Socio-Technical Adoption and Diffusion Model for Healthcare (STAD-HC) based on the results of the SST-based content analysis and the DOI–SST matrix. The analysis shows that the implementation and spread of telemedicine in the German healthcare system are shaped by a complex interaction of socio-technical factors. These include cultural, organizational, political, and economic influences that affect not only adoption decisions but also longer-term integration outcomes across all stages of the innovation process.

The four key dimensions of SST - cultural, organizational, political, and economic - reflect different types of shaping forces. Cultural factors relate to attitudes, norms, and mindsets that may support or hinder innovation. Organizational factors include infrastructure, workflows, staffing, and internal capacities. Political influences refer to governance, policy consistency, and regulatory support, while economic factors concern cost expectations, funding models, and long-term financial viability. These categories do not operate in isolation; rather, they interact dynamically across levels and throughout the adoption trajectory.

The developed model incorporates the adoption stages of the Diffusion of Innovations (DOI) framework — knowledge, persuasion, decision, implementation and confirmation — and maps them across the micro, *meso* and macro levels of the healthcare system, in order to describe the phenomenon of innovation diffusion in healthcare systems. It builds on recent DOI findings (Rauner & Stummer, 2024a, 2024b) and helps to explain how digital innovations are perceived, adopted, and sustained in practice.

The following section outlines the key findings that informed this model, drawing on empirical quotes, analytical insights, and a set of derived hypotheses. Together, they illustrate how socio-technical factors shape the path of telemedicine adoption and diffusion across the system.

4.4.1. STAD-HC model description

This model, using the example of digital telemedical innovation, describes how such innovative technologies are introduced into a healthcare system composed of both individual actors and broader

social structures. At the micro level, individuals—such as clinicians or administrators—engage with the innovation through the stages described by Rogers' Diffusion of Innovations (DOI) theory: knowledge, persuasion, decision, implementation, and confirmation. These decisions are shaped by the perceived alignment between the innovation and individual needs, routines, and perceived problems. Resulting outcomes may include full adoption, partial use, reinvention (adaptation), confirmation, or rejection. At the level of social systems, innovations are evaluated in relation to institutional structures and operational demands. Meso-level actors, such as hospitals or care networks, assess how well a technology integrates with workflows and resource capacities. Macro-level systems, including national policy frameworks and funding mechanisms, consider whether innovations address broader system goals and constraints. Across all levels, adoption outcomes depend on how well the innovation fits the contextual realities of each actor group.

A central feature of the model is the communication of problems and solutions—both within and across micro, *meso*, and macro levels. These interactions shape how innovations are understood and acted upon, and are influenced by four key socio-technical dimensions: cultural, organizational, political, and economic. These dimensions are grounded in the social shaping of technology approach proposed by Williams and Edge (1996), which emphasizes that technological change is co-constructed through institutional, social, and material conditions rather than being solely technology-driven.

In this framework, individuals play a dual role: they are both decision-makers and embedded members of broader systems. Their adoption pathways may diverge from organizational strategies but also contribute to collective decisions through feedback and adaptation processes. Moreover, technologies are not static; through reinvention or local tailoring, they can be modified during use and re-enter the diffusion cycle as newly perceived innovations.

By combining the DOI framework with the socio-technical dimensions outlined by Williams and Edge, the model offers a dynamic and systemic view of innovation adoption and diffusion in healthcare. It reflects the recursive nature of technological change and highlights the importance of context, communication, and adaptation in shaping telemedicine integration.

4.4.2. Key findings informing the STAD-HC model

Findings across the five DOI stages reveal a consistent pattern in which the adoption and diffusion of telemedicine are shaped by a multi-level interaction of socio-technical factors. In the knowledge phase, early engagement was hindered by structural inertia, cultural skepticism, limited exposure, and fragmented political and economic support. At the individual level, clinicians working within analogue routines demonstrated reduced information-seeking (H1_KC–H1_KE). On the organizational level, weak integration of digital tools and budget constraints limited institutional readiness (H2_KO–H2_KE). At the system level, regulatory ambiguity, underfunded initiatives, and broader distrust in digital health technologies slowed the overall momentum (H3_KC–H3_KE).

During the persuasion phase, the development of supportive attitudes was shaped by cultural conservatism and hesitant communication. Professional skepticism and enduring narratives emphasizing risks over benefits decreased openness to innovation among clinicians (H1_PC), while institutional communication tended to reinforce traditional perspectives (H2_PC). At the macro level, cautious public discourse and lack of a clear narrative contributed to widespread hesitation (H3_PC). Additionally, structural and political complexity, along with weak patient demand, hindered the development of positive attitudes across levels (H1_PO–H3_PE).

In the decision phase, adoption was influenced by perceptions of top-down imposition, lack of visible benefits, and financial uncertainty. Clinicians were reluctant to commit when innovations were perceived as externally mandated or incompatible with existing routines (H1_DC, H1_DO). At the *meso* level, organizational actors struggled with decision-

making in the absence of local adaptation mechanisms or clear policy signals (H2_DC–H2_DP). On the macro level, misaligned financial incentives and fragmented regulatory environments further delayed the formal adoption of telemedicine (H3_DC–H3_DE).

The implementation phase highlighted the importance of practical integration into daily workflows. At the micro level, clinicians disengaged when digital tools disrupted established routines or were perceived as technically inadequate (H1_IC–H1_IE). Organizational limitations—such as insufficient planning capacity and lack of flexibility—posed significant barriers at the *meso* level (H2_IO). System-level responsiveness was constrained by underfunded infrastructure programs and rigid policy frameworks that did not allow for context-sensitive adaptation (H3_IC–H3_IE).

Finally, in the confirmation phase, sustained use and institutionalization of telemedicine depended on its perceived alignment with clinical workflows, adequate organizational support, policy continuity, and economic viability. Continued skepticism—particularly in relation to tools such as the electronic patient record (ePA)—led to disengagement when expected value was not realized (H1_CC). Stronger institutional commitment was observed in settings with structured training, peer learning mechanisms, and reliable funding (H2_CO–H2_CP). At the macro level, the continuation of telemedicine initiatives was linked to strategic policy frameworks, return-on-investment logic, and the integration of new digital care roles into long-term workforce planning (H3_CC–H3_CE).

Taken together, these findings inform the Socio-Technical Adoption and Diffusion Model for Healthcare (STAD-HC). The model integrates the DOI stages with key socio-technical determinants to offer a system-wide perspective on how telemedicine innovations are adopted, implemented, and sustained. By accounting for both individual and institutional dynamics, it captures the conditions under which innovation efforts succeed or stall. The model emphasizes the importance of communication, contextual alignment, and adaptive reinforcement throughout the diffusion process, providing practical guidance for the strategic design, implementation, and governance of digital health solutions.

4.4.3. STAD-HC model

The following figure (Fig. 6) presents the developed Socio-Technical Adoption and Diffusion Model for Healthcare (STAD-HC) based on the results of the SST-based content analysis and the DOI–SST matrix.

5. Discussion

5.1. Overview and conceptual framing

This study examines the adoption and diffusion of telemedical innovations in the German healthcare system through an integrated socio-technical framework. The Socio-Technical Adoption and Diffusion Model for Healthcare (STAD-HC) was developed by combining theoretical insights from Rogers' Diffusion of Innovations (DOI) framework (Rogers, 2003) with the Social Shaping of Technology (SST) approach (MacKenzie & Wajcman, 1999; Williams & Edge, 1996). The model systematically maps the five DOI stages—knowledge, persuasion, decision, implementation, and confirmation—onto four socio-technical shaping dimensions: cultural, organizational, political, and economic, each considered across micro, *meso*, and macro levels of the healthcare system.

The shaping dimensions are grounded in the SST tradition, which conceptualizes technology as socially embedded and co-constructed through interpretive, institutional, and political processes (Bijker, 1997; MacKenzie & Wajcman, 1999; Williams & Edge, 1996). These dimensions capture how contextual conditions, values, and institutional structures shape the perception, evaluation, and evolution of technological innovations.

The results of the theory review - based on the Decision Matrix of

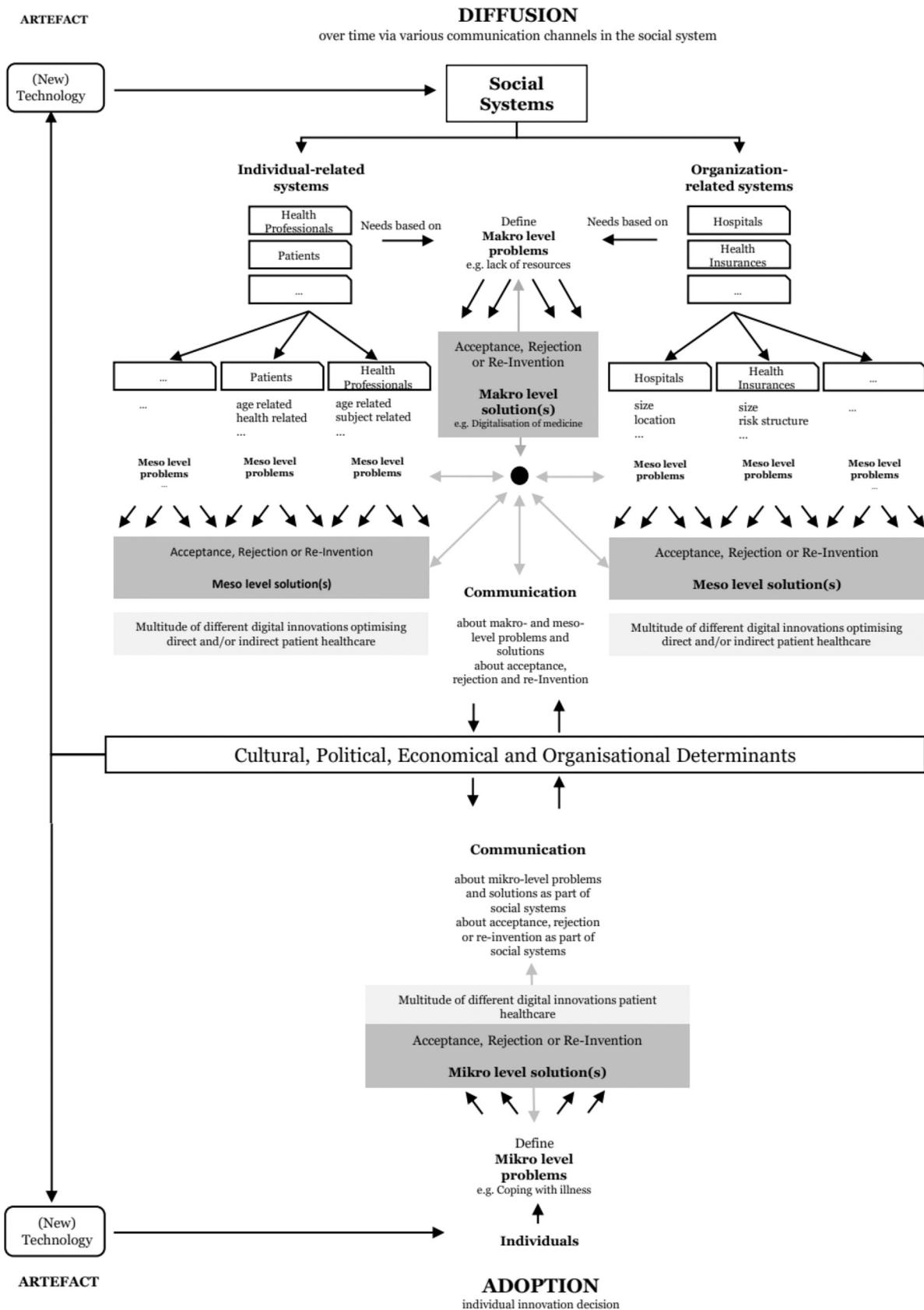


Fig. 6. Socio-technical adoption and diffusion model for healthcare (STAD-HC). The figure illustrates how the adoption and diffusion of digital health technologies are shaped by interactions between individual- and organization-related systems, mediated by micro-, meso-, and macro-level dynamics, and influenced by cultural, political, economic, and organizational determinants within broader social systems. (Original depiction by the authors).

Theory Borrowing by Hanafizadeh and Alipour (2024) - and the exploratory literature review indicate that integrating DOI and SST enables a more holistic understanding of innovation diffusion in healthcare. While DOI provides a structured, sequential view of individual adoption processes, SST contributes an interpretive lens that emphasizes the influence of socio-political, cultural, and organizational dynamics on system-level outcomes (refer to chapter 4.1, *sec. Justification for selection, Description of the General Theoretical Conceptualization and Description of theoretical assumptions and reasoning mechanisms*).

Findings from the transcript analysis show that telemedicine adoption is neither linear nor solely technology-driven. Instead, adoption and diffusion processes unfold through a complex interplay of cultural mindsets, organizational readiness, regulatory clarity, and financial feasibility. Across all DOI stages, barriers such as cultural skepticism, fragmented communication, policy inconsistency, and limited economic incentives were identified at multiple system levels. These findings are consistent with earlier research that critiques overly linear innovation models and supports the development of more context-sensitive, multi-actor frameworks (Cresswell & Sheikh, 2013; Greenhalgh et al., 2004; Lyytinen & Newman, 2008).

The hypotheses derived through the DOI-SST mapping are informed by systematic qualitative analysis and show strong resonance with the empirical data. The interview transcripts reflect recurring themes that align with the analytically constructed hypotheses, suggesting a high degree of consistency between theoretical assumptions and stakeholder perspectives. This correspondence indicates that the STAD-HC model offers a promising framework for capturing the multi-level and socially embedded nature of innovation processes in healthcare.

By embedding the structured stages of DOI within the socio-contextual sensitivity of SST, the STAD-HC model offers a comprehensive analytical framework for examining how telemedical innovations are interpreted, adopted, and institutionalized across complex healthcare environments. The following sections expand upon the model's theoretical contributions, empirical grounding, and implications for future research and implementation practice.

5.2. Discussion of SST-content analysis and DOI-SST mapping

The results of the SST-based content analysis, in combination with the DOI-SST mapping, highlight that the adoption and diffusion of digital telehealth innovations are influenced by a complex interplay of socio-technical factors. These include cultural attitudes, organizational capacities, political environments, and economic conditions, all of which intersect across micro, *meso*, and macro levels of the healthcare system. The proposed Socio-Technical Adoption and Diffusion Model for Healthcare (STAD-HC) conceptualizes diffusion as a multi-level process, in which new technologies are assessed, adopted, confirmed or rejected depending on their perceived fit with needs, routines, and structural conditions at each level.

At the micro level, adoption is understood as a staged process consistent with Rogers' Diffusion of Innovations (DOI) framework (Rogers, 2003), involving knowledge, persuasion, decision-making, implementation, and confirmation. Numerous studies support this sequential logic (Greenhalgh et al., 2004; Mohammadi, Poursaberi, & Salahshoor, 2018), though deviations are common in practice (Dearing, 2009). The STAD-HC model builds on this foundation while integrating the insights of Social Shaping of Technology (SST), which posits that technology is not adopted in isolation but co-constructed within specific institutional, political, and cultural contexts (MacKenzie & Wajcman, 1999; Williams & Edge, 1996). To reflect these dynamics in our sample, we ensured professional diversity across medical, technical, and hybrid roles. As shown in Table 1 (Participant Overview), the dataset includes clinicians (e.g., internal medicine, anaesthesiology), health economists, digital infrastructure consultants, and telemedicine managers. This allowed for comparative analysis of SST dimensions - particularly cultural and organizational factors - across stakeholder groups.

At the *meso* level, organizational routines, team structures, and managerial priorities mediate the translation of individual attitudes into collective action. This level has been identified as critical in shaping whether innovations are institutionalized or obstructed (Lennon et al., 2017; X. Zhang et al., 2015). The model positions the *meso* level as a bridge between personal decisions and systemic adoption, capturing how leadership, interprofessional collaboration, and infrastructural readiness enable or constrain implementation.

At the macro level, broader institutional dynamics—such as regulatory frameworks, funding models, and political discourse - shape the systemic legitimacy and sustainability of digital innovations (Acemoglu & Robinson, 2021; Robinson et al., 2003). Technologies are legitimized or contested in this domain through public narratives and policy processes, which influence whether innovations are scaled, modified, or abandoned.

This three-tiered conceptualization aligns closely with SST's social constructionist view, which emphasizes that technologies are negotiated, contested, and redefined within dynamic sociocultural environments (Ulucanlar et al., 2013). The integration of SST with DOI enables a multi-dimensional perspective that links structured adoption stages to the socio-political and institutional realities of healthcare.

Recent digital health advancements - such as IoT-based monitoring systems, blockchain for data interoperability, and contactless services - further demonstrate the relevance of this integrated framework. For instance, user acceptance of IoT technologies has been shown to depend on task-technology fit and perceived usefulness at the micro level (Alkhwaldi, 2022), while blockchain adoption relies on trust, governance alignment, and infrastructure at the *meso* and macro levels (Dbesan, Abdulmuhsin, & Alkhwaldi, 2025). Similarly, the uptake of contactless services, particularly during the COVID-19 pandemic, has been driven by patient trust, institutional communication, and perceived safety - highlighting the relevance of cultural and political communication for implementation (Alkhwaldi, 2022). However, many of these studies focus on selected determinants and levels in isolation. In contrast, the STAD-HC model provides a more comprehensive conceptual tool to understand the full spectrum of sociotechnical conditions shaping innovation outcomes. By integrating cultural, organizational, political, and economic dimensions across micro-, *meso*-, and macro-levels, the model offers a structured yet flexible framework for examining how emerging technologies like IoT and blockchain are adopted, adapted, or contested within complex health systems. Future research could benefit from applying this model to investigate interdependencies across system levels and identify alignment gaps that may otherwise remain unobserved.

While these technologies were not central to the interviews - due to their limited implementation in the German healthcare context - some participants described IoT as "novel" or "not yet relevant," pointing to an important future research opportunity. The STAD-HC model offers a conceptual foundation to investigate how such innovations may be embedded, reframed, or resisted across different system levels.

To further delineate the model's theoretical position, it is important to reflect on alternative frameworks that were considered but not adopted. The Consolidated Framework for Implementation Research (CFIR) (Damschroder et al., 2009) is well established for identifying implementation barriers and facilitators, particularly at the *meso* level. However, CFIR does not sufficiently capture interpretive, discursive, and political dynamics, especially those shaping legitimacy and public trust. While Actor-Network Theory (ANT) (Latour, 2005) offers valuable tools for mapping relationships among heterogeneous actors, it places comparatively less emphasis on institutional norms, power asymmetries, and value-laden decision environments - factors that are particularly relevant in the context of health innovation. SST, by contrast, offers a theoretically grounded lens to explore how technologies are shaped and legitimized through institutional narratives, normative frameworks, and political authority (MacKenzie & Wajcman, 1999). The STAD-HC model bridges these perspectives by combining DOI's structured stage logic

with SST's contextual and interpretive depth. This integration enables a layered, multi-level understanding of how digital health technologies emerge, evolve, and are embedded within healthcare systems. However, it also presents conceptual challenges. While DOI assumes linear, rational progression, SST reveals how adoption trajectories are often non-linear, contested, and shaped by resistance, institutional inertia, and power asymmetries (Lyytinen & Newman, 2008). From the perspective of network theory, the STAD-HC model aligns with research suggesting that innovation diffusion is not the result of isolated decisions, but of interactions within dynamic, interdependent networks (Burt et al., 2012). Healthcare systems can be understood as multi-level networks, in which communication flow, actor centrality, and relationship quality determine whether innovations are coordinated or fragmented (Borgatti & Foster, 2003). In this context, missing or misaligned ties between key stakeholders - such as policymakers, clinicians, and IT units - can delay feedback loops, impede shared learning, and hinder coherent implementation. These insights underscore the need to incorporate network structures, communicative density, and strategic alignment into the study of socio-technical diffusion (Klijn & Koppenjan, 2016).

In sum, the STAD-HC model integrates the strengths of DOI and SST, further enriched by insights from network theory, to offer a context-sensitive, multi-level analytical framework for understanding digital innovation in healthcare. By linking individual behavior, organizational structures, and systemic governance with cultural narratives and political legitimacy, the model captures the multi-layered nature of telemedicine adoption and diffusion. While the framework offers significant explanatory power, it also invites empirical validation - particularly concerning conflicting stakeholder interests, governance misalignments, and variation across innovation types. As such, the STAD-HC model serves both as an analytical foundation and a heuristic device for guiding future research and policy design in digital health transformation.

5.3. Theoretical contributions and implications

The Socio-Technical Adoption and Diffusion Model for Healthcare (STAD-HC) offers several key theoretical contributions by integrating the structured, stage-based logic of Diffusion of Innovations (DOI) with the contextual sensitivity of the Social Shaping of Technology (SST) approach. While previous frameworks have contributed significantly to understanding specific dimensions of innovation adoption - such as organizational readiness (CFIR - (Damschroder et al., 2009)) or networked actor relations (ANT - (Latour, 2005)) - they often emphasize either process or context, but not both. The STAD-HC model bridges this gap by providing a holistic, multi-level perspective that captures the interdependencies between actors, institutions, and systemic structures across the entire innovation lifecycle.

One of the model's primary contributions is its ability to integrate stage-based adoption logic with multi-dimensional shaping conditions, thereby offering a nuanced lens through which to understand how digital health innovations are interpreted, negotiated, and institutionalized. By linking each DOI stage (knowledge, persuasion, decision, implementation, confirmation) with SST dimensions (cultural, organizational, political, economic) across micro-, meso-, and macro-levels, the model provides a comprehensive analytical map for examining adoption trajectories and its influence on innovation diffusion. This integration moves beyond static or linear views of adoption by illuminating how disruptions - such as political uncertainty, regulatory ambiguity, or professional skepticism - can stall or redirect innovation processes at any point along the continuum. Moreover, the model advances SST-informed theorizing by formalizing communication and alignment dynamics between system levels. The analytical mapping of interview data demonstrated that misalignments across levels - such as fragmented macro-level policy undermining meso-level implementation, or cultural resistance at the macro level weakening individual engagement - are critical determinants of adoption outcomes. In this

regard, the model supports and extends prior research on the importance of cross-level coordination and communicative coherence in shaping the diffusion of digital technologies (Borgatti & Foster, 2003; Klijn & Koppenjan, 2016).

The model also contributes to the growing field of network-informed diffusion studies. By conceptualizing healthcare systems as multi-nodal networks, the STAD-HC framework accommodates the structural and relational aspects emphasized in network theory while retaining DOI's explanatory clarity and SST's contextual nuance. This allows for the analysis of innovation diffusion not only as a function of individual behavior or organizational structure, but as the result of dynamic interactions between trust, actor centrality, communication density, and strategic alignment. From a theoretical standpoint, the model's dual alignment with DOI and SST offers a unique contribution. While DOI provides an explanatory sequence for how adoption unfolds, SST captures the meaning-making processes and structural constraints within which that unfolding takes place. This synthesis enables a more realistic representation of adoption and its influence on diffusion as both structured and emergent, planned and reactive, rational and negotiated.

Finally, the model has the potential to serve as a foundational framework for comparative studies. Its modular structure - anchored in well-established theoretical traditions - allows for adaptation across innovation types (e.g., AI, IoT, blockchain), care settings (e.g., primary, acute, long-term care), and governance systems (e.g., centralized vs. federal health systems). By doing so, it encourages contextualized theory-building while maintaining a consistent analytical structure.

5.4. Strengths and limitations

The Socio-Technical Adoption and Diffusion Model for Healthcare (STAD-HC) was developed through the integration of SST content analysis and DOI stage mapping. This dual methodological approach offers important advantages in understanding the layered and contextual nature of telemedicine adoption and diffusion in healthcare. At the same time, both the model and the methods used to construct it entail limitations that warrant careful consideration.

5.4.1. Methodological strengths

A core strength of the combined method lies in its ability to integrate theory-driven structure with inductive interpretation. The SST content analysis offered an interpretive lens that allowed empirical material to be categorized according to the broader socio-technical dimensions of culture, organization, politics, and economy, in line with foundational work by Williams and Edge (1996) and MacKenzie and Wajcman (1999). These categories supported a nuanced, context-sensitive understanding of how digital innovations are shaped by their implementation environments. Complementing this, the mapping of SST themes onto the five DOI stages—knowledge, persuasion, decision, implementation, and confirmation—provided a temporal and processual framework for analyzing the unfolding of adoption across system levels (Greenhalgh et al., 2004; Rogers, 2003). This allowed for the structured identification of phase-specific determinants, a feature that has been highlighted as essential in health innovation research (Damschroder et al., 2009; Greenhalgh et al., 2004).

The DOI-SST matrix further enabled a detailed multi-level analysis by aligning micro-, meso-, and macro-level influences with each stage of the innovation adoption process. This approach resonates with Geels' Multi-Level Perspective (MLP) on socio-technical transitions, which emphasizes the interaction between niches (micro-level practices), regimes (meso-level structures), and landscapes (macro-level contexts) in shaping the trajectory of innovation (Geels, 2002). By adopting a similar layered structure, the matrix captures how institutional routines, individual behaviors, and system-wide forces intersect to shape adoption dynamics. This structured mapping supports the derivation of empirically grounded, testable hypotheses, and allows the model to serve as a foundation for future mixed-methods or longitudinal studies (Weiner,

2009).

5.4.2. Model-level strengths

Beyond its methodological rigor, the STAD-HC model provides a valuable tool for analyzing communicative negotiation processes in complex, multi-actor settings. By distinguishing between individual, individual-related, and organizational systems, the model captures the dynamics and fragmentation of communication between levels. This capacity to link communication with systemic and institutional structures adds interpretive depth and is particularly relevant in the healthcare context, where multi-level coordination is essential for successful innovation (Klijn & Koppenjan, 2016).

A particularly noteworthy strength is the model's explicit inclusion of reinvention, as conceptualized by Rogers (2003). The model acknowledges that innovations are not simply adopted or rejected, but often adapted or reshaped in response to local needs, professional identities, and institutional constraints. This feature enhances the model's real-world applicability, especially in dynamic environments such as healthcare, where innovation is often co-constructed through use (Greenhalgh et al., 2017).

5.4.3. Methodological and contextual limitations

Despite these strengths, several limitations must be acknowledged. First, the application of SST in content analysis is inherently interpretive and relies on the analytical judgement of researchers to assign themes to broad and sometimes overlapping categories. This can lead to coding ambiguity, especially when political and economic factors intersect, or when cultural norms are expressed through regulatory language (Pope, Ziebland, & Mays, 2000). Second, the temporal mapping of interview data onto DOI stages assumes that participants describe their experiences in phase-specific terms. In practice, however, these narratives often span multiple stages, complicating efforts to clearly distinguish between knowledge, persuasion, and decision, for example (Dearing, 2009). Third, the data collection during the COVID-19 pandemic introduces several important contextual limitations. The pandemic likely influenced interviewees' perceptions by heightening openness to digital health tools in light of emergency conditions. Temporary policy relaxations, crisis funding, and rapid implementation pathways may have artificially accelerated adoption or produced short-term adaptations that do not reflect stable structural change. These pandemic-specific dynamics may limit the generalizability of findings beyond the acute phase and complicate comparisons with data collected under more stable conditions. Longitudinal studies are needed to assess whether observed shifts represent lasting transformation or reactive measures. Additionally, it is important to note that post-pandemic reforms—such as the Hospital Future Act and the broader integration of DiGA and video consultations—may be contributing to a gradual shift in institutional attitudes toward digital innovation. While the interviews reflected persistent skepticism, particularly in traditional care environments, emerging patterns suggest that professional mindsets and policy narratives are beginning to evolve in response to both structural necessity and external drivers of change.

5.4.4. Model-level limitations

At the conceptual level, the model currently does not account for the strategies of influence and agenda-setting within communication flows - strategies that are often decisive in adoption or rejection outcomes. Understanding how actors frame technologies, manage tensions, or leverage institutional narratives would require the addition of tools from discourse analysis, frame theory, or critical policy studies. Furthermore, deciphering the differential weight of communication content across individual and organizational contexts remains a challenge. Diverging attitudes between clinicians, administrators, and policymakers can create fragmented interpretations of innovations, which are difficult to capture through stage-based frameworks alone (Denzin & Lincoln, 2011; Patton, 2015). Additionally, the model, while conceptually rich, may be

at risk of overgeneralization. Its broad structure may be carefully adapted to specific innovations, technologies (e.g., AI vs. IoT), or system types. Not all innovation processes will exhibit the same stage dynamics or cross-level interactions.

6. Conclusion

This study examined how the Diffusion of Innovations (DOI) and Social Shaping of Technology (SST) frameworks can be combined to explain the adoption and diffusion of telemedical innovations within the complex environment of the German healthcare system. The analysis focused on how innovation processes unfold within and across individual, organizational, and institutional levels, and how cultural, political, economic, and organizational factors interact to shape these trajectories over time.

Through the integration of SST content analysis and a DOI - SST mapping, this study developed the Socio-Technical Adoption and Diffusion Model for Healthcare (STAD-HC). The model provides a theoretically grounded and empirically informed structure for analyzing digital innovation across all five DOI stages - knowledge, persuasion, decision, implementation, and confirmation - while embedding these stages in a socio-technical framework that spans micro, meso, and macro levels. This structured analytical mapping enables the identification of interdependencies and misalignments that influence adoption outcomes.

The STAD-HC model demonstrates that adoption and diffusion are not linear processes. Instead, they are shaped by negotiation, resistance, institutional dynamics, and communicative processes that traverse different actors and system levels. Cultural mindsets, regulatory ambiguity, resource constraints, and infrastructural readiness were shown to determine whether and how telemedicine innovations are adopted, adapted, or rejected. These findings affirm critiques of actor - centric or technologically deterministic models and highlight the need for approaches that account for context, power dynamics, and interpretive variability in innovation processes.

The practical implications of this research are manifold. For policy-makers, the findings underline the importance of moving beyond regulatory and technical concerns to include cultural perceptions and public trust. Transparent and targeted communication that resonates with the values of professional groups and societal norms can strengthen uptake at the micro level. At the macro level, coordinated and long-term digital health policies are needed to reduce fragmentation and ensure systemic consistency.

For healthcare organizations, readiness must extend beyond infrastructure to encompass leadership, team dynamics, and the training of staff. Meso-level governance structures should actively bridge the gap between policy imperatives and clinical workflows. Digital adoption is more likely to be sustained when innovations are perceived by clinicians as compatible with existing practices and responsive to local needs. Supporting reinvention and contextual adaptation can facilitate deeper engagement and more lasting use.

Technology developers are encouraged to co-design solutions with end users in mind. Addressing stakeholder needs across all levels - clinicians, administrators, and system-level actors - can improve usability, legitimacy, and implementation success. Moreover, the diffusion of telemedicine must be understood as a continuous and communicative process that involves negotiation, feedback loops, and cross-level alignment. Especially with the emergence of complex technologies such as IoT, blockchain, and AI, strategies that incorporate institutional learning and policy adaptation will be crucial.

From a research perspective, the STAD-HC model provides a structured yet adaptable framework that supports the generation and empirical testing of hypotheses. For instance, the model can be used to examine how macro-level cultural narratives influence clinician-level attitudes, or how meso-level policy implementation affects micro-level engagement. The model's matrix structure also facilitates

operationalization for multilevel survey research, policy analysis, and structural equation modelling -making it a valuable tool for comparative evaluation and policy-oriented studies.

Future research should refine and apply the model in other health-care contexts and innovation domains. Longitudinal studies are needed to determine whether the behavioural and institutional shifts observed during the COVID-19 pandemic represent enduring systemic transformation or temporary adaptation. The model also holds promise for analyzing adoption pathways of next-generation technologies, including remote patient monitoring, AI diagnostics, and blockchain-based infrastructures.

The integration of SST and DOI brings conceptual richness, but also complexity. DOI offers a stage-based, process-oriented view of adoption, while SST emphasizes the socially embedded, non-linear, and often contested nature of technological change. Their integration in the STAD-HC model results in a powerful but demanding framework. Application of the model requires attention to setting-specific dynamics and may benefit from triangulation with complementary theories - such as network theory, frame analysis, or critical policy studies - to better capture power relations and agenda-setting in healthcare innovation.

It is important to acknowledge the limitations of this research. Data collection occurred during the COVID-19 pandemic, a time of exceptional digital momentum and regulatory flexibility. These conditions may have influenced participants' responses and introduced a temporary bias toward openness or optimism. Additionally, the model does not fully capture strategic communication processes, such as framing or discourse coalitions, that often determine innovation trajectories in complex policy environments. Further refinement is needed to explore the communicative and political aspects of adoption processes in more depth.

In conclusion, the STAD-HC model offers a comprehensive, multi-level framework for understanding how telemedical innovations are shaped by socio-technical conditions. It advances theoretical integration between DOI and SST, demonstrates methodological innovation through structured mapping, and provides practical guidance for the design, governance, and evaluation of digital health strategies. Most importantly, the findings underscore that successful diffusion depends not only on technological functionality, but on cultural resonance, institutional capacity, political coherence, and economic feasibility - all of which must be aligned to enable meaningful and sustainable innovation in healthcare.

CRedit authorship contribution statement

Yvonne Rauner: Writing – original draft, Visualization, Resources, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Harald Stummer:** Writing – review & editing, Validation, Supervision, Software, Data curation.

Declaration of competing interest

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

Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.digbus.2025.100135>.

Data availability

Data will be made available on request.

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